Stevenage Bioscience Catalyst

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	450046
Project lead and author	AECOM
Report date	2013
InnovateUK Evaluator	Unknown (Contact www.bpe-specialists.org.uk)

Building sector	**Location**	**Form of contract**	**Opened**
Office	Stevenage	Design and build	2012
Floor area (GIA)	**Storeys**	**EPC / DEC**	**BREEAM rating**
4750 m^2	3	B / N/A	Excellent

Purpose of evaluation

A building of *in-situ* concrete frame with rainscreen and metal cladding, and 530 m^2 of façade-mounted solar photovoltaics. Variable volume mechanical ventilation systems with energy recovery and high efficiency motors. Three air source heat pumps provide heating and chilled water for spaces and ventilation air conditioning. CO_2-based heat pumps are used for domestic hot water. Heat was to be recovered from extract systems. PV was to primarily supply the heat pumps offsetting the need for grid electricity.

Design energy assessment	**In-use energy assessment**	**Electrical sub-meter breakdown**
No	No data reported	Partial

Although a CIBSE TM22 assessment was said to have been carried out to understand and reconcile the energy use in the SBCat building, no electrical or fossil fuel energy data are quoted, beyond histograms and a sub-meter table. The sub-meters did not monitor all end uses. Lighting, fan-coil unit and small power electricity consumption were not separately sub-metered for the labs, offices or landlord areas.

Occupant survey	**Survey sample**	**Response rate**
BUS, paper-based	22 of 38	58%

In general the Incubator building performed well in terms of performing better than scale midpoint on most of the comfort variables. Areas where users have felt that the building performed unsatisfactorily relate to the temperature and air in winter. This was attributed to a reported failing of the heating system during cold spells, perhaps as a result of insufficient whole building system commissioning, and inadequate control of the building's heating and ventilation system by the Building Management System (BMS).

Innovate UK is the new name for the Technology Strategy Board - the UK's innovation agency. Its role is to fund, support and connect innovative British businesses through a unique mix of people and programmes to accelerate sustainable economic growth.

For more information visit www.innovateuk.gov.uk

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.

Technology Strategy Board
Driving Innovation

Contents

Executive Summary

A Building Performance Evaluation (BPE) has been carried out for the Stevenage Bioscience Catalyst Incubator building as part of a Technology Strategy Board (TSB) funding initiative related to the energy performance of buildings. This is a “Phase 1” TSB study for a non-domestic building. A “Phase 1” study covers post completion and early occupation of a building.

The Technology Strategy Board (TSB) has accepted to provide funding for a hundred projects around the UK to carry out Building Performance Evaluation (BPE)

Findings from the BPE programme will be shared across the industry and are intended to help designers, builders and developers deliver more efficient, better performing buildings.

About the Incubator building

SBCat is a joint venture between the UK Department of Business, Innovation and Skills (BIS), GlaxoSmithKline (GSK), the Wellcome Trust, the East of England Development Agency (EEDA) and the Technology Strategy Board (TSB). The Incubator building is being developed for multi-tenant occupation by start-up and Small to Medium sized Enterprises (SMEs), to achieve a culture of open innovation and shared-learning at the science park.

This forms part of the first phase of a new open innovation bioscience park on the GSK campus in Stevenage, Hertfordshire.

The following are the key facts about the Incubator:

- 4,750 m² floor area (60% labs, 40% offices) over 3 floors
- Office wing and lab wing connected by central atrium (meeting rooms, breakout areas, boardroom
- The conception of the Incubator was carried out using a 2-stage design and build procurement route
- It has been designed to maximise low carbon potential through passive control measures including orientation, glazing types and size, internal arrangement, minimising energy use out of occupied hours, etc.
- The building includes a number of renewable and low carbon technologies:
    - 530 m² of façade-mounted solar photovoltaics for on-site electricity generation.
    - Three 500 kW Reverse Cycle Air Source Heat Pumps to provide heating and chilled water for spaces and ventilation air conditioning
    - CO_2 Heat Pumps to generate domestic hot water.
- An air intake labyrinth has been provided to use the thermal mass of the building and surrounding ground to temper the incoming fresh air to reduce the associated heating and cooling demands.
- High efficiency fume cupboards have been specified in accordance with BREEAM. It is anticipated that this will minimise operational energy use by tenants as far as practicable and reduce the overall CO_2 emissions of the building.
- Rainwater harvesting to supply toilet flushing and external landscaping requirements

What are the aims of the Incubator building BPE?

The aims of the BPE study are multi-faceted and are intended to achieve the following:

- establish the robustness of the procurement process for the Incubator building
- evaluate changes that led to a discrepancy between specifications and the as-built building
- identify key issues with building systems and operations
- evaluate the effects of build quality and operations on occupant thermal comfort, productivity and the building energy and water use
- develop an improvement action plan to address and rectify the issues identified

What Building Performance Evaluation has been carried out for the Incubator building?

The BPE carried out on the Incubator building has involved reviews and investigations into the following areas:

- Procurement review
- Commissioning review
- Handover review
- Design Review
- Monitoring and Evaluation of building systems
- Building User Survey

What has worked well and what issues have been found as part of the Incubator Building Performance Evaluation?

The BPE found that there are some elements of the building that are working well; however significant problems were found with the commissioning of the mechanical services.

What has worked well?

- Architectural intent delivered – aesthetically pleasing building
- Lighting installation – all working well
- Good construction of building fabric
- Solar Photovoltaics – working well

What issues are there?

- Thermal comfort – there have been complaints of feeling too cold or of overheating in the highly glazed offices and meeting rooms.
- Hot water system – there have been technical problems with the CO_2 heat pump and it is not clear whether the hot water system has been setup to operate as per the Employer's Requirements. The hot water system consists of a CO_2 heat pump and electric immersion heaters.
- Ventilation system – there were problems with the commissioning of the Air Handling Units and there has been unnecessary energy use by the ventilation system to ventilate unoccupied labs.
- Building management system (BMS) & Control issues:

  - Key operational characteristics of vital plants are not monitored on the BMS. These include the electricity used by the CO_2 heat pump and back up immersion boilers, heat and cooling output from each air source heat pump
  - Lack of control of space temperature conditions
  - A significant number of meter readings were not recorded correctly for over a year after the official handover date, which meant that it was more difficult to check whether all building systems were operating properly within the 12-month defects period.
- The lack of holistic commissioning of different building systems that need to interact with each other is likely to be the major contributor to the operational problems reported with the Incubator building.

Details about key problems found, potential causes and what has been done to help resolve them

Air source heat pumps (ASHPs)

- Insufficient monitoring of ASHPs to assess coefficient of performance (CoP) of individual heat pumps and therefore, whether each ASHP is performing as expected (e.g no information about heat generated by each ASHP)
- Failure of ASHPs in cold weather – related to commissioning of defrost cycle operation
- Erratic operation of individual heat pumps – e.g frequent cycling between defrost mode and heating mode and tripping of ASHPs. It's not clear whether this is related to poor control by BMS (Building Management System) or problems with ASHPs.
- Low coefficient of performance for the whole-building heating system in January 2013 of between 1.3 and 1.6
- The ASHP manufacturer witnessed the commissioning of the ASHPs but was not ultimately responsible for the commissioning. In hindsight, it would have been preferable for the ASHP manufacturer to have been responsible for the commissioning and to have retained the manufacturers proprietary control software as part of the ASHP installation. There is no documentary evidence to show that the ASHP has been commissioned in a holistic manner with the building's heat distribution system, ventilation system and the buffer vessels
- As part of the BPE, AECOM has carried out an analysis of the performance of the ASHP system, result of which has been provided to ASHP manufacturer and the Building Manager to feed into the ongoing efforts to commission the ASHPs to a satisfactory standard.

Hot water system

- Insufficient monitoring of hot water system to assess performance – the electricity consumption of the CO_2 heat pump and the immersion heaters is not recorded on the BMS. Furthermore, the hot water generated by the immersion heaters is also not recorded on the BMS.
- Failure of the CO_2 heat pump
- Problems relating to sequencing of hot water system – it appear that the electric immersion heaters are operating as lead hot water generators instead of the CO_2 heat pump.
- The hot water system maintenance arrangement is not holistic despite the hot water plant operating in a very inter-dependent manner. The maintenance of the CO_2 heat pump is carried out by the CO_2 heat pump supplier, while the maintenance of the immersion heaters is the responsibility of another organisation. The result is that when problems are resolved for one part of the system, the whole system does not get re-commissioned, which is likely to result in sub-optimal performance of the hot water system. This will in turn lead to higher energy use, energy cost and CO_2 emissions.
- As part of the BPE study, AECOM has fed findings to the Incubator building manager for inclusion into the buildings defects list to be addressed by the Main Contractor.

Ventilation system

- Air Handling Units (AHUs) commissioning was inadequate
- Instructions were not provided in building log book on how to switch off the ventilation to empty labs. This resulted in energy waste by the AHUs supplying pre-heated ventilation air and by the roof extract fans, which extract air from the empty labs.
- As part of the BPE study, AECOM has found out how to stop the supply and extract of ventilation air to unoccupied labs and this has been conveyed to the Building Manager. This will result in energy and cost savings for the Incubator building.

Temperatures in highly glazed offices and meeting rooms

- Occupants have complained of over-heating on sunny days and feeling too cold during winter months.
- Comfort problems reported by occupants are related to a number of factors:
    - Insufficient heating/cooling capacity near the glazed facade.
    - Facade specification not sufficiently high
    - Inadequate commissioning of FCUs that did not take into account the radiant temperature, particularly significant for rooms which are highly glazed.
    - Inability of building manager to adjust fan coil unit operation set-points (despite this being an Employer's Requirement).
- As part of the BPE, measurements confirmed that temperature requirements in a number of areas were not being met and this information has fed into the discussion of the Client with the Main Contractor as part of the resolution of defects. The Main Contractor arranged for the control of FCUs to be provided to the Building Manager via the BMS.

Building management system and controls

- Incorrect/zero readings shown for some items for a year after handover making it difficult to check that equipment was operating properly
- No evidence of heat meter commissioning; no evidence of holistic commissioning of BMS and ASHPs, ventilation system, hot water system.
- BMS not intuitive or user friendly
- Operating instructions specific to the Incubator building were not provided at time of the BPE study.
- As part of the BPE, AECOM provided evidence of problems relating to the BMS, which were then addressed as part of the building defects. It is not known whether holistic commissioning of the inter-dependent building systems will be carried out.

What will the client do differently as a result of the BPE?

The client has indicated the following as what they will do differently as a result of the BPE project:

- Reduce energy use for ventilation by switching off fume cupboards in unoccupied labs
- Use information generated as part of this study to help resolve problems in the Incubator building, in particular relating to

- air source heat pumps,
- thermal comfort and
- the hot water system.

Items for which further study is recommended

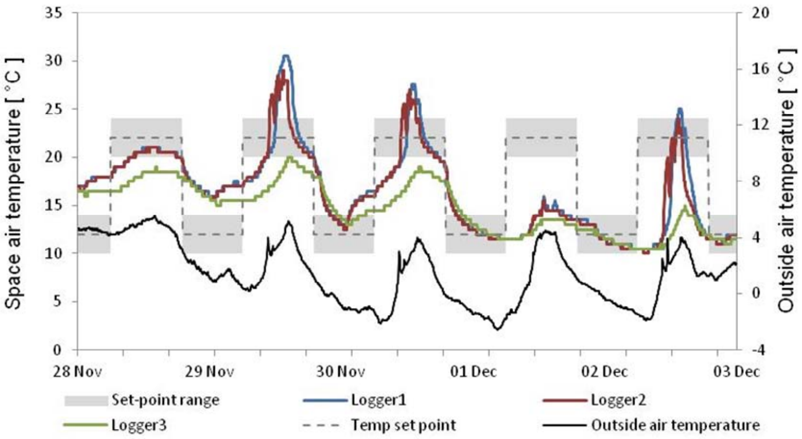
- Air source heat pumps – efficiency and reliability
- Hot water system - CO_2 heat pump and immersion heaters
- Thermal comfort in offices
- Performance of labyrinth over an entire year
- Performance of rainwater harvester as building becomes more occupied

What are the key lessons learnt and what do AECOM intend to do differently?

- For buildings that require a complex interaction of different systems, consider carefully whether a design and build route is the most appropriate method of delivery of the building.
- Write Employer's Requirements (ERs) in a more prescriptive way for key items of plant such as air source heat pumps; for key items, avoid using the phrase "or equivalent product" or other similarly ambiguous phrases. This is especially important for design and build projects as there is a significant chance that important elements of the overall design philosophy could be lost when the responsibility for a design changes from the Client mechanical and electrical services consultant to the Main Contractor.
- For key items of plant, ensure that the sub-contractors appointed by the Main Contractor have the relevant experience to carry out the installation and commissioning of the equipment in question.
- Consider more carefully the impact of value engineering for key items such as the air source heat pumps.
- Provide more resources to allow for more thorough auditing of proposed designs by the Main Contractor. Items that will be focused more include plant sizing, design for comfort in highly glazed rooms and control strategies to be implemented by the BMS.
- Encourage the Main Contractor to appoint an AECOM approved/preferred BMS supplier. AECOM is currently looking into producing a list of approved/preferred BMS suppliers.
- Although BREEAM requires the installation of energy efficient equipment, from the BPE carried out on the Incubator building, it does not have a significant effect on operational energy use. The operational energy use of the Incubator building is dominated by the commissioning and controls of installed equipment.
- Carry out "pilots" of video training. The use of video training should help improve the standard of training as it will encourage those providing training to better prepare training content and presentation. This will encourage those for whom the training is intended to attend the training sessions. AECOM will specify the client member of staff to attend training and ensure competency in building operation
- If commissioning is delayed, ensure the client is made aware of the importance of pushing back the handover date to allow commissioning to be carried out to a high standard.
- Ensure that commissioning is carried out in a holistic manner. Using the example of the Incubator building, this would comprise of the commissioning of the BMS, the air source heat pumps, ventilation system and fan coil units together. This will require producing a holistic commissioning template that the organisation carrying out the commissioning will have to complete to demonstrate that holistic commissioning has been carried out.
- Ensure that sufficient information is recorded (e.g on the BMS) to allow the operation of key plant to be checked. For heat pumps, this should include the heat/coolth output and the electricity input as a minimum.

- In addition to standard commissioning, which tests that an installed piece of equipment operates under specific conditions, use commissioning graphs to demonstrate that systems operate as expected over a period of time (e.g a week). This will help ensure that future buildings are commissioned in a more holistic manner.

Example of a graph that could be used to show "operational commissioning" of temperatures in a room (graph shows temperatures at 3 locations in an office over a 5-day period)



- Offer Soft-landings and Building Performance Evaluation (BPE) services to clients as an inclusive package
- Continue to develop expertise in BPE, including through sharing of experiences between those involved via quarterly meetings, and developing our offer further

How will findings from the Incubator Building Performance Evaluation be disseminated?

- A presentation of the findings from the BPE study has been made to the Client
- The study findings and lessons learnt have been presented to colleagues within AECOM as part of a knowledge-sharing seminar, which was filmed and has been made available to all 40,000+ AECOM staff around the world.
- Publication to CarbonBuzz
- Input to CarbonBuzz – Andrew Cripps is the AECOM lead on CarbonBuzz and the learning from this and other BPE projects that AECOM is involved with has fed into the development of CarbonBuzz.
- Publish articles in trade journals (subject to permission from Incubator building management)
- Send key findings to organisations involved in procurement, design, installation, handover and commissioning of the Incubator building.

Technology Strategy Board
Driving Innovation

1 Introduction and overview

SBCat is a joint venture between the UK Department of Business, Innovation and Skills (BIS), GlaxoSmithKline (GSK), the Wellcome Trust, the East of England Development Agency (EEDA) and the Technology Strategy Board (TSB). The Incubator building is being developed for multi tenant occupation by start-up and Small to Medium sized Enterprises (SMEs), and will achieve a culture of open innovation and shared learning at the science park.

The building forms part of the first phase of a new open innovation bioscience park on the GSK campus in Stevenage, Hertfordshire.

Figure 1 Photograph of the finished Incubator building

The 3-storey building comprises an office wing and a laboratory wing with Containment Level 2 laboratories and attached write-up spaces. A central 'hub' connects the two wings. The total floor area of the Incubator building is approximately 4,750 sqm.

The building targeted a BREEAM 'Excellent' rating and has been designed to maximise the benefit from low and zero carbon technologies through passive control measures, including orientation, glazing types and size and internal layout. The renewable and low carbon technologies included in the building are facade mounted Photovoltaics and Air Source and CO_2 Heat Pumps

The purpose of the BPE study is multi-faceted and intended to achieve the following:

- establish the robustness of the procurement process for the Incubator building

- evaluate changes that led to a discrepancy between specifications and the as-built building
- identify key issues with building systems and operations
- evaluate the effects of build quality and operations on occupant thermal comfort, productivity and its energy and water use
- develop an improvement action plan to address and rectify the issues identified

The scope of the BPE Phase 1 study can be divided into several tasks:

Stages	**Task description**
Commissioning	Design review covering the process of design, procurement and operation of the building Review of plans for commissioning Review of commissioning & testing management, planning, procedures and test documentation
Handover	Review of Pre-Handover and Handover planning and procedure documentation Review of client training sessions Review of O&M manuals and documentation, and log book
Post Completion	Evaluation of Labyrinth ventilation system, heat pumps and BMS and controls Metering of test laboratory space to determine proportional energy use of individual systems and large equipment Evaluation of building fabric performance, including thermal imaging and air tightness test Social evaluation of commissioning, handover and modifications stages Initial Improvement Action Plan
Early Occupancy	Review of tenant user guide Review of thermal models and EPCs Review of building sustainability performance Monitoring of whole building energy and water consumption Monitoring and evaluation of Labyrinth ventilation, heat pumps, lifts, lighting and PV in use. TM22 assessment. Evaluate interactions between systems Monitoring and evaluation of rainwater harvesting system Monitoring and evaluation of different sized lab spaces and offices in use Monitoring and evaluation of lab equipment and IT equipment in use Tenant social evaluation (Arup BUS) SBCAT Building manager social evaluation

The following are key facts about the Incubator:

- The conception of the Incubator was carried out using a 2 stage design and build procurement route
- It has been designed to maximise low carbon potential through passive control measures including orientation, glazing types and size, internal arrangement, minimising energy use out of occupied hours, etc.
- The building includes a number of renewable and low carbon technologies:
    - 530 sqm of facade mounted solar photovoltaics for on-site electricity generation.

    - Three 500 kW Reverse Cycle Air Source Heat Pumps to provide heating and chilled water for spaces and ventilation air
    - CO_2 Heat Pumps to generate domestic hot water.
- An air intake labyrinth has been provided to use the thermal mass of the building and surrounding ground to temper the incoming fresh air to reduce the associated heating and cooling demands.
- High efficiency fume cupboards have been specified in accordance with BREEAM. It is anticipated that this will minimise operational energy use by tenants as far as practicable and reduce the overall CO_2 emissions of the building.

The BPE project has highlighted the following key findings as summarised below:

- There should be adequate time and planning for commissioning and handover phases to avoid poor operational performance of building. Ensuring satisfactory completion of commissioning (which should include performance testing of the building) should take priority over the official handover date of the building.

- Greater emphasis needs to be paid to writing Employer's requirements in a manner that allows easier comparison of constructed building with original design intention and philosophy.

- Quality assurance procedures should be more robust to ensure any changes to designs or Employers Requirements are signed off by and ramifications explained to the client team.

- The air source heat pumps do not appear to have operated with the efficiency and reliability anticipated in the design – a number of manufacturer faults have occurred. Efforts are ongoing by the client and project team to resolve the problems. It is recommended that their operation should be monitored on an ongoing basis. This would assist in identifying the factors associated with this and help to ensure that the system operates efficiently and reliably in the future.

- The hot water system (CO_2 heat pump and electric immersion heaters) may not have been configured correctly. The operation and configuration of this system should be checked, potentially combined with measurements of the energy inputs and outputs of all the associated systems.. This would enable any beneficial modifications and/or adjustments to be identified to ensure that the system would be kept operating efficiently and reliably in the future.

- Thermal comfort in the highly glazed offices (in particular the corner offices with a dual aspect and the meeting rooms in the hub) is not necessarily achieving the desired levels. Occupants have complained that these spaces have been too cold in the winter and sometimes too hot in the summer. For spaces which are designed to have a high proportion of glazing, it is important that the design and commissioning of the systems serving the rooms take into account the radiant effect through the glazing.

Full discussion of proposed future actions is given in Sections 8 and 9.

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

This section describes the building, and how it was designed and delivered.

2.1 Background to the Stevenage Bioscience Catalyst (SBCAT)

Stevenage Bioscience Catalyst campus is a unique bioscience community created to provide small biotech and life sciences companies, and start-ups with access to the expertise, networks and scientific facilities traditionally associated with multinational pharmaceutical companies.

A key aim of Stevenage Bioscience Catalyst is to pioneer a culture of open-innovation that will place the UK bioscience sector at the forefront of worldwide biomedical discovery and deliver cutting edge healthcare solutions. Supported by Government, business, and the charitable sector, Stevenage Bioscience Catalyst campus offers a fertile environment for scientific innovation and commercial success.

The site has been designed to foster collaboration and interaction between tenant companies with the hope that the combination of opportunity and cooperation will breed innovation and commercial success. This will provide small biotech companies with new insights into their research and development activities and should accelerate the progress from discovery to product development.

With long-term plans to expand the campus by five fold from the first phase to the third phase, the Stevenage Bioscience Catalyst campus will offer a range of equipment and commercial opportunities that would be impossible for a small or medium sized enterprise (SME) to develop alone.

In addition to its outstanding scientific facilities Stevenage Bioscience Catalyst also offers valuable opportunities for scientific and commercial networking. Tenants retain full independence and the freedom to interact with any commercial partners.

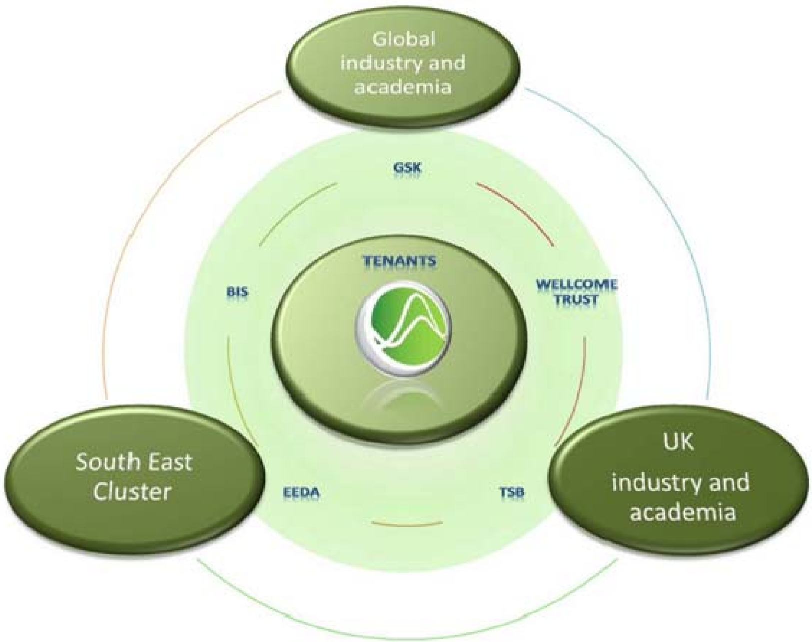


Figure 2 Image showing the SBCAT collaboration model

2.2 SBCAT Incubator building overview

The 3-storey building is located in the GSK science park in Stevenage, just off Junction 7 of the A1. It comprises an office wing and a laboratory wing with Containment Level 2 laboratories with attached write-up spaces. A central 'hub' and atrium/lobby connects the two wings. The total floor area of the Incubator building is approximately 4,750 sqm.

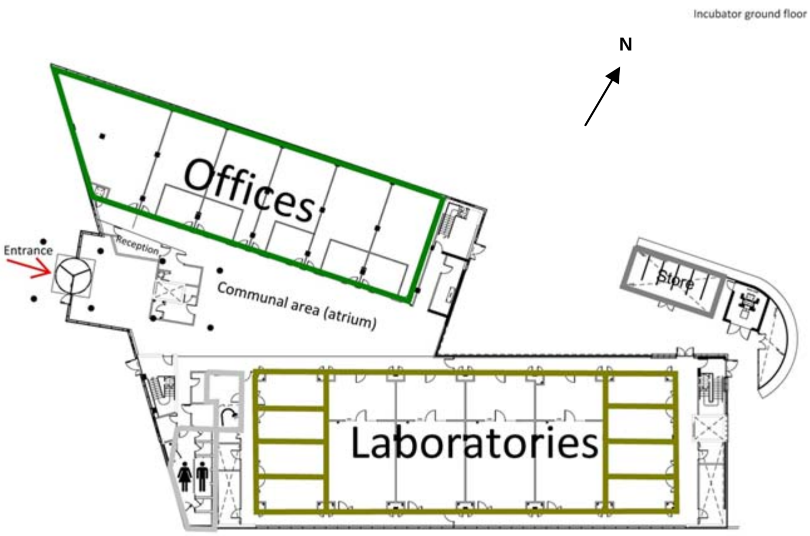
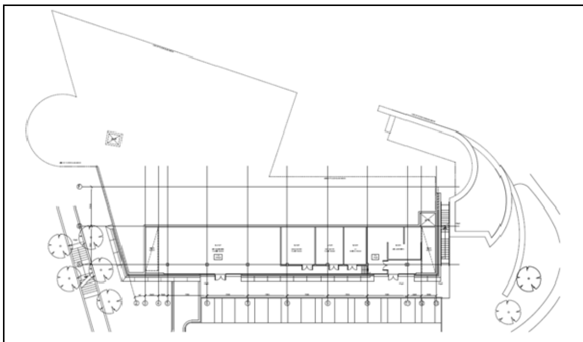
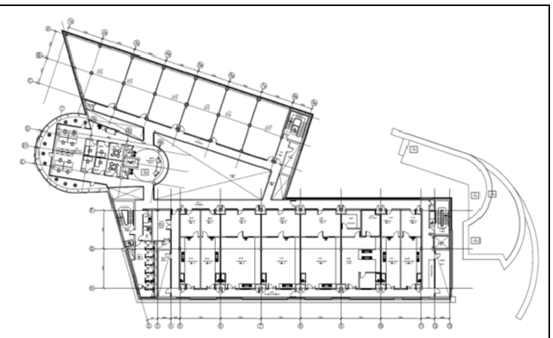


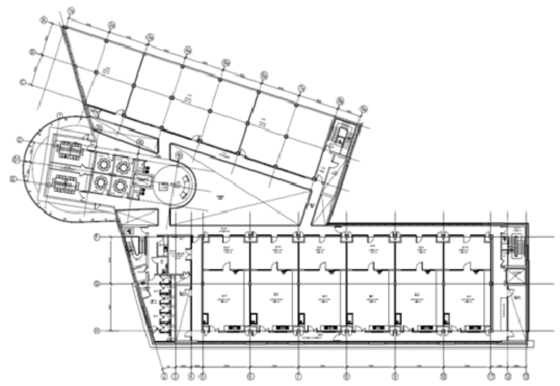
Figure 3 Incubator ground floor plan



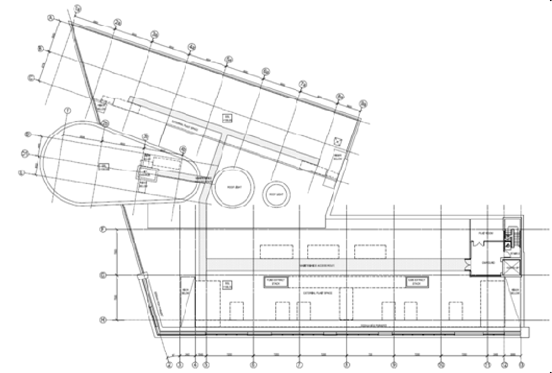
Lower ground floor



First floor



Second floor



Roof

Figure 4 Incubator floor plans

The building axis runs from north east to south west, with the offices located on the northern side and the labs on the southern side of the building.

The Incubator building is designed to have a maximum occupancy of 375 people (Stage D Report). As of November 2012, the occupancy of the Incubator was approximately 38 people.

Description	**Number of people**
Incubator design occupancy level	375
Total allocated staff members (Nov 2012)	38
Approximate daily no. occupants in the building	35

Table 1 Occupancy level in the Incubator building (November 2012)

The building has good transport links:

- The building can be accessed by road – it's close to Junction 7 of the A1.
- Stevenage train station is a 25 minute walk away
- Cycle rack facilities and shower facilities have been provided
- Stevenage is 12 miles from Luton Airport, 35 miles from Heathrow Airport and 35 miles from Stansted Airport

Sources: http://www.stevenagecatalyst.com/about/

2.3 Space use within the Incubator

The masterplan requirement was to provide a good quality of laboratory with a service routing strategy that minimises disruption to existing tenants as other spaces are reconfigured, i.e. adaptable rather than flexible.

The incubator space has been fitted out with a basic level of laboratory furniture and services, including fume cupboards, lab water, structured cabling and power via dado trunking together with regular lab waste points.

Although the base build fit out is at this generic level, the building has the capability to accommodate more specialist needs. For example, it is capable of accommodating a number of chemistry based tenants, who will require additional fume cupboards and the larger air handling capacity that goes with them. Hence, the building is designed and built to allow for accessible risers and plant space with spare capacity.

Labs:

Proposals for 25m^2, 50m^2 and 100m^2 lab modules have been developed, with the appropriate provisions made for fixed furniture and services. Laboratories are provided with write up areas to increase their functionality. A service corridor also serves the laboratories allowing the movement of people, equipment and materials between them.

Labs are fitted out with some benching, sinks and fume cupboards, as well as basic service provisions. Certain areas of the incubator have been nominated to receive a higher concentration of fume cupboards namely the second floor where each laboratory has a redundant riser opening situated above within the roof structure which has been weather protected.

Within the labs and write up spaces, suspended ceilings with metal tiles have been specified. These will allow easy access to services above the ceiling. The proportion of ceiling tiles allows for large areas to be opened up providing the necessary space for maintenance

Offices:

The office spaces of the Incubator building are designed to be fully fitted out, including all services, finishes, and loose furniture, making it a functioning facility at handover. Offices are to be provided to accommodate 137 people (average rate 1 per 8m^2) along with further provision for hot desks, break out areas and meeting rooms.

Within office spaces, part of the environmental design dictates that the concrete soffit is exposed to allow for the use of the thermal mass. The heating, cooling and fresh air to these spaces is delivered through ductwork so there is an element of exposed services.

By leaving the concrete soffit exposed in office spaces, easy access to ductwork is provided making maintenance unproblematic.

Atrium/ lobby

The atrium is intended to provide a light and open lobby area. It is a flexible area where informal meetings can be held or demonstrations held. The atrium is approximately 250m^2.

The atrium has been designed with plasterboard ceilings and feature areas around the roof lights. Lighting will be provided by a combination of fittings and mirrors at high level. Low level projectors (uplighters) allow for easy replacement of lamps.

Hub

The hub provides a mixed use environment consisting of break out areas and meeting rooms to help facilitate open innovation. The area is approximately 250m^2.

In order to tackle problems of overheating and radiant cooling – a number of design features have been incorporated into the the hub's facade. A ventilated void has been specified between the external PTFE facade (also known as the "bubble") and the glass walls enclosing the office / meeting space. This design feature is intended to control solar gain and means glare can be controlled without excessive need for cooling

Lifts

There are 2 machine-room less (MRL) lifts in the Incubator building - one passenger lift and one goods lift.

Plant

The main building services plant is located either on the roof or on the lower ground floor.

Sources: Tenant Information Pack; Operation & Maintenance Manuals – Part 1 General Information Text

2.4 Building Fabric

The Incubator sits on CFA piled foundations and pile caps with suspended ground floor slabs. The superstructure frames is formed from reinforced concrete with a small element of structural steel at roof level.

The façades are finished with a mixture of curtain walling and windows, rainscreen metal cladding, integrated PV panels, brickwork and non-structural gabion walls. The hub to the incubator building also includes a feature ETFE air cushion (Ethylene tetrafluoroethylene) exterior.

The roof comprises of a hot melt roof covering over laid with stone ballast or pavers with a free standing (counterweighted) handrail positioned around the roof edge.

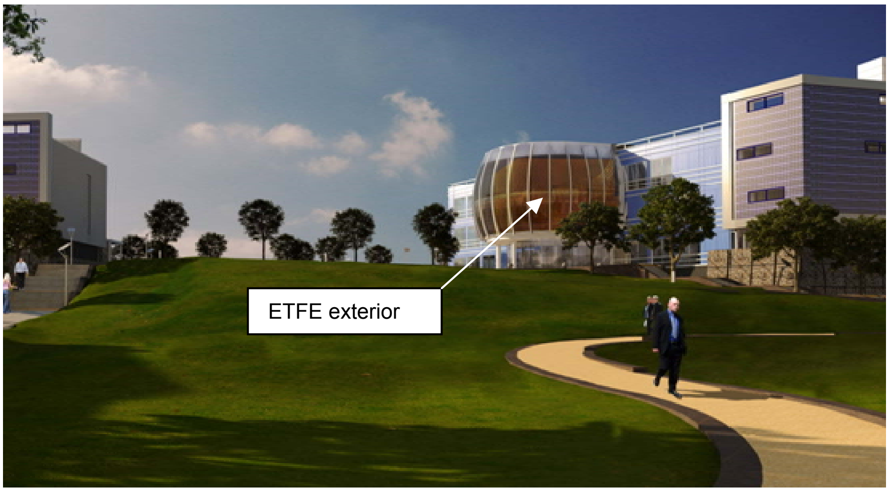


Figure 5: Photo render showing ETFE ("the bubble") exterior around hub of Incubator building

The internal walls are constructed with a mixture of dry-lined partitions and demountable partitions, some of which are glazed. Lab floors consist of concrete floors finished with a levelling screed and vinyl, offices are provided with raised access flooring. The change from one to the other occurs on the office side of the link bridges.

Ceiling construction varies: demountable ceilings to labs and some exposed soffits to offices with rafts hanging beneath.

The building services have been designed with spare capacity or space for future expansion. Renewable energies have been incorporated, including air source heat pumps, CO_2 heat pumps for hot water generation, and PV panels integrated into the façade. The project also makes use of attenuated air intake via a labyrinth and rainwater harvesting.

There is a steep gradient across the site. The building has been designed with a ground floor level to suit the road at its northern boundary, the landscaping between and around the Incubator incorporates sand slopes from the road to the north of the Incubator down to the entrance of the existing GSK building.

Sources: Operation & Maintenance Manuals – Part 2 Building Fabric Text

2.5 Procurement of the Incubator building

The Incubator building was procured via a two – stage design and build process which was necessitated by the part funding of the building with public money.

Stage 1 – Employer's requirements (ERs) were developed on behalf of the Client (SBCAT) by the Client's design team which comprised of FDG (architects) and AECOM (Engineering consultants). The client's design team produced the ER's at RIBA Stage D. See Figure 7 for details of the Client's design team.

Stage 2 – After a tendering exercise was carried out based on the RIBA Stage D ERs, MACE was appointed as lead contractor to design and build the Incubator building. This involved producing a detailed design, construction, commissioning and handover of the Incubator building to SBCAT. MACE in turn appointed sub-contractors to design, construct, commission and handover the building. MACE held overall responsibility for the delivery of the building. See Figure 8 for details of the sub-contractor team appointed by MACE.

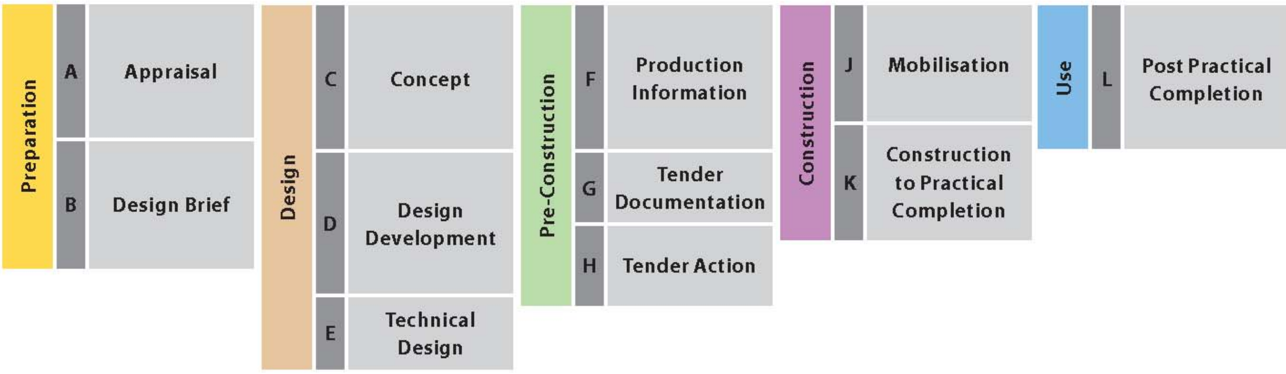


Figure 6: The RIBA Stage design, procurement and construction route

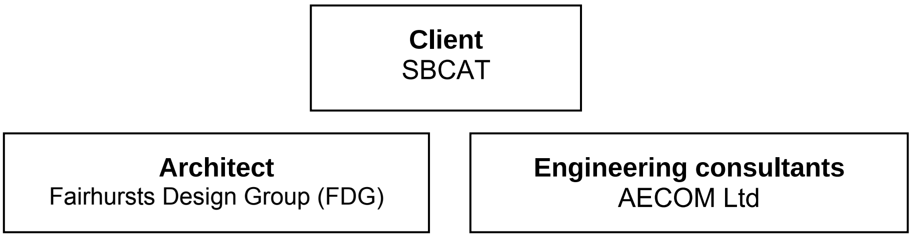


Figure 7: Stage 1 of procurement – client team for development of Employer's Requirements

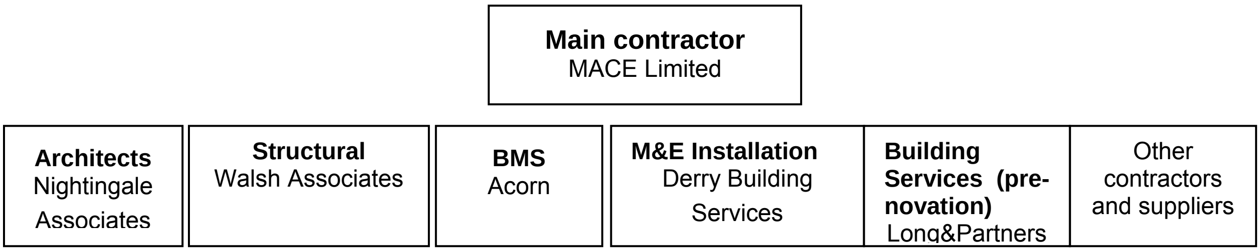


Figure 8 Stage 2 of procurement – Design & Build team for delivery of building

2.6 Conclusions and key findings for this section

The evaluation of the procurement of the Incubator building was undertaken through a combination of reviewing documents, interviews and conversations with individuals involved in the procurement process and through observations made by AECOM staff during several site visits. Individuals were interviewed from the main consultants involved in the procurement process FDG, AECOM, GSK, Mace and Derry as well as the client (SBCAT). The evaluation considered the procurement route, commissioning, handover, training and a design review (a comparison of the constructed building specification as compared to the pre-construction design).

The evaluation produced the following key findings:

Procurement route

When choosing the procurement route, the team needs to consider how the design philosophy is maintained for complex buildings. In particular, the procurement route needs to ensure critical design details aren't lost when design responsibility is passed to another party. Perhaps a traditional procurement route would be better or the Client Consultants could be novated to the Design and Build Contractor to help this, although this can reduce the clients influence on the post novation design.

More time could have been allowed for the Client to review tender returns before appointing the main contractor.

The eventual building management of (SBCAT) would have liked to have been involved earlier in the procurement process, so as to allow them to have more influence over the layout and fit-out of the building. In the initial stages, a board consisting of representatives from the funders were leading the procurement process on the client side.

Commissioning, Handover & Training

Planning (based on AECOM documentation review)

There was no evidence found of detailed planning of the commissioning works. Although a commissioning programme and flow chart were produced by MACE, no information was found about how the commissioning of different elements would be carried out e.g the whole building heating and cooling system.

It is likely that a lack of detailed commissioning plan providing a description of how various items are to be commissioned contributed significantly to a number of operational problems experienced with the SBCAT building in operation. A detailed commissioning plan would have allowed the client team to comment on and influence how key equipment was commissioned.

There was no evidence found of detailed planning of the pre-handover training of people who were going to operate the Incubator building.

Commissioning

More time should have been allowed for commissioning and handover stage when delays occurred. Where delays occurred, the building delivery date could have been extended and the commissioning programme updated accordingly. (Contractor comment)

One contractor involved in the delivery of the Incubator building suggested that more face-to-face meetings to resolve snagging issues in an expedient manner would have been beneficial. (Contractor comment)

No evidence was found that systems in the building were commissioned in a holistic manner – it appears that elements of building services equipment were commissioned separately. Although it has been stated through interviews with the Client team that the individual building services elements that were commissioned were commissioned well, there is no evidence that the building was commissioned to be fit-for-purpose i.e. that all elements worked together in an efficient way to produce the desired environmental conditions in the building.

(based on AECOM documentation review)

Communication & Change Control

SBCAT management would have liked ERs to be written in a more explicit manner so as to allow them to more easily compare commissioning of the mechanical and electrical systems with ERs. A number of ways that future ERs could be improved include:

- More prescriptively written ERs to ensure D&B contractor is especially clear about how key items in the building should be delivered (although this could have unintended disadvantage of reducing the design flexibility for the Design and Building Contractor). This could be achieved by completing the ERs at a later stage in the design process. (AECOM suggestion)
- With respect to commissioning, ERs could provide a results format that the D&B contractors have to follow to show that building elements have been commissioned to a satisfactory standard. (AECOM suggestion)

A more robust quality assurance procedure should be used for future projects so that change in design is signed off and controlled effectively and so that it would be easier to determine whether the Main Contractor continues to comply with the Employer's Requirements. It should also be made clearer which documents have been approved. (AECOM suggestion)

When contractors make technical submissions, Client Contractor should request this information in a form that allows easier comparison between these submissions and ERs. (AECOM suggestion)

Snagging lists and schedules of work outstanding were used to manage and resolve ongoing problems. This appears to have worked well. (AECOM observation)

O&M Manuals

Information could be presented in more relevant and accessible way.

- Most of the information about commissioning does not have any accompanying descriptive text and as a consequence it is not clear what the relevance of testing documentation is. (AECOM observation)

- Initially, only paper O&M manuals were available on site although electronic copies were supplied subsequently. The paper O&Ms are difficult to navigate and it is difficult to find specific information quickly. (Incubator building manager and AECOM observation)

During the Defects period, the Client said that the main D&B contractor was helpful in resolving outstanding problems. However, it does not appear that the O&M manuals are being updated to reflect changes made to the operating conditions of the building.

At the time that the evaluation of the procurement of the building occurred (which encompasses the appointment of the D&B contractor, commissioning and handover), the Building Log Book was not found for review. Therefore the evaluation of the Building Log Book has not been undertaken. (AECOM observation)

Handover Training

There should be earlier involvement of SBCAT staff in building delivery to gain better understanding of building operation. (Client comment)

Training was described by the Client as adequate (on a scale of Excellent/Adequate/Not useful). A number of recommendations were made by the Client on how to improve training:

- Training tended to be unstructured and a more structured training schedule would have been beneficial.
- Documents and handouts were not always provided – it was felt that these would have been extremely useful after the training for reviewing and familiarisation.
- A more hands on approach could have been used (i.e. hands-on training actively operating the building systems rather than passively receiving presentations)
- Information on how to troubleshoot and resolve faults could have been provided
- The training happened over a short space of time. It may have been more beneficial to spread the training over a longer period to give the building management team time to absorb new information.

Design Review (based on AECOM documentation review)

Mechanical and Electrical

Insufficient information was found to allow a meaningful comparison between the Employers Requirements, the Contractor's proposals and the As-Built building. In order to allow more effective future design reviews, the following is recommended:

- ER's should be written in a way that requires the D&B contractor to provide installation and commissioning information in a form that allows the systems installed in the building to be compared against
- The Quality Assurance process should make it very clear which designs have been commented on and and whether the contractor has accepted the comments and amended the design to suit.

Architectural

In general, the architectural design features specified in the Stage D Employer's Requirements have been implemented in the constructed Incubator building. The general consensus is that building occupants are pleased with the aesthetic and layout of the building. Further details are provided below:

- Elevation appearance - As per the ER's, the elevation appearance of the building includes the use of a variety of materials and textures including facade mounted solar PV, aluminium fascias, structural glazing, zinc shingles and a stone gabion.
- Internal space layout – As per the ER's, the Incubator building consists of a lab and office wing, joined together by a hub (consisting of the boardroom and meeting rooms) and a central atrium
- Fit out – As per the ER's, the Incubator building has been fitted out with services, finishes and the necessary loose furniture to make it a functioning facility at handover. Tenants can bring additional furniture if this is agreed with the building manager.
- Ceilings – As per the ER's, there are suspended ceilings in labs. The offices consist of an exposed concrete soffit to make use of thermal mass with floating panels to allow for some acoustic controls. The intention is that the ceiling in the labs and offices will allow easy access for maintenance of building services. There have been no difficulties reported regarding the maintenance of building services located in the ceilings.

Sustainability – BREEAM

- SBCAT can be considered to be a highly sustainable building in the context of BREEAM assessments as it is on course to achieve the targeted "Excellent" rating.
- Key sustainability features include air source heat pumps to supply all space heating and cooling needs, a CO_2 heat pump to supply hot water, rainwater harvesting, low flush toilets, water metering for individual labs and solar PV.
- There has been a lack of attention to the detail of some aspects of the building that could contribute to its overall sustainability and specifically the BREEAM criteria requirements. This has led to a lower BREEAM score (though still achieving the targeted "Excellent" rating targeted during the pre-assessment and design stages)
- A better understanding of the BREEAM credit requirements throughout the design and construction process would have resulted in more BREEAM credits being achieved and a slightly more sustainable building in the context of BREEAM assessments
- The most important lessons are to include more detail of the BREEAM requirements in the tender documents. The requirements were not explicit enough and a lack of BREEAM experience in the contractor team led to the team not realising the implications of requirements until it was too late. The early requirements could be added in a section of specifications providing the details of measures to be taken that relate to BREEAM and could also serve as an easy reference for the team throughout design
- The entire design team would ideally be involved in the BREEAM progress meetings
- The BREEAM assessor must be kept informed about the construction programme
- Key dates for evidence collection should be agreed at the beginning of the construction process.
- Although BREEAM requires the installation of energy efficient equipment, from the BPE carried out on the Incubator building, it does not have a significant effect on operational energy use. The operational energy use of the Incubator building is dominated by the commissioning and controls of installed equipment.

Tenant Information Pack (Tenant User Guide)

The Tenant Information Pack (TIP) is clearly set out and provides comprehensive information regarding the general usage of the building. However more specific information is required to inform tenants of specialist systems and equipment installed in the building along with guidance on their operation and controls.
It would also be beneficial to provide tenants with guidance outlining measures that can be taken to utilize features of the building to maximize energy efficiency and building performance.

Specific recommendations on how the Tenant Information Pack can be improved are:

- The building description should be located in its own separate section.
- Provide a description of other areas in the building that an occupant would use in addition to information provided regarding the hub and atrium, for example – individual labs, community lab, offices, SBCAT building management office.
- The TIP should include descriptions of energy efficiency features that occupants have control over, along with detailed reference information outlining their controls and the benefits that can be achieved by undertaking certain actions.

3 Review of building services and energy systems.

3.1 Energy systems in the Incubator

The Incubator is an all-electric building with no provision of gas to the building. Information has been provided to document key energy and water services and controls as per the list below:

- Heating and chilled water – Air Source Heat Pumps
- Ventilation
- Domestic hot water – CO_2 heat pump and back up electric immersion heaters
- Cold water supply – Mains water and rainwater harvester
- Lighting
- On-site electricity generation – Solar Photovoltaics
- BMS
- Lifts
- COMMS/IT

3.2 Heating and chilled water generation – Air Source Heat Pumps

There are three 500 kW air-to water heat pumps located on the roof of the Incubator building which generate either heating or chilled water for the purposes of providing space heating, space cooling and tempering of ventilation air. Heating water is stored in an 5m^3 hot water buffer vessel. Chilled water is stored in a separate 5m^3 chilled water buffer vessel. A CO_2 heat pump, which is used to generated hot water, also supplies some chilled water to the chilled water buffer vessel as a by-product of its hot water generation process. The CO_2 heat pump is discussed further in the section on domestic hot water.

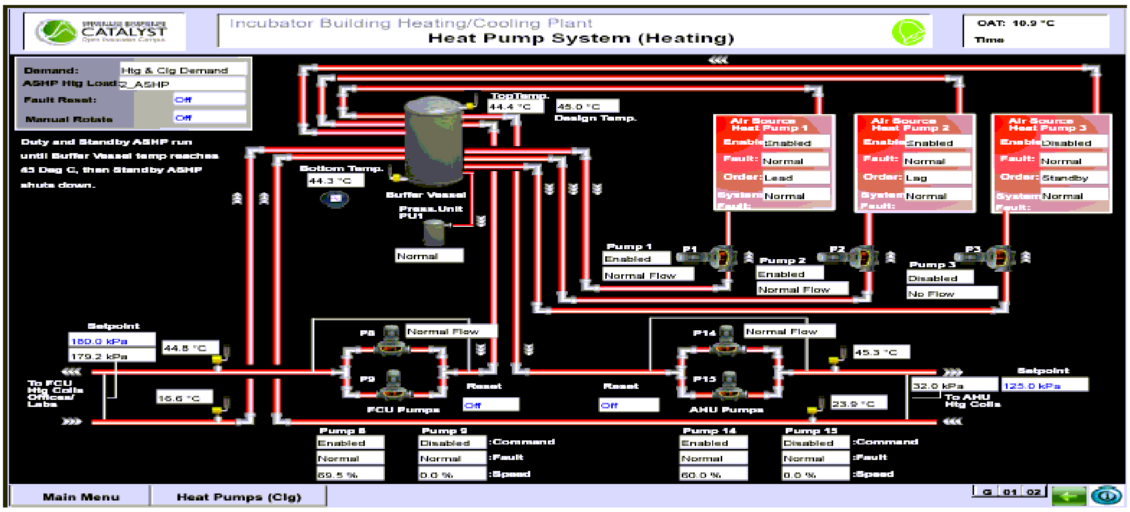


Figure 9: BMS Screenshot showing the building heating system

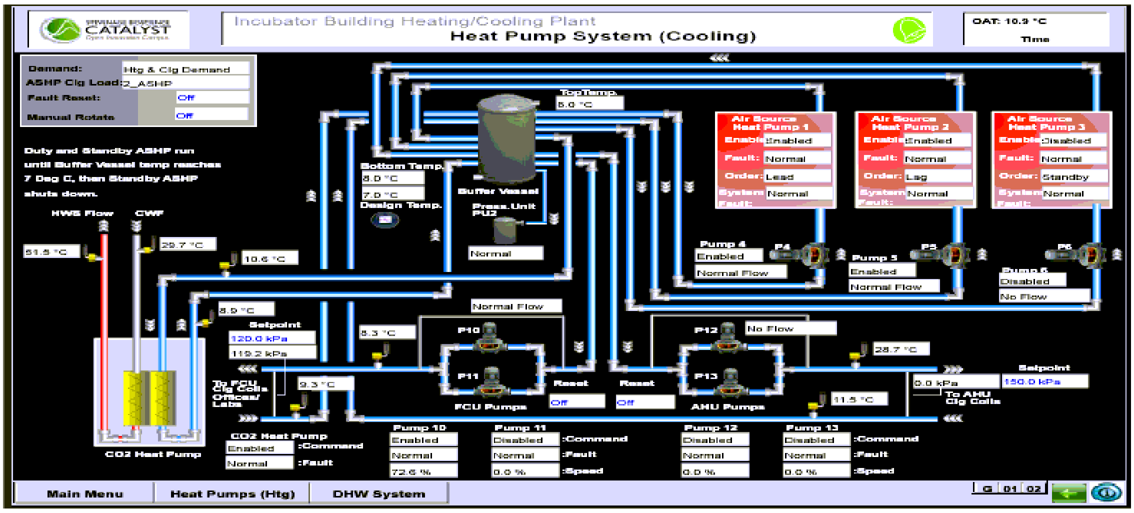


Figure 10: BMS Screenshot showing the building cooling system

3.3 Space heating and cooling

Labs, offices and meeting rooms

To provide either space heating or space cooling to labs and offices, hot water or cold water is pumped from the hot or cold buffer vessel respectively to fan coil units located in each lab or office. The fan coil units use a fan to blow air over the heating and/or chilled water pipes to provide heating or cooling to the space.

Atrium

Hot water from the hot buffer vessels is pumped around an underfloor heating circuit to provide space heating o the atrium. Cooling is provided from the cooled fresh air supply.

Comms/IT room

The Comms rooms each have two DX cooling units with dedicated heat rejection on the roof. Each DX unit was sized to meet the full design cooling capacity of the respective Comms rooms.

Other areas

Space heating and cooling is supplied to the labs, offices, hub meeting rooms and atrium from the whole building heating system. The stairwells are fitted with electric panel radiators to provide space heating. No other areas in the building are provided with space heating or cooling.

3.4 Hot water

The CO_2 heat pump is called an “Envitherm50” and is provided by Star Refrigeration. It uses CO_2 as a refrigerant. It is designed to produce domestic hot water at 60degC by extracting heat from the buildings cooling circuit. This enables it to simultaneously provide cooling to the building while providing hot water. The

CO_2 heat pump can also be run by extracting heat from a mains cold water supply. The design is based on a mains cold water supply temperature of 15degC.

Conventional heat pumps are not able to provide heat at a sufficiently high temperature to heat hot water to 60degC. The CO_2 heat pump is specifically designed to be able to achieve this by using the specific properties of the CO_2 refrigerant.

The heat pump has been provided with two buffer vessels to "buffer" the heat output of the heat pump for when it is required. These buffer vessels are provided with immersion heaters to provide additional heat to the hot water when the heat pump is unable to meet the full heating demand.

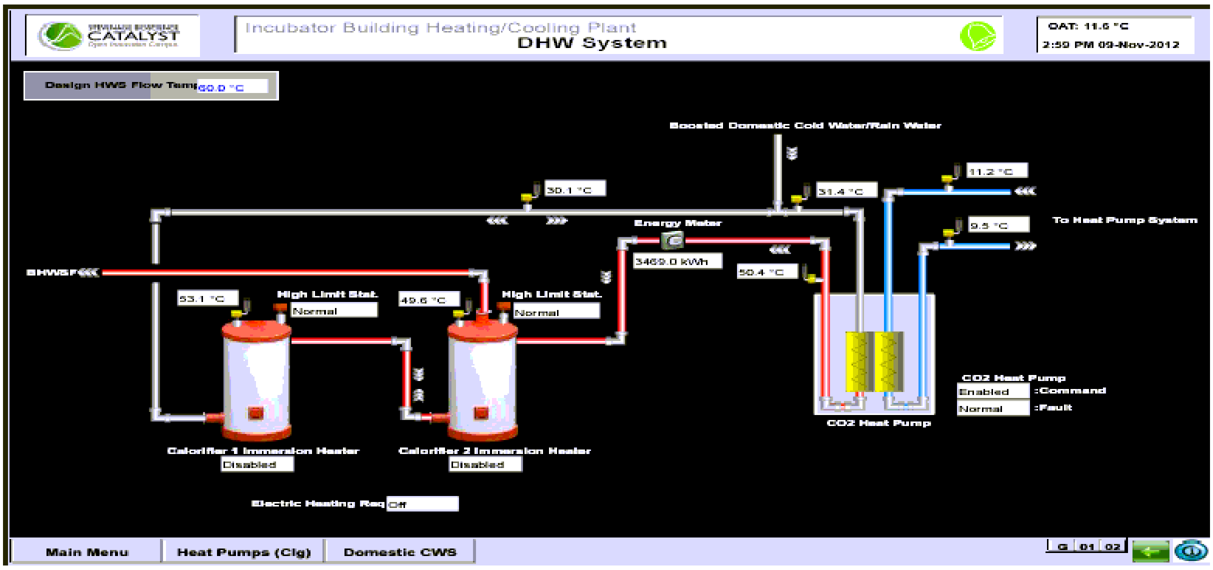


Figure 11: Screenshot of BMS showing the DHW system

3.5 Ventilation

Supply of ventilation air

There are four Air Handling Units (AHUs) – three AHUs to supply ventilation air to the labs and communal areas and one AHU to provide ventilation air to the offices. These AHU's supply the ventilation air for the Incubator building via ductwork.

The AHUs incorporate filtration, inlet and outlet noise attenuation, heating, cooling and heat recovery. Heat is recovered from all of the extract systems apart from the toilet extract (See *Air extraction* below for more details.) The office AHU delivers air directly into the offices whereas the Lab AHUs deliver air into the corridors adjacent to the labs to serve both the labs and the central circulation space in the building. Air is then drawn into the labs as a result of the extraction of air from the fume cupboard. (See *Air extraction* below for more details.)

The AHUs temper the air that they deliver to the building by passing the air through heating and cooling coils which are part of the AHUs. These coils are in turn supplied with heating and chilled water from the hot and cold buffer respectively. The air that is drawn by the AHUs passes through a labyrinth before reaching the AHUs

Labyrinth

The labyrinth in the SBCAT building is an experimental feature of the building. The idea of the labyrinth is that it will either pre-heat air entering the air handling units (AHU's) in winter or pre-cool air entering the AHU's in summer.

The logic underpinning this idea is that the building structure and surrounding ground would act as a thermal buffer. In the winter it would store heat during the warmest part of the day that it has absorbed from the incoming fresh air and release it during the colder parts of the day back into the incoming fresh air.. The result is that the building energy systems should need to use less heating energy to bring the incoming fresh air up to the required operating temperatures during the morning start-up and any latent heat remaining in the structure should further reduce the building heating energy consumption during the day.

Over the course of the year, the building would make use of the relatively constant ground temperature to further provide pre-heating in the winter and pre-cooling in the summer.

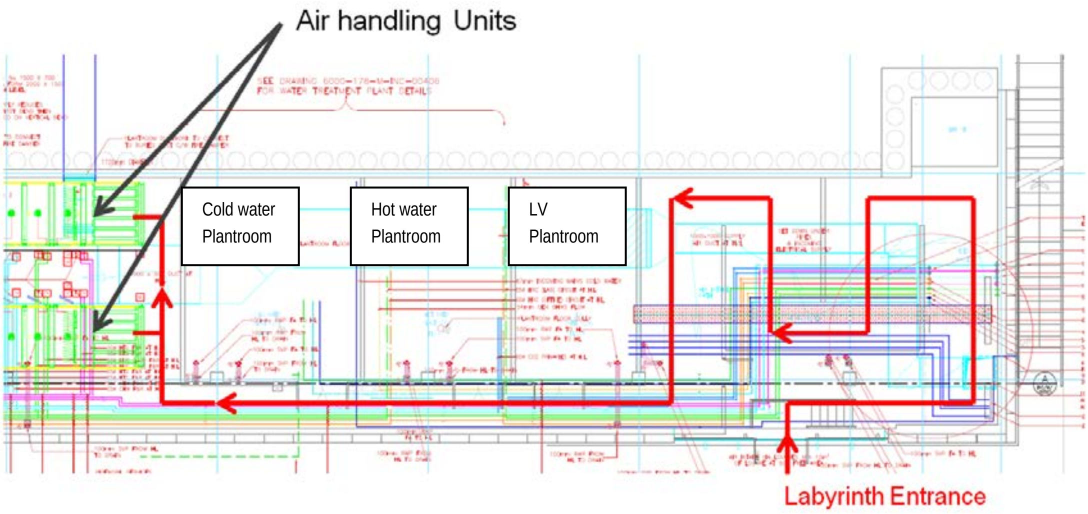


Figure 12: Diagram showing layout of labyrinth and adjacent plant rooms

Air extraction and heat recovery

All extract fans are located on the roof and extract air from rooms within the Incubator building via ductwork. An office extract fan extracts air from the offices. A "hub" extract fan extracts air from the manager's office, meeting rooms and boardroom. Two lab extract fans extract air from the labs via the fume cupboards. A twin fan toilet extract fan extracts from the toilets.

A solvent extract fan provides continuous extract of air from the labs via the solvent cupboards. The purpose of this extract is to ensure that any substances that may give off fumes, which would be stored in the fume cupboard, would have any fumes extracted from the solvent cupboard out of the building. This allows fume cupboards to be turned off over night as they are not required for solvent storage.

Heat is recovered from the air extracted from the offices and laboratories prior to its release to the atmosphere. This heat is then used to provide pre-heating to the ventilation air via heat recovery coils located in the AHUs.

3.6 Lighting

The lighting is designed to exceed or, at a minimum, comply with Part L of the building Regulations and to suit the requirements of BREEAM. In principle, the lighting strategy is to provide low energy design solutions making use of low energy technologies, LED where possible and using efficient controls.

Offices

Dimmable linear fluorescent luminaires are provided in the tenant office areas, suspended between the floating ceiling panels, and supported from the structural slab. A number of the luminaires are provided with integral LED lamps for emergency lighting purposes. Square recessed fluorescent luminaires are provided in the meeting room, supplemented by LED downlights in plasterboard margins. The raised ceiling in the breakout space is illuminated with cove lighting at high level, and LED downlights provided to illuminate the work plane. The offices are controlled by local presence / absence detection from sensors integral to the luminaires. Sensors in luminaires local to external windows also incorporate photocells to provide automatic dimming in response to changes in daylight contribution. Local dimming controls are provided for user override.

Laboratories

Recessed fluorescent luminaires are integrated into the metal plank ceilings in the laboratory and write up areas. These are twin lamp fittings to achieve the target illuminance and these replace two metal planks. The laboratory luminaires additionally provide a return air path to the ceiling void for the ventilation system. The lighting in each tenant space is controlled by local presence / absence detection to reduce unnecessary energy use. Local dimming controls provide user override.

Atrium

The atrium lighting is timer controlled to suit the operating hours of the building, and where possible is automatically dimmed in response to daylight.

Core / Circulation

LED downlights are used throughout the circulation spaces around the laboratories, in stair lobbies and in toilet cores. This is controlled primarily by local presence / absence detection, and is automatically dimmed in response to changes in daylight contribution

Emergency Lighting

Emergency lighting is installed to illuminate parts of the building when part or all of the normal lighting fails. The emergency escape lighting is provided using integral 3-hour batteries and chargers within the mains fittings and similarly within the self-contained emergency fittings.

An illuminated exit sign is installed above each fire escape door and emergency illumination is provided to illuminate signage on escape routes where necessary to direct persons to the designated escape doors.

External Lighting

External lighting comprises of bollards and column lighting with supplies from the LV switchboards, for each respective building. Lighting control is via contactors controlled by time/solar sensors set by the lighting control system.

3.7 Solar Photovoltaics (PV)

Facade mounted PV is installed on the south and south west facade to generate zero carbon electricity to offset the electricity use in the Incubator building.

The total amount of PV installed on the Incubator building is 80.8 kWp (approx 67.1 kWp on the south facade, 13.7 kWp on the south west facade). The total area of PV installed is approximately 530 sqm.

Figure 13: Photo showing PV array on South and South west facade.

3.8 BMS and control system

The BMS system is a Delta Controls system that is supplied by Acorn. The BMS provides control and monitoring of key plant and equipment and cumulative energy use labs, offices and major energy end uses such as the Comms room, lifts and building services equipment. However the BMS does not provide long-term storage of the energy consumption readings.

3.9 Cold water services and rainwater harvester

The incoming main cold water supply provides water to 3 tanks located in the cold water plantroom on the lower ground floor. These 3 water tanks provide water in turn feed various end uses as described below.

- Potable tanks 1 – Feeds Laboratory Domestic water
  Potable Tank 1 serves the cold water supply to the laboratory sinks and wash hand basins on the ground, first and second floors. From the 15mm supply to the laboratory wash hand basin, a pulsed water meter complete with isolation valves has been installed.

- Potable tanks 2 - Feeds Toilet Domestic water
  Potable Tank 2 serves the cold water supply to the Toilet core on the ground, first and second floors.

- Potable tanks 3 – Is fed from the Rain water harvesting system
  Potable Tank 3 provides water for toilet flushing and external irrigation. The principal supply of water for this tank is from an externally located 12m^3 storage tank. The system includes a make-up supply from the mains cold water supply to provide water during periods of low rainfall.

3.10 Lifts

There is one passenger lift (1,000 kg capacity) and one good's lift (1,600 kg capacity) in the Incubator building.

3.11 Key Questions

In order to inform the evaluation the building services and energy systems in the Incubator building, a number of key questions are posed:

- Are the air source heat pumps operating in a reliable and efficient manner?
- Is the hot water system (CO_2 heat pump and back up electric immersion heaters) operating in a reliable and efficient manner?
- Is the building achieving satisfactory internal environmental conditions?
- Does the labyrinth result in a reduction in energy use for heating during the heating season?
- Overall, how does the energy use of the Incubator building compare with benchmarks?

For more details regarding energy and water use, see Section 6 and 7

4 Key findings from occupant survey

4.1 Introduction

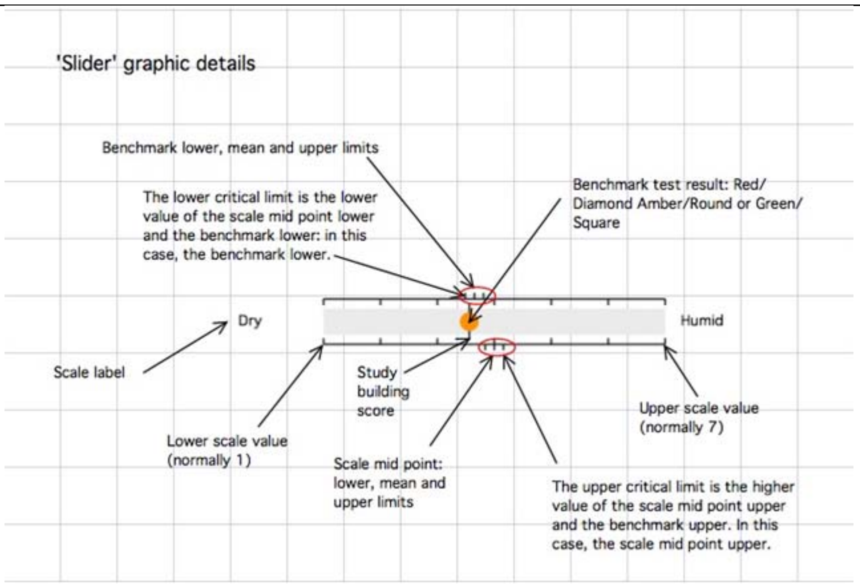
As well as protecting its occupants from the outside elements, a building also has to provide the necessary internal environmental conditions to allow them to work comfortably and productively. In order to understand whether these objectives have been met and to identify areas where improvements can be made, building user surveys have been undertaken for the Incubator building.

About the Building User Survey

The Building Use Studies (BUS) survey is a licensed occupant survey developed by others but now owned by Arup. The questionnaire was given out to occupants and it queries the different aspects of comfort and accessibility issues related to the SBCAT Incubator building. It also seeks to gauge the occupant views of the building and how well it serves to cater to their personal needs and ability to perform their work.

4.2 Survey Outcomes

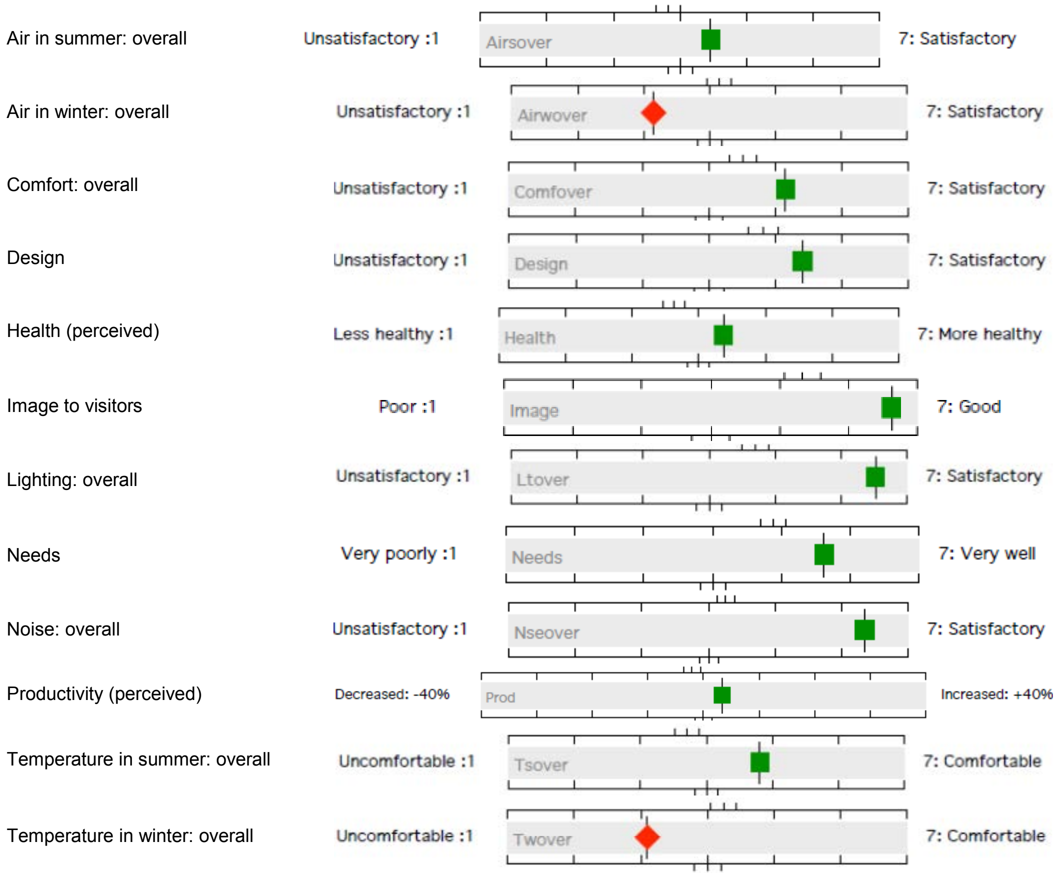
22 responses were received from the 38 occupants at the time of the survey, and these were processed by AECOM and sent to Arup for analysis. The diagram below illustrates how to interpret the scaling system used.



In terms of rating on each parameter, the indicator can be interpreted as:

	Green square	Above benchmark
	Amber round	Same as benchmark
	Red diamond	Below benchmark

Below are summary of the outcomes of the survey of the Incubator building.



In general the Incubator building has done well in terms of performing on-par with or better than average on most of the aspects considered.

However occupants have expressed dissatisfaction with space temperatures in winter. The dissatisfaction of is linked to the following issues that were found as part of the BPE study:

– Difficulty in adjusting fan coil unit (FCU) performance for individual rooms. The FCUs that were installed have their own proprietary control software which cannot be adjusted without specialist programming knowledge – the building manager only has the ability to change the fan coil unit (FCU) output temperature on a floor by floor basis. In order to change FCU output for individual rooms, the BMS supplier was required to be called in to manually reprogram the BMS.
– Failure of whole building heating system during cold weather. There is no evidence from the commissioning documentation that the whole building heating and cooling system was commissioned as a whole. In particular the air source heat pumps have stopped working on several occasions. However it is not clear whether there is only a problem with the air source heat pumps or whether there is also a problem with how the Building Management System controls the ASHPs as part of the whole building heating/cooling system.
– Unnecessary use of heat for ventilation. During the investigation of the Incubator, every fume cupboard in the building was found to be switched on and therefore called for extraction of air by the roof extract fan. In turn, the AHUs were operating to match the rate of extraction of the air from all the labs. As almost all the labs were unoccupied, this represented a significant wastage of heat. The heat used to heat the fresh air was extracted from the hot buffer vessel, which meant that an already struggling heating system was providing heat unnecessarily to heat ventilation air that was not required.

- Heating systems in highly glazed offices does not always provide thermal comfort even when whole building heating system is operational. Discussions with occupants who sat adjacent to the glazing in the offices yielded complaints of feeling too cold (on cold days) and feeling too hot (on sunny days). This suggests that radiant heating and cooling is a particular issues in the highly glazed offices, in particular the corner offices with a dual aspect.

Figure 14: Photo showing fan heater in Incubator building

4.3 Conclusions and key findings for this section

From the outcome of the survey, several conclusions can be made about the Incubator building.

- In general, the Incubator building has done well in terms of performing on-par with or better than average on most of the aspects considered.
- Specifically, it has performed well in catering to the occupants overall needs.
- Areas where users have felt that the building has performed unsatisfactorily relate to the temperature and air in winter. This is most likely linked to:
    - the reported failing of the heating system during cold spells perhaps as a result of insufficient whole building system commissioning
    - inadequate control of the building's heating and ventilation system by the Building Management System (BMS)
    - heating system not achieving thermal comfort in highly glazed offices

5 Details of aftercare, operation, maintenance & management

5.1 Introduction

The building manager has overall responsibility for the operation and maintenance of the Incubator building. This role encompasses liaison with occupants to ensure they are happy with the building environment, organising of events and facilities management. Specifically, he is the key user of the BMS and any day to day changes in the key operational parameters of the building are supposed to be made by him.

There is an in-house staff member who carries out day to day maintenance of the building.

A mechanical and electrical (M&E) contractor has been appointed to carry out weekly maintenance checks on key building systems, in particular relating to central building services plant such as the air source heat pumps, air handling units and associated pumps.

During the period when the building performance evaluation took place, the Incubator was still covered by its defects period. Therefore, the design and build main contractor (MACE) and their sub-contractors also attended site to resolve building defects and to make modifications to building services equipment that was not performing satisfactorily.

5.2 How were users trained to use equipment and do they demonstrate the right competencies?

Training in the operation of the building was reported as being unstructured and comprising primarily of presentations. Documents and handouts were not always provided at these presentations. The majority of the training took place over a short period of time (over about 2 weeks).

- There was no handout for the Building Management System training
- At the time of the commissioning and handover evaluation, the building manager, who has the main responsibility for use and operation of the BMS in the Incubator building, had not received any electronic or paper instructions on how to use the BMS.
- There was no training about how the building operated as a whole

All of the above has contributed to a situation where those charged with the operation and maintenance of the building (building manager, in-house maintenance staff and mechanical and electrical maintenance contractor) received training that does not appear to bring them to an adequate level of competence to fully understand how the Incubator building works and how to operate it and maintain it to ensure its continued efficient performance.

5.3 Was the maintenance team employed, trained and up to speed at handover?

The official handover date of the Incubator building was in December 2011. However the actual time that practical handover of the building took place spanned the period between December 2011 and December 2012. This is because the commissioning of the building had not been completed by December 2011 and there have been ongoing operational issues with key building services equipment, in particular the whole building heating system and the air handling units.

The maintenance team was trained, but it not to an adequate standard. For example, building staff were unaware of how to switch off the ventilation system for unoccupied labs.

5.4 Was a proper system put in place to log problems and did this help resolve teething issues?

Snag lists helped for resolving minor issues. However for major items such as the ASHPs and air handling units, there is no fit for purpose system in place for logging and resolving issues.

Although an engineer's receipt is produced after works to equipment, it does not necessarily explain the work carried out and the impact on the operation of the piece of equipment concerned, or any knock on impacts on related building systems.

5.5 Conclusions and key findings for this section

The maintenance team was trained, but it cannot be concluded that they were up to speed as there have been ongoing technical issues which had not yet been resolved at the time of the building performance evaluation study.

The training given in the operation and maintenance of the building is not considered to bring those responsible for the ongoing operation and maintenance of the Incubator building to a sufficient level of competence to keep the building running in an efficient and reliable manner.

At the time of the building performance evaluation, there was not a proper system put in place to log ongoing problems and this has led to a situation where some changes that have been made to key building services equipment (such as the air source heat pumps) have not been documented in the operation and maintenance manuals or in the log book.

This is likely to lead to future operation and maintenance problems with the building - as there would be no record of changes made, another person coming in to do maintenance may revert unrecorded changes back to settings in the operation and maintenance manuals, thinking that it was an error when in fact that change had actually been made to resolve a particular problem.

6 Energy use by source

6.1 Introduction

TM22

A TM22 assessment was carried out to understand and reconcile the energy use in the SBCat building. The general objective of a TM22 assessment is to ensure that as many aspects of energy use in the building can be accounted for.

Metered energy data was obtained from the building BMS for the period 1st February to 31st October 2012. This data was then pro-rated to generate an approximate annual energy consumption figure. Where relevant, degree-day adjustment was applied to approximate heating and cooling energy use for the whole year.

Whole building energy use for one month

In order to produce an appraisal of where energy is consumed in the Incubator building, the energy consumption for the last month assessed as part of the TM22 evaluation (October 2012) has been analysed. In preceding months, there were ongoing commissioning issues and a lower occupancy. Therefore October 2012 represents a month which would be most typical of energy consumption of the months assessed for the TM22.

Water use & Rainwater harvester

The performance of the rainwater harvesting system has been reviewed to determine its contribution towards meeting the Incubator building's water needs. The amount of rainwater used in the building was found by taking manual readings of the rainwater harvester water use meter. The amount of mains water used in the building was found from water bills.

Fabric performance and air-tightness test

The air-tightness test results for the Incubator were reviewed to ascertain how the actual air-tightness value achieved by the Incubator building compares to the intended value.

Thermal Imaging was undertaken for the Incubator building to assess if the building fabric was performing as expected and to highlight any areas where there may be problems with the fabric.

6.2 TM22

Figure 15 and Figure 16 present the TM22 assessment output showing the comparison of the actual in-use energy consumption against corresponding benchmarks (TM46 and ECON19) based on end-use categories. As the Incubator building is an all-electric building, space heating and DHW generation are also included in Figure 4, resulting in the omission of in-use energy in Figure 16.

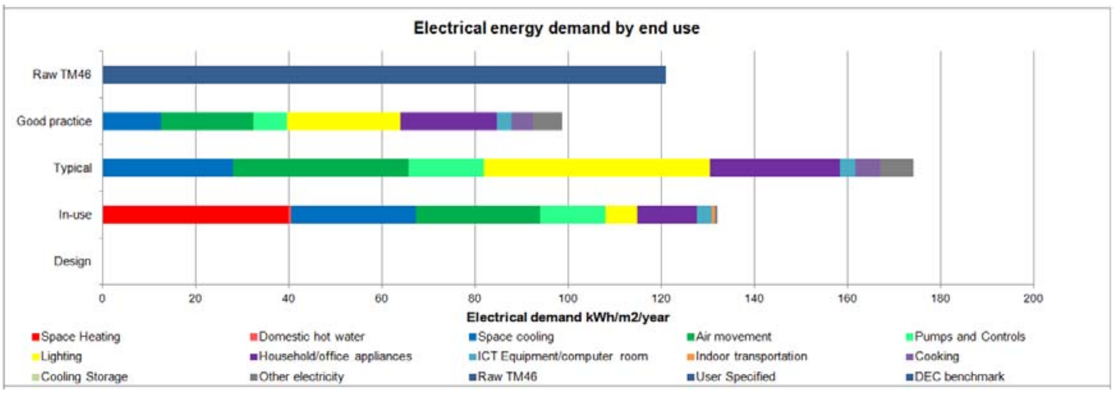


Figure 15: Snapshot from TM22 for the electrical energy demand by end use

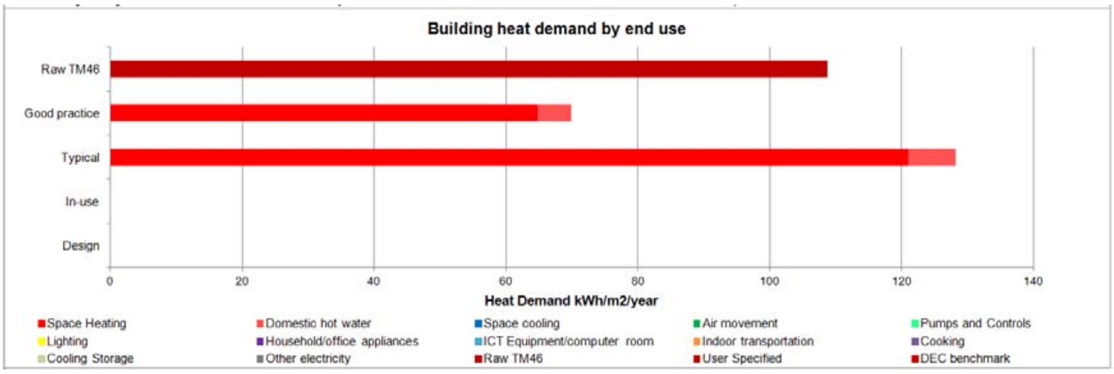


Figure 16: Snapshot from TM22 for the building fossil fuel based heating demand by end use

The Incubator building actual in-use electrical energy consumption is 35% in excess of the ECON19 Good Practice benchmark.

However the overall energy use (Electrical energy demand by end use + Building heat demand by end use) is 22% less than the ECON19 Good Practice benchmark.

Therefore, overall the Incubator building consumes less energy overall than its corresponding ECON19 benchmark (The ECON19 benchmark relates to offices. This benchmark was used as there is no benchmark for labs or a lab/office mix). The following factors could explain why the Incubator uses less overall energy than the ECON19 benchmark:

- Low occupancy leading to low small power and lighting use
- Good lighting and controls resulting in reduced lighting energy use
- Poor air source heat pump controls leading to faulty operation and significant system down time, in particular during the coldest metered period. Thus the building could have been undersupplied with heating while the air source heat pumps were being repaired.

No adjustment for low occupancy has been carried out for this comparison as this is outside the scope of the assessment under the TM22 methodology.

Table 2 provides commentary on the comparison of the Incubator energy demand by end use with Good Practice benchmarks (ECON 19 – Energy Use in offices)

End use	Comparison with good practice benchmark (ECON19)	Comments
Space heating	n/a	Good practice benchmark does not include space heating as an electrical demand. Therefore no comparison possible.
Domestic hot water	n/a	Good practice benchmark does not include space heating as an electrical demand. Therefore no comparison possible.
Space cooling	SBCAT Incubator lies between good practice and Typical.	
Air movement	SBCAT Incubator lies between good practice and Typical.	Ventilation air in excess of building requirements was circulated through the building (air handling units supplied air, roof extract fan extracted air from fume all cupboards despite majority of labs being empty).
Pumps and controls	SBCAT Incubator performs worse than good practice – performance is closer to Typical.	See above comment. Operational problems were also experienced with the heat pumps and fan coil units (FCUs) which are understood to have resulted in excess pumping of water through the heat pump and increased flow rates of water through the FCUs.
Lighting	SBCAT Incubator performs significantly better than good practice	Energy efficient light fitting have been installed in conjunction with occupant control of lighting levels and presence detection.
Appliances	SBCAT Incubator performs significantly better than good practice	This could be due to the low occupancy of the building. It is expected that if the building were fully occupied, it would use significantly more electricity for appliances.
ICT	SBCAT Incubator performs similarly to Good practice (which is also similar to Typical).	As the building has a low occupancy, it is possible that the Incubator building would perform worse than the Good practice benchmark when fully occupied.
Indoor transportation	n/a	Good practice benchmark does not include for indoor transportation. Therefore no comparison possible.

Table 2: Comparison of SBCAT Incubator building electricity demand with Good practice and Typical benchmarks from ECON 19

6.3 Whole building energy use for one month

The SBCAT Incubator sub-meters do not monitor all end uses. In particular, lighting, fan coil unit and small power electricity consumption are not separately sub-metered for the labs, offices or landlord areas. Table 3 shows the end uses that are sub-metered in the Incubator building along with their associated electricity consumptions in October 2012.

The Incubator sub-meters monitor the following end uses:

Electricity end use	October 2012 electricity consumption, kWh	What does this monitor?
Total landlord	9,023	Lighting in communal areas (inc. Roof and lower ground floor), FCUs in meeting rooms (boardroom, Redrooms, Bluerooms), small power
Total lab	7,025	Lighting, FCUs, small power
Total office	5,110	Lighting, FCUs, small power
ASHP	37,931	ASHP consumption (excluding ancillary equipment)
Central distribution - space heating, cooling, ventilation	16,453	Heating and chilled water distribution pumps, AHU and extract fans, fan for PTFE facade “bubble”, control equipment for roof plant
DHW generation, DHW & cold water services distribution	6,485	CO2 heat pump, immersion heaters, pumps for DHW and cold water services (inc. Rainwater harvester), AHU fans
External Lighting	436	External lighting
Comms/IT room	1409	Central IT infrastructure
Lifts	324	Goods & passenger lifts

Table 3: Summary of end-uses sub-metered in SBCAT Incubator building

Estimating the breakdown of energy use for lighting, fan coil units, small power, space heating and ventilation air heating.

In order to produce estimates for a breakdown of lighting, fan coil unit and small power electricity consumption, the annual calculated split of energy consumption generated as part of the TM22 reconciliation has been used to approximate the percentage split between these elements.

In order to estimate the split of ASHP electricity consumption that is used for space heating and ventilation in October 2012, the proportion of heat delivered to fan coil units and air handling units respectively was calculated based on data recorded from the BMS (Building Management System). This data shows heat meter readings of the amount of heat that was delivered from the buffer vessel to the FCUs and AHUs between 9th November and 10th December 2012. This time period was chosen as it was the earliest period for which data was available regarding heat delivered from the buffer vessel. During this time period, no chilled water was delivered to the building. Therefore it has been assumed that all heat pump electricity consumption during October 2012 was for the purposes of space heating and ventilation air heating.

Breakdown of energy consumption for October 2012.

Based on the estimates for the breakdown of end use consumption for lighting, fan coil units, small power and ASHPs, the breakdown end uses of Incubator electricity has been plotted in Figure 17 and Figure 18.

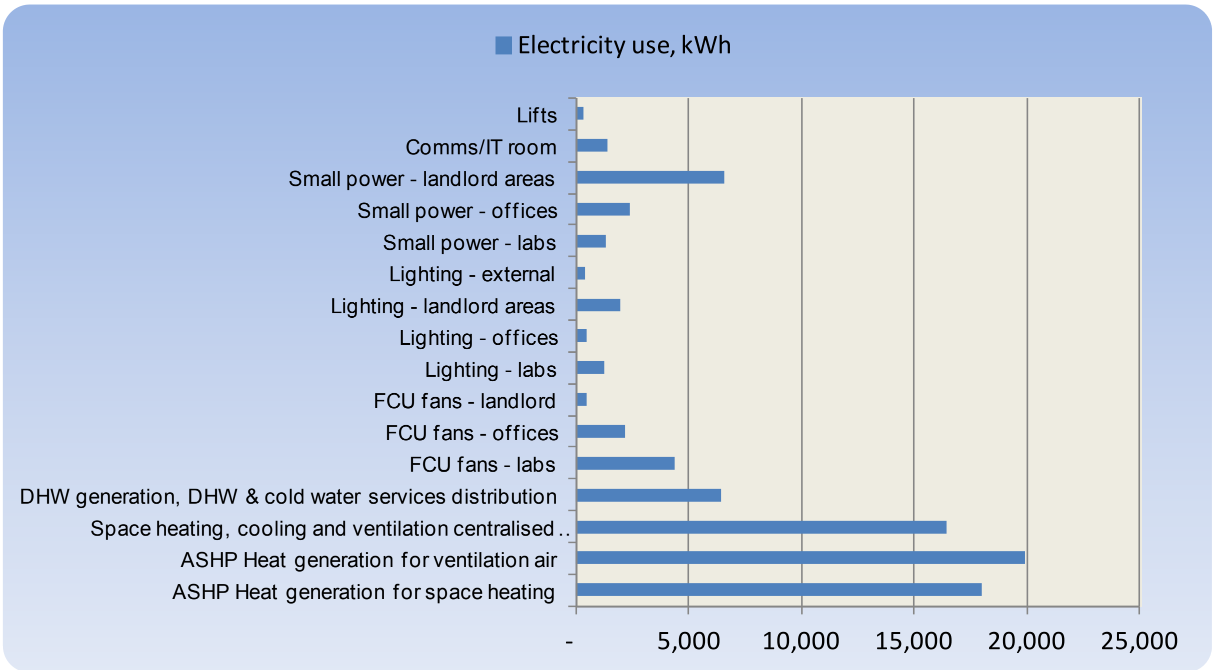


Figure 17: Detailed breakdown of end-uses in Incubator building

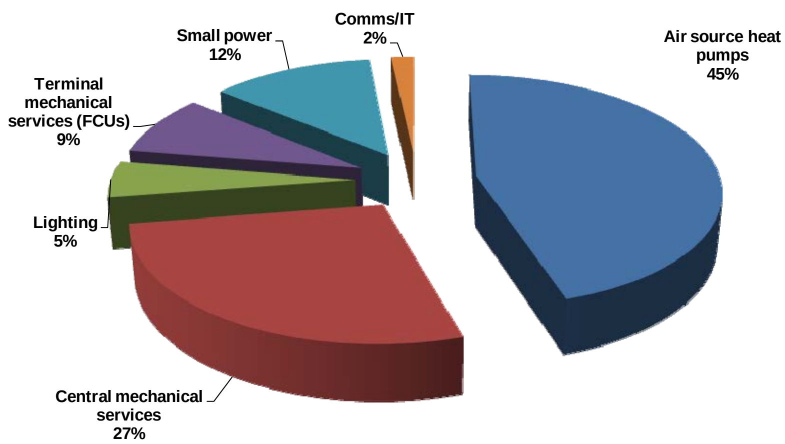


Figure 18 : Pie chart showing a breakdown of electricity use in the Incubator building based on major end use categories.

The building energy use is dominated by heating, and the services to distribute heat and ventilation. Given that the building has laboratory areas, with high potential requirements for air exchange rates, this might be expected. However the low rate of occupancy suggests that this energy use could be reduced substantially for times of low usage.

A review of the operation of the air source heat pumps and central mechanical services (which are mainly affected by AHUs and fume cupboard operation which in turn drives the fume cupboard roof extract fan) offers the main opportunities for reducing energy use in the Incubator building. Resolving ongoing problems with the performance of the ASHPs should also save energy.

6.4 Water use & Rainwater harvester

Annual usage of rainwater in Incubator building and for external irrigation

	Rainwater meter reading for period between 16th December 2011 to 3rd January 2013	Pro-rata annual use of rainwater in Incubator building
Volume of water used, m^3	102	97

It should be noted that on the date of the rainwater harvester reading, there was a discrepancy between the volume recorded on the physical meter and the reading for the rainwater harvester displayed on the BMS. The BMS displayed 87m^3 whereas the physical meter displayed 102 m^3 on the 3rd January 2013.

Annual usage of mains water

	Mains water consumption for period between 16th December 2011 to 28th September 2012	Pro-rata annual use of rainwater in Incubator building
Volume of water used, m^3	692	874

Annual total water use in Incubator building

Total annual water use in Incubator building is estimated to be 97 + 874 = 971 m^3

Percentage of total Incubator water use that comes from rainwater

Rainwater harvester is estimated to provide the following percentage of the total water demand for the Incubator building: 97/971 = 10%

Estimate of the volume of rainwater used in the Incubator building in a month

Average volume of rainwater used in a month = 97/12 = 8 m^3

6.5 Fabric performance and air tightness test

Air permeability

The targeted air permeability was 5 $m^3/hr/m^2$ @ 50 Pa. An air permeability test was carried out on 22nd November 2012. The Incubator building achieved a performance of 4.91 $m^3/hr/m^2$ @ 50 Pa. Therefore the Incubator building measured air permeability performance just achieved the target shown in the As-Built Part L model.

Thermal imaging

Although the thermography report produced by BSRIA for this study highlighted a number of "anomalies", it should be noted that the majority of these anomalies are an expected by-product of the building design.

These anomalies include warm and cold bridges. For example, it is expected that the frame around glazing will be colder than the centre of the glazing as a result of the thermal bridge created by the spacer between the two window panes in a double-glazed unit.

There are a few minor parts of the building that further investigation is recommended as the anomalies shown for these could demonstrate a defect in the building fabric.

Building fabric improvements that can be made to SBCAT Incubator building to further reduce heat losses from building envelope

- Close blinds to reduce radiation heat loss in winter and reduce overheating in summer
- Retrofit panels to block lower section of glazed facade that is located below workplane level
- Draught-proof service door in North-west corridor

6.6 Conclusions and key findings for this section

Energy

After reconciliation, the overall resulting discrepancy between the main meter and sub-metered energy is approximately 2%. Comparison against CIBSE TM46 benchmarks shows the SBCAT building to be a reasonably low energy building when compared against its corresponding benchmark (See Figure 15 and Figure 16). Noting the problems with the heat pumps and over-provision of ventilation, this relatively good performance is probably because of a combination of low occupancy during the metered period and the low energy equipment and lighting installed in the building. However, it is suggested that several aspects of the building systems should be investigated further, in particular the operation or the Air Source Heat Pump and fume cupboard extract fan as it is believed that this equipment was not operating in an energy efficient manner.

Water use & Rainwater harvester

Rainwater harvesting system is estimated to provide around 10% of the Incubator building's water needs (including for external irrigation). However, the Incubator building is currently below its design occupancy and so as the occupancy changes, the percentage of the building's water needs met by the rainwater harvester may change.

As no design prediction was found for the amount of water that would be supplied by the rainwater harvester, it is not possible to comment on whether the amount of rainwater used in the building is high, low or as expected. It is recommended that further work be carried out to determine whether the rainwater harvester could meet a higher proportion of the Incubator's water demand, given its current low occupancy.

There is discrepancy between the reading for the rainwater harvester water usage between the physical meter in the lower ground floor plantroom and the BMS, and this should be checked for future use.

Fabric performance and air-tightness test

Although the thermal imaging of the Incubator building highlighted a few areas where there may be heat lost through elements that is higher than expected, overall the Incubator building appears to have been constructed well and the whole the fabric is performing as expected.

The air-tightness result for the Incubator building is 4.91 against a target of 5 m3/m2/hr. Based on the air-tightness result it can be concluded that the Incubator building has been constructed to a reasonable standard to minimise air leakage pathways.

7 Technical Issues

7.1 Air source heat pumps

An evaluation of the performance of the air source heat pumps was carried out to investigate whether they were performing as expected.

Coefficient of Performance (COP) for whole building and air source heat pumps (ASHP)

The whole building COP was estimated to be in the range of 1.3 to 1.6 over the dates when the analysis was carried out, based on the heat metering on the buffer vessels and measurements of electricity use to heat pumps.

The ASHP COP was estimated from measurements to fall between the range of -0.6 and 1.9, based on measurements of the surface temperature of the flow and return. This uncertainty is so large because the difference between flow and return temperatures is small – and much smaller than the design intent. Because of the losses in the buffer vessel, it would be expected that the ASHP COP would be slightly higher than the whole building COP, if perfect measurements were available.

There is no obvious correlation between the outside air temperatures and the whole building COP on the dates that the analyses have been carried out.

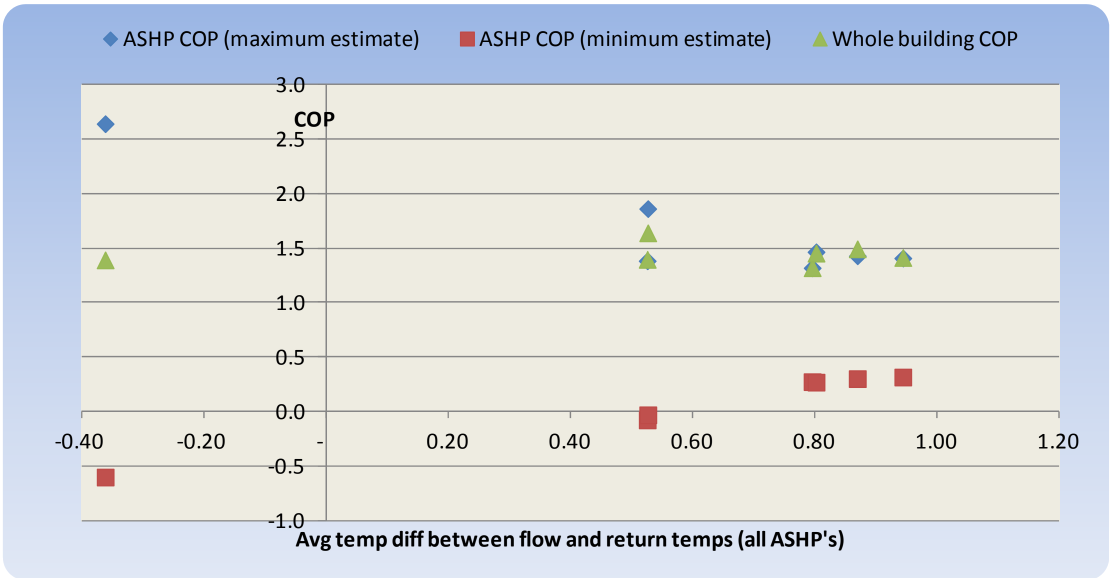


Figure 19: Graph showing calculations of ASHP COP and whole building heating system COP for study periods in January 2013

Potential reasons why the ASHPs are not achieving a very high COP

ASHP are supposed to be commissioned to operate with a 10deg delta T (between 45 and 35 degC flow and return) at full load. However analysis suggests ASHP's produce average delta T between flow and return temperatures during normal operation of less than 1 degC during the analysis periods.

Therefore it can be concluded that there is no evidence that the ASHP return temperature specified for commissioning is being achieved. This could be as a result of the ASHPs being oversized for the building demand that they currently have to meet and therefore they never operate at full load conditions which may produce the expected delta T of 10 degC between the flow and return temperatures. Another potential explanation is that the heat pumps are not being controlled in an optimal way.

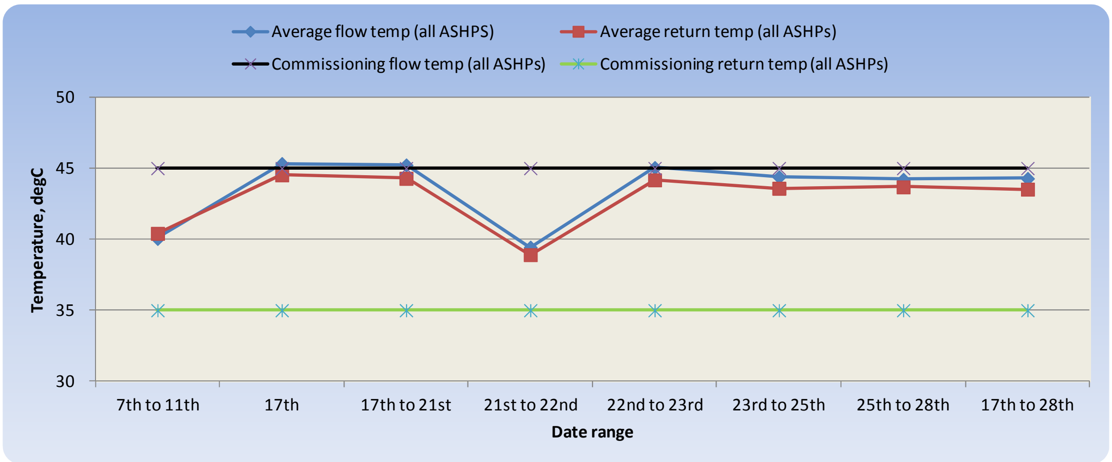


Figure 20: Graph showing average measured flow and return temperatures for the analysis dates in January 2013

The temperature difference between flow and return that is supposed to be achieved is also not being met. This is one potential reason why the whole building COP measured is estimated to be in the range of 1.3 to 1.6, whereas the manufacturer's technical datasheet quotes a full load heating COP of 2.2 (with the ASHPs required to be able to operate down to -5 degC dry bulb temperature in winter) and a seasonal COP of 3.3 @ 7degC dry bulb ambient temperature. Further investigations are ongoing by the client.

Cold weather operation

Failure

The ASHPs are supposed to be able to operate down to temperatures of -5degC dry bulb (db) temperature. However the ASHPs failed on 16th January 2013 when the outside air temperature in Stevenage was recorded to be in the range of 0 and -3 degC*. This is a major concern, but has been addressed by changing the performance settings for the defrost process. This may result in increased energy use as the defrost cycle will be entered more frequently.

Defrost

Stable operation

As Figure 21 shows, ASHP operated in heating mode for the majority of the time between 9am and 6pm on the 19th January with only 3 apparent defrost cycles (at 9am, 11:15am and 2:15pm). These apparent defrost cycles last for approximately 30 mins, during which period the temperature measured on the return water pipe to the heat pump is lower than the flow temperature. During these cycles, the temperature difference between the flow and return water peaks at around - 2.5 degC. The ASHP then switches off at approximately 4pm.

This appears to represent the expected performance of one of the ASHPs (majority of the time in heating mode with periodic defrosting when temperatures are less than +7degC). However it should be noted that the flow and return temperatures measured during all the ASHP assessments (and the difference between them) do not follow a set pattern.

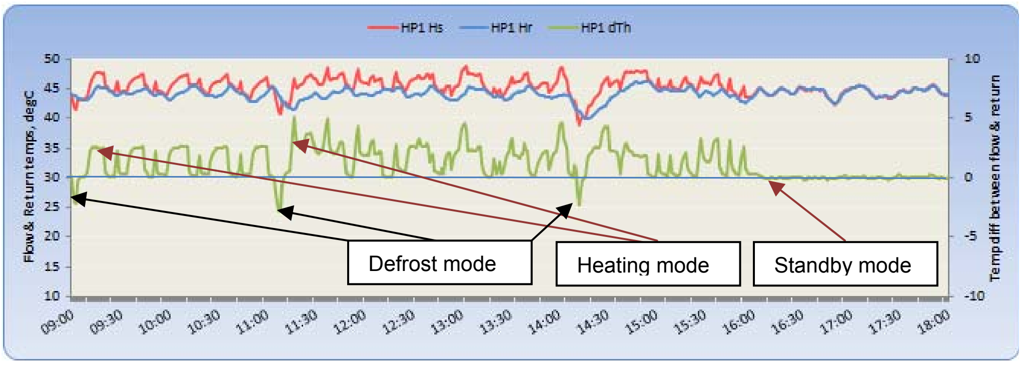


Figure 21 : Stable operation in heating mode with intermittent defrost cycles (ASHP no.1 on 19th January 2013). Outside air temperature in Stevenage was between 1 an -1 degC*.

Erratic operation

In contrast to Figure 21, Figure 22 shows an ASHP operating with approximately 12 apparent defrost cycles between 9am and 6pm. ASHP3 on the 18th January 2013 appears to switch between defrosting and operating in heating mode on a frequent basis. This could represent a problem with the control strategy or a malfunction with the ASHP.

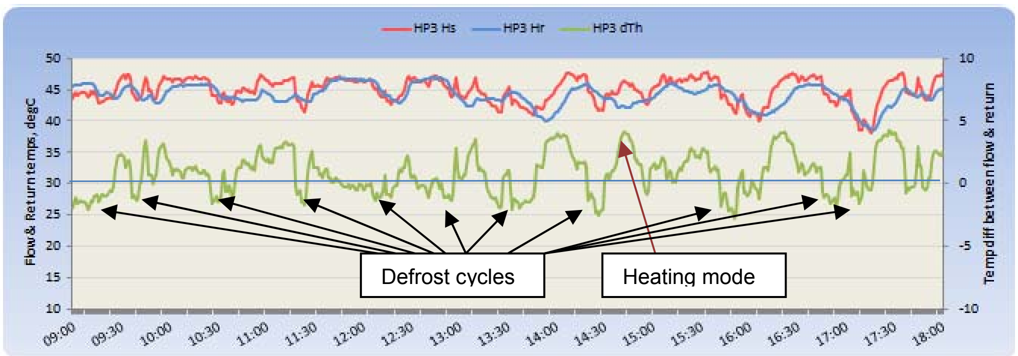


Figure 22: Erratic operation in heating mode with frequent defrost cycles (ASHP no.3 on 18th January 2013) Outside air temperature in Stevenage was between 1 an -2 degC*.

7.2 Thermal comfort

A review of whether the building system, under the control of the BMS, is meeting the temperature requirements in different parts of the building was carried out and revealed a number of technical issues. There are areas in the building not achieving the required set-point temperature, which correspond with complaints received by occupants.

The building manager has implemented some changes and overrides to the BMS and increased space set-point temperature and output of FCUs; however, this has not resolved the problems. This suggests that although the BMS appears to be showing that the required set-point temperatures have been met, this is not true in reality.

Potential reasons for the BMS not achieving the required set point temperatures include:

- Cold draughts in highly glazed areas due to convection
- Radiant coolth from the glazing
- Fan coil units are undersized
- Fan coil units are not optimally distributed in the spaces to provide the most heating capacity in the areas with the highest heat demand. The BMS shows that the Heating and Cooling Optimisers are Inactive.

7.3 BMS and controls

Read-only access has been granted to the AECOM project manager to allow review of the BMS (Building Management System)

A review of the BMS found a number of problems including:

- Individual room fan coil unit set point temperatures cannot be changed by the Building Manager. This process requires a BMS specialist.
- A number of meters were not functioning, for example the main water meter, a number of heat meters, main electricity meter, PV electricity generated.
- A number of meters on the BMS did not match the manual readings on the meter, for example for the rainwater harvester and lab water use
- The procedure for resetting, switching order or switching on and off of heat pumps is not clear. This information was not provided during training, nor in handouts, nor in electronic format.
- There is no practical user guide for operating the BMS

7.4 Hot water system - CO_2 Heat pump and electric immersion heaters

The evaluation of the CO_2 heat pump produced the following findings:

- The hot water system was not achieving the required hot water temperatures. If the CO_2 heat pump does not achieve the required 60degC hot water temperature, the immersion heaters should provide the necessary additional heat input. Currently the immersion heaters appear to not be adding the additional heat.

As shown in Figure 23, the immersion heaters are not raising the hot water to the required 60degC setpoint. The two immersion heaters are only achieving 53.1 and 46.6 degC respectively while the CO_2 heat pump was achieving 50.4 degC on the 9th November 2012.

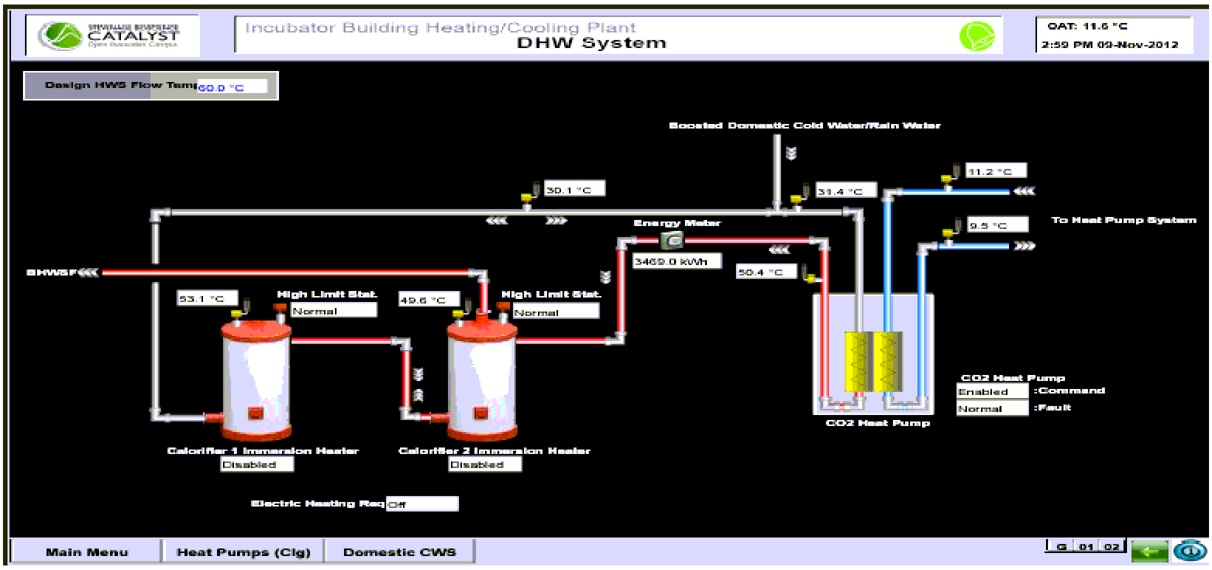


Figure 23: Screenshot showing hot water system – 60degC setpoint is not being achieved according to the BMS

- The CO_2 heat pump was not performing properly as there was an oil leak. This could be linked to the high pressures that the CO_2 heat pump operates at when compared to other heat pumps that do not use CO_2 as a refrigerant.
- While the CO_2 heat pump is supposed to be the lead generator of hot water, with the immersion heaters only operating as backup at times of high hot water demand when the CO_2 cannot produce hot water at the required rate, a maintenance engineer for the CO_2 heat pump pointed out that it was not clear whether the CO_2 heat pumps were acting as the lead generator. It is possible that the hot water system has been set up with the immersion heaters operating as lead generators. However, as the CO_2 heat pump maintenance team (who are also the heat pump supplier) only have responsibility for keeping the CO_2 heat pump running in an efficient and reliable manner (and not the immersion heaters), the engineer was not in a position to investigate this further.
- The electricity consumption of the CO_2 heat pump and the electric immersion heaters is not sub-metered on the BMS. Therefore, it would be very difficult to determine how efficiently or for how much of the time that the hot water generating equipment has been operating for.

7.5 Conclusions and key findings for this section

Air source heat pumps

- There is no evidence that the ASHP return temperature specified for commissioning is being achieved.

- There is no evidence that the ASHPs are achieving the full load COP of 2.2 stated in the Employers Requirements based on the analyses carried out between the 7th and 28th January 2013.
- The ASHP system appears not to be working correctly, and is likely to be underperforming compared to the design intent.

Potential further work

- Monitor ASHPs over a whole year to see how performance varies with outside air temperature.
- Record temperature traces to see if each ASHP is operating in an expected manner. For example, ascertain whether the frequency and length of defrost cycles is not excessive (which could lead to significant unnecessary electricity usage by the ASHPs).

Thermal comfort

There have been problems with the control of the internal temperature of different areas in the building, in particular the offices, which have a high proportion of their external facade highly glazed. This is evidenced by complaints from occupants that the building is too cold and has been supported by independent monitoring equipment which shows that the achieved room temperature is more than 2degC below the required set-point until the middle of the working day

BMS and controls

A review of the BMS found a number of problems including:

- Individual room fan coil unit set point temperatures cannot be changed by the Building Manager. This process requires a BMS specialist.
- The procedure for resetting, switching order or switching on and off of heat pumps is not clear. This information was not provided during training, nor in handouts, nor in electronic format.
- There is no practical user guide for operating the BMS
- A number of meters were not functioning, for example the main water meter, a number of heat meters, main electricity meter, PV electricity generated

Potential solutions to problems identified with the BMS include:

- Check to see whether the BMS can be adjusted so as to allow the Building manager to adjust fan coil unit operating parameters
- Commission heat meters and ensure that commissioning documentation is added to the Operation and Maintenance manual
- Produce written guidance on the safe shut-down and start up of key building services equipment. This should include as a minimum the air source heat pumps, hot water system, air handling units, fume cupboard and fume cupboard roof extract fans
- Produce written guidance on how to operate the BMS in practical terms for the Building Manager. Ideally there would be one paper copy and one electronic copy.

Hot water system – CO_2 heat pump and electric immersion heaters

- The domestic hot water system may not be configured as per the Employer's requirements. This may lead to excess electricity usage and therefore excess spending for the generation of hot water if the immersion heaters have been configured to act as the lead hot water generators. This requires further investigation

- If it is feasible, the electricity consumption of the CO_2 heat pump and the electric immersion heaters should be recorded separately on the BMS.
- It would be beneficial if the hot water generation system was maintained as a whole system, rather than the current scenario where the CO_2 heat pump and electric immersion heaters are maintained separately, despite them having a close and interdependent relationship as part of the hot water generation system.

8 Key messages for the client, owner and occupier

8.1 Key messages: process

Drawing from the findings established in this study, there are a set of key messages specifically for the client/owner and indirectly for the occupiers of the building:

<u>Recommendations for improving pre and post handover processes</u>

Handover - Training

- Better, user-oriented training needed on building systems, key operation of plant (shut-down, start-ups after failure/shut-shut down).
- Evidence of handover training should be produced in advance (e.g a month) of the handover training. This will give the client and building manager a chance to comment on the content and nature of the training to be provided.
- Training provided should be spread out over a longer period to give those receiving training an opportunity to absorb and learn about an aspect of the building before being trained in new area.

Commissioning

- Commissioning should be carried out for the whole building as a system and not just for individual pieces of equipment.
- The operation and maintenance manuals should be written in a more user friendly manner. In particular, there should be more descriptive text to explain the relevance and method of different commissioning tests.
- If there is a delay in the delivery of the building, the amount of time allocated to commissioning and handover should not be shortened simply to maintain the official handover date. This leads to the rushing of the commissioning of key building services that are key to the reliable and efficient operation of the building which in turn is likely to lead to future problems in operation.

<u>A summary of lessons learned: Things to do, things to avoid and things requiring further attention/study</u>

Procurement

- Employer's Requirements: these should be written in a more prescriptive manner when it comes to maintaining key aspects of the design philosophy.
- Employer's Requirements: these should be written in a manner that will allow a simple comparison between the delivered building and the requirements relating to design intentions (architectural, mechanical & electrical) and commissioning standards.
- Employer's Requirements: these should be more prescriptive with respect to commissioning requirements so that the client and client representatives can check that commissioning of key systems has been carried out to a standard that will help ensure that the systems operate in an efficient and reliable manner.
- Quality assurance: For complex buildings, procedures need to be put in place to ensure that key design details and philosophy is not lost when there is a transfer of design responsibility as occurred as part of the 2 stage design and build process that the Incubator building underwent. This could be achieved by novating the mechanical and electrical contractors from the 1st stage of the building procurement to the design & build contractor team to ensure continuity. Alternatively, more robust quality assurance

processes can be introduced so that the Client team can ensure that the designs proposed by the design and build contractor will continue to meet the Employer's Requirements.
- Value engineering: While Value Engineering / cost cutting may make sense at the time, do not deploy this on the BMS and controls without taking great care to ensure vital functionality is not lost
- Include soft-landings in the contract

8.2 Key messages: technical

In order to inform the evaluation the building services and energy systems in the Incubator building, a number of key questions were posed in Section 3.11. These questions are answered below:

Are the air source heat pumps operating in a reliable and efficient manner?

The air source heat pumps do not appear to be operating in a reliable or efficient manner. It is recommended that their operation should be monitored on an ongoing basis. This would help ensure that the system would be kept operating efficiently and reliably in the future. Ongoing work is attempting to overcome the problems associated with the heat pumps and the their controls.

Is the hot water system (CO_2 heat pump and back up electric immersion heaters) operating in a reliable and efficient manner?

The hot water system (CO_2 heat pump and electric immersion heaters) may not be configured correctly. This should be checked and if it is feasible the electricity consumption of the CO_2 heat pump and the electric immersion heaters should be monitored separately. This would help ensure that the system would be kept operating efficiently and reliably in the future. It is not clear whether the hot water system is currently operating in a reliable and efficient manner. Ongoing work is attempting to overcome the problems associated with the hot water system.

Is the building achieving satisfactory internal environmental conditions?

Thermal comfort in the highly glazed offices (in particular the corner offices with a dual aspect and the meeting rooms in the hub) have had thermal comfort problems. Occupants have complained that these spaces have been too cold in the winter and sometimes too hot in the summer. For spaces which are designed to have a high proportion of glazing, it is important that the commissioning of the room temperatures take into account the radiant effect through the glazing. From the evaluation undertaken, the Incubator building does not achieve satisfactory internal environmental conditions at all times. Ongoing work is attempting to overcome the problems associated with the internal environmental conditions of the building.

Does the labyrinth result in a reduction in energy use for heating during the heating season?

It seems that the labyrinth contributes little to the reduction in active heating by the whole building heating system This is likely a reflection of the very high volumes of air passing through the system.

Overall, how does the energy use of the Incubator building compare with benchmarks?

Notwithstanding these problems, the energy use is in line with benchmarks. This reflects the high quality facade and lighting, and the low occupancy. However, it may also result from a failure to achieve temperature targets.

It would be expected that the energy use within the building would change (mainly increase) with increased occupancy, particularly for lighting and small power. However there is scope to improve the control of the ventilation system to reduce the flow rates in lowly or unoccupied spaces. The Building Manager has been informed of how to disable the ventilation air flow to unoccupied labs.

8.3 Key messages: impact of the project

Over the course of the study, there have been a number of improvements and changes to the Incubator building and benefits beyond the study for the AECOM project team:

- Learning to control fume cupboard operation which in turn allows the energy used for ventilation in the building to be reduced
- Changes to de-frost mode of heat pumps
- Site visits by supplier/maintainer of CO_2 heat pumps to rectify faults
- Investigation into air handling unit operation which revealed problems which are being resolved
- Review of fan coil unit operational parameters which fed into ongoing work by the Main Contractor to resolve thermal comfort issues
- Rectification of incorrect readings on BMS
- Replacement of faulty heat meters
- Development of skills within the project team, to be applied on other projects

Items requiring further study

- Air source heat pumps – efficiency and reliability
- Hot water system - CO_2 heat pump and immersion heaters
- Thermal comfort in offices
- Performance of labyrinth over an entire year
- Performance of rainwater harvester as building becomes more occupied

9 Wider lessons

Dissemination workshops with AECOM's in-house design teams were carried out where the findings and outcome from the study were presented o the design team directly involved in the project and to the wider group. Discussions with the team members on the findings and relating them back to the company's processes have managed to establish the following feedback.

9.1 Lessons learned from the BPE project

The BPE project has highlighted several aspects of a building project, which require closer attention, more accountability and a feedback mechanism for continuous improvement. These aspects relate to the:

- procurement process
- commissioning and testing
- building BMS and controls
- training and building operations manuals

It has been acknowledged in the dissemination workshop that the current procurement process meant that designers and consultants normally 'part-specify' the design (through RIBA Stage D, E) and then handover to contractors to develop the details. This leads to work separation, risking the loss of an understanding of the overall design scheme and resulting in the lack of integration of the design intent for the building. There are normally insufficient details and guidance produced at Stage D/E to effectively inform or support design intent throughout the rest of the project.

9.2 What AECOM will do differently

Through the dissemination workshop, the design teams have expressed the need to consider and implement the following:

- Formulate a commissioning 'proving' and verification process
- Procurement of a company (AECOM) approved/preferred BMS supplier
- Video-record future building user training sessions conducted by the contractors
- More prescriptive training content to be included in the tender documents, such as:
    - Protocol on plant/system operation
    - Instructions on how to carry out system parameter change/adjustment
    - Energy saving options in building and system operation
- Specify client member of staff to attend training and ensure competency in building operation
- Offer Soft-landings and Building Performance Evaluation (BPE) services to clients as an inclusive package
- Continue to develop expertise in BPE, including through sharing experience between those involved through quarterly meetings, and developing our offer further

9.3 How will the design and delivery of future buildings be improved

In order to improve the design and the delivery of future buildings, the following should be considered:

- User-oriented training
- Require the production of detailed commissioning plans for key services. These plans should list the commissioning actions that are going to be carried out for specific equipment, e.g air source heat pumps. This would allow the client team (in particular the Building Manager) to comment and influence the commissioning carried out which in turn will result in a building more likely to perform to the user requirements.
- Introduce seasonal commissioning. Commissioning should include the testing of how the whole building performs during operation, not just of individual pieces of equipment.
- Improve handover process for change of members of the project team
- Ensure that satisfactory commissioning of the building takes priority over meeting a handover date
- The use of Soft Landing as a set of aftercare principles to ensure that all of the issues highlighted are properly monitored and addressed. Soft Landings means designers and constructors staying involved with the building beyond practical completion. This will assist the client during the first months of operation and beyond, to help fine-tune and de-bug the systems, and ensure the occupiers understand how to control and best use their buildings.
  (**http://www.bsria.co.uk/services/design/soft-landings/**)

9.4 What will SBCAT (the client) do differently

The client has indicated the following as what they will do differently as a result of the BPE project:

Reduce energy use for ventilation by switching off fume cupboards in unoccupied labs

Use information generated as part of this study to help resolve problems in the Incubator building, in particular relating to

- air source heat pumps,
- thermal comfort and
- the hot water system.

9.5 Dissemination

Several avenues for dissemination are underway, these include tasks already done:

- Client presentation
- Dissemination workshop with design team
- Publication on CarbonBuzz

- Input to CarbonBuzz: Andrew Cripps is the AECOM lead on CarbonBuzz, and learning from this and other projects has been helping inform the development of CarbonBuzz

We are also planning

- CPDs to colleagues, including away from base office
- Strengthening of AECOM BPE network
- Paper (conference – target CIBSE Technical symposium) publication - probably drawing on common strands within our projects
- Offer to trade press if client is in agreement
- BPE case study

9.6 Conclusions and key findings for this section

The study has identified a number of un-resolved problems in the building, over a year after the official handover date. These relate particularly to the heat pumps, the control system in general, and over-provision of ventilation. The client has further work to do to resolve these, as they are resulting in ongoing higher than expected energy costs.

It appears that the labyrinth system is providing little pre-heating to the building, but this will be affected by the high air flow rates. The PV and rainwater harvesting systems, and lighting all appear to be working well, and the building is generally well liked by occupants, apart from some concerns over low temperatures.

Both AECOM and SBCAT have identified areas for different action in future. For AECOM we are also combining these with findings from other TSB BPE projects, to inform a wider set of possible changes. These would relate to the way in which we develop Employer's Requirements, and details of our specifications, to help ensure the most likely achievement of a successful project. AECOM are also seeking to make the assessment and management of operational performance a part of more of our design projects.