Pines Calyx

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Innovate UK project number	450115
Project lead and author	University of Kent for the Bay Trust
Report date	2015
InnovateUK Evaluator	Peter Tse (Contact via www.bpe-specialists.org.uk)

Building sector	**Location**	**Form of contract**	**Opened**
Events building	Dover	Traditional	2006
Floor area (GIA)	**Storeys**	**EPC / DEC**	**BREEAM rating**
370 m^2	2	N/A / N/A	N/A

Purpose of evaluation

The study focused on measuring energy consumption of the heat pump and PV installation under different climate and use conditions, internal comfort conditions (temperature, relative humidity and carbon dioxide), compared to user satisfaction, user satisfaction with a range of comfort variables, daylighting performance, the effectiveness of the earth tube ventilation system, an investigation of the thermal weaknesses in the building fabric, the energy contribution of the renewable energy systems (including payback periods), and the carbon balance of the building.

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

Electricity consumption was estimated at 75.2 kWh/m² per annum for heat and power. There was potential for significant improvement related to optimising energy and building services systems, optimising user operation and management of the building, and from planned fabric improvements (glazing). The energy contribution of the heat pump was significant, with the PV and solar thermal element of the PV panels performing well below their optimum due to siting and shading. Measures needed to be taken to optimise the operation of the system within the constraints of the shaded site. The earth tube system was said to be highly effective in energy and cost terms, with room for further improvement.

Occupant survey	**Survey sample**	**Response rate**
BUS, paper-based	24	Unknown

Satisfaction levels were generally very high for the building and comfort conditions. Satisfaction levels were high for lighting, temperature, and air movement and air quality. Response rates were low for the controls questions. Ease of use of controls was varied but generally not considered ‘easy’. Improvements needed to be made for kitchen and events staff.

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About this document:

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

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

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

Contents

1 Introduction and overview

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

1.1 Scope of this BPE

This BPE sits within the wider context of the TSB Non-Domestic BPE project as a whole. Therefore, this report seeks to contribute to achieving the following:

1. The Objective: obtaining evidence and data required by the industry as a whole which will be a) disseminated and b) used for further research;
2. The Aim: studying the performance of the Pines Calyx building at a distinct stage in its life – in this case soon after completion of primary renewable energy systems;
3. The Outcomes:
   a) Understanding the effect of certain design, delivery and operational variables on i) the energy (and other resource) performance and ii) occupant satisfaction, in both specific circumstances and generically;
   b) Actions being taken to improve the performance of the Pines Calyx (in both energy and occupant satisfaction terms) and to transfer the knowledge arising from this BPE project to other buildings ;
   c) Production of an exemplar case study of the Pines Calyx ;
   d) Development of UK skills ;
   e) Helping establish a range of BPE protocols, tools and techniques across the sector.

More specifically, to achieve the above, the scope of this BPE for the Pines Calyx building, which is a conference and events venue that was designed to achieve high levels of sustainability performance, is to establish the following:

- Energy consumption under different climate and use conditions
- Internal comfort conditions (t, RH, CO_2), compared to user satisfaction
- User satisfaction
- Daylighting performance
- Effectiveness of the earth tube ventilation system
- Thermal weaknesses in the building fabric – using thermographic survey
- Energy contribution of the renewable energy systems, including payback periods
- Carbon balance of the building

We are satisfied that the aims, objectives and outcomes of the Pines Calyx BPE project have been achieved, and that continuation of the monitoring and performance evaluation will further enhance these in 2015, and beyond.

The information gathered as part of this evaluation will be used to guide the building users and operators, such that energy and performance improvements have been implemented during the BPE project, and will continue to be implemented in 2015 and beyond.

Three important points to highlight in relation to the context of this study are:

1. This BPE study commenced after completion of replacement renewable energy systems (PVT plus heat pump Hybrid solar system) were initially commissioned, which was 6 years after the original completion and commissioning of the Pines Calyx building into use as a conference and events venue - most BPE projects have started after initial completion of the building.
2. Virtually every aspect of the structure, building services and energy systems for the Pines Calyx from the start of this study have been innovative, with few if any tried and tested in-use examples of how they 'should' work to draw on – therefore it is as relevant to consider the Pines Calyx as an experimental building, as it is to consider it a conference and events venue;
3. Whilst the building has been experimental, it is only at the point of this study that the building has been studied and analysed in a form that allows the experimental aspects of building to generate data that can be used to consistently learn about the functioning of the building in detail.

1.2 Key findings from this BPE

In relation to the scope of this BPE study the following sets out the key findings:

Area of Focus	**Key Findings**
Energy consumption under different climate and use conditions	Very good in comparison with benchmarks. There is potential for significant improvement related to: a) optimising energy and building services systems, b) optimising user operation and management of the building, c) planned fabric improvements (glazing). 2015 should be targeted for achieving optimum operation of the building and its component systems, with a target of at least a 30% reduction on 2014 energy consumption.
Internal comfort conditions (t, RH, CO_2), compared to user satisfaction	Generally good, with improvements to be made, particularly for kitchens. Measures need to be taken to monitor and manage CO_2 levels more effectively during larger events when windows are not likely to be opened.
User satisfaction	High for clients, with room for further improvement. Improvements need to be made for kitchen and events staff. User satisfaction needs to be measured more effectively and much more extensively, linking this to what is of interest to clients.
Daylighting performance	Good
Effectiveness of the earth tube ventilation system	Highly effective in energy and cost terms, with room for further improvement

Thermal weaknesses in the building fabric – using thermographic survey	Thermographic weaknesses are now known. Realistic strategies for addressing these need to be systematically assessed and costed.
Energy contribution of the renewable energy systems, including payback periods	The energy contribution of the heat pump element of the energy systems is significant, with the PV and solar thermal element of the PVT panels performing well below their optimum due to siting and shading. Measures need to be taken to optimise the operation of the system within the constraints of the shaded site. Payback periods need further work to be assessed, when the system is working at optimal levels on an ongoing basis.
Carbon balance of the building	The kg CO_2 / m^2 / year figure of 52.3 compares well at 65% of the DEC benchmark, with scope for significant improvement in 2015.

Other key findings from this BPE are as follows:

- In relation to design intention and actual functioning, overall the building performs well in comparison with benchmarks, however it has a significant performance gap primarily relating to a) energy and building services systems, and b) user operation of the building.
- From the TM22 Simple Assessment, energy use figures for June 2013-June 2014 are as follows:
    - Overall energy use: 21,183 kWh
    - Energy use/m2: 116.7 kWh/m2/year
    - Net CO_2 emissions: 52.3 kg/m2/year
- Our target for 2015 is to reduce energy use by at least 30% to 81.69 kWh/m2/year, which we believe is achievable through optimising the use of Pines Calyx energy and building services systems, and completing final glazing elements, assuming there are no catastrophic events such as the 2014 flood caused by a plumbing failure
- The figures above compare favourably with other BPE projects detailed on the CarbonBuzz website.
- Energy and building services systems have experienced a number of problems, largely linked to poor plumbing installation, with some issues relating to performance of the technology components
- The estimated payback[1] on the £39,996 cost (design and installation) of the Hybrid Solar Solution (PVT panels + Heat Pump) will be assessed in 2015 when the system is operating at optimal performance on an ongoing basis – initial indications are positive since the installation achieved a reduction of net energy use of nearly 50% in 2013, compared to 2012.
- The Pines Calyx project has been dominated by the use of experimental and innovative materials, construction methods and energy and building services systems – these have all contributed significantly to achieving the design objectives of the project, and to the excellent energy and carbon performance of the Pines Calyx
- The Bay Trust plans to continue ongoing monitoring of the Pines Calyx, as well as continuation of the BPE approaches used in this project in 2015 and beyond in order to further enhance the learning of the organisation and the performance of the Pines Calyx

- The environmental data captured by the project has shown the building generally to have good qualities in terms of its internal environment although: a) measures are needed to ensure CO_2 levels are kept within acceptable levels under conditions where the building has high occupancy and windows are closed; b) further analysis of environmental data is needed.

Given the buildings use and the Bay Trust's aspiration for the Pines Calyx to be recognised as the most sustainable events venue in Europe, metrics need to be produced that relate to the building's function as a conference and events centre, as well as in relation to general energy and CO2 performance. Therefore the following are recommended as standard metrics that should be monitored for the years 2015-2019:

	Total Impacts	**Impacts / m2**	**Impacts / Event**	**Impacts / User**
Energy Use	kWh/year	kWh/m2/year	kWh/event	kWh/user
Carbon emissions	kg CO_2/year	kg CO_2/m2/year	kg CO_2/event	kg CO_2/user

It is expected that with an informed approach to marketing these metrics can be of significant commercial value for the promotion of the Pines Calyx.

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

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

2.1 Design intent and design process

The overall design intent for Pines Calyx project was to create an optimum healthy space for creative thinking, learning and working, which evolved to the aim of producing a conference facility that would be a centre for 'Healthy Living', and carbon neutral overall in terms of construction and operation.

The initial design evolved through discussions between the client and concept architect. It was developed in collaboration with a number of general and specialist design consultants and engineers. In this way, within the overall objective, the four key design objectives for the project were to achieve:

- Very low impacts in construction
- Low operational energy in use
- An extremely healthy building for its users
- A beautiful building, both internally and externally.

The overall objective was therefore to create an exemplar in healthy building design, construction and operation, and to do so working with a range of local resources including repurposed and reclaimed materials wherever possible – the low carbon and sustainability objectives were implied and taken on board as part of a larger concept of the optimal healthy building, recognising the inseparability of human health from a healthy environment.

One of the key considerations at the design brief stage was to deliver a building where the local landscape and the natural world would be key influences on the design, allowing the gardens where the building is sited to remain visually pre-eminent.

It should be noted that the client that commissioned the Pines Calyx was a) well informed on matters of healthy and sustainable design, and b) part of the design team – this naturally had a significant influence on both the form and performance objectives for the building. This led the client to create a collaborative design team including high levels of expertise in key areas from an early stage, so that these general design objectives could lead on to more detailed and specific technical objectives:

Low Embodied Energy and Low Impact Design Objective: involvement in the design team of experts with a deep understanding of design using low impact materials, including maximum use of natural, local and reclaimed materials or recycled materials, low embodied energy materials, and minimum pollution in supply chain;

Low Operational Energy Design Objective: Passivhaus design principles informed the approach to achieving low energy design, aided by the form of the building and its earth sheltered design - inclusion of green building experts Conker Conservation in the design team, and use of one of the UK's pre-eminent energy consultants (David Olivier, Energy Advisory Associates) meant that well-informed low energy strategies and objectives where confirmed at an early stage, at a time when the Passivhaus methodologies and standard were not widely recognised or understood in the UK, or available in English.

Healthy Building Design Objective: this area was a particularly strong area of existing knowledge for the client, therefore there was a good understanding of how to bring relevant expertise into the design process, in particular in relation to a) non-toxic materials in construction and fit-out, b) healthy light conditions, c) healthy air quality, d) the overall nature of the building as one that brings about positive enjoyment of the building, and a sense of creativity and inspiration.

Aesthetic Design Objective: this area was particular driven by strong confidence in 'nature inspired design', working with architect Issy Benjamin as the lead concept designer within the Helionix team.

2.2 Location of the Pines Calyx

The Pines Calyx has been built in a quiet and peaceful area. It is surrounded by six acres of gardens and within 300 metres of the beach at St. Margaret's Bay, near Dover – the UK's closest point to the European mainland. This uniquely beautiful and tranquil environment is formally protected through two designations of 'Heritage Coastline' and 'Area of Outstanding Natural Beauty'.

The site overlooks the English Channel and the building is orientated primarily to the south, to maximise solar gain, with significant glazing also toward the southeast.

Figure 2.1: Pines Calyx from the SW, overlooking the English Channel (source: The Bay Trust)

The Pines Calyx is 70 miles from London and well connected by road via the M20/A20 or the M2/A2, with Canterbury around 20 miles away and Maidstone 46 miles away by road. The venue is served by two train stations, Dover Priory (5.5 miles) and Martin Mill (2 miles). The venue is also easily reachable from France and the continent, via the Channel Tunnel and Ferry Port. Calais is just 33 miles away by road and ferry i.e. much closer than Maidstone and London.

The building is accessed by road, with parking for approximately 25 cars within 50-100 metres of the building's entrances, which are accessed by paths through the Pines Garden.

The Pines Calyx and Pines Garden are owned and operated by The Bay Trust, an environmental education charity, within a larger property portfolio which includes a residential environmental education centre primarily used by visiting school groups, and a number of residential investment properties.

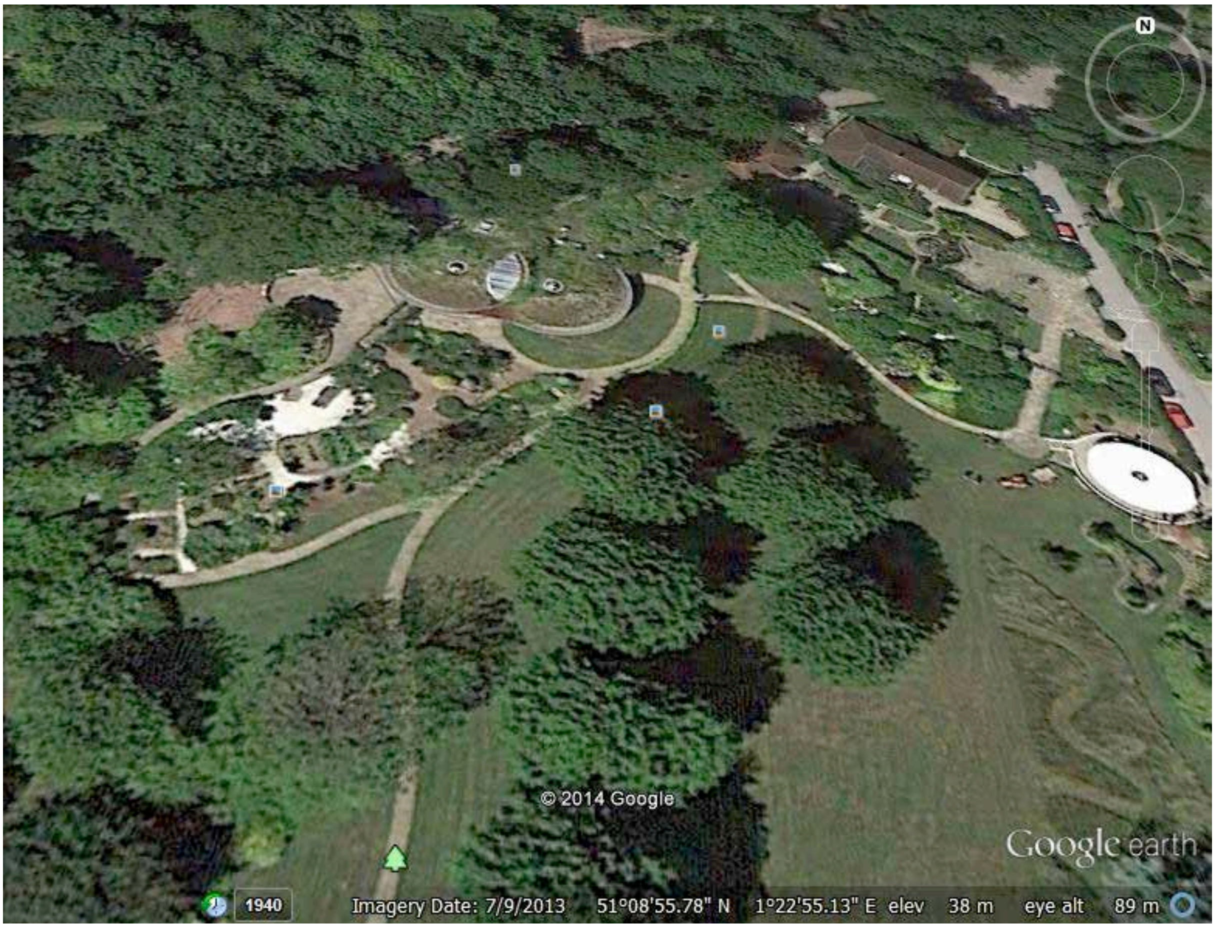


Figure 2.2: The building and its immediate surrounds, sited within the Pines Garden (source: Google earth)

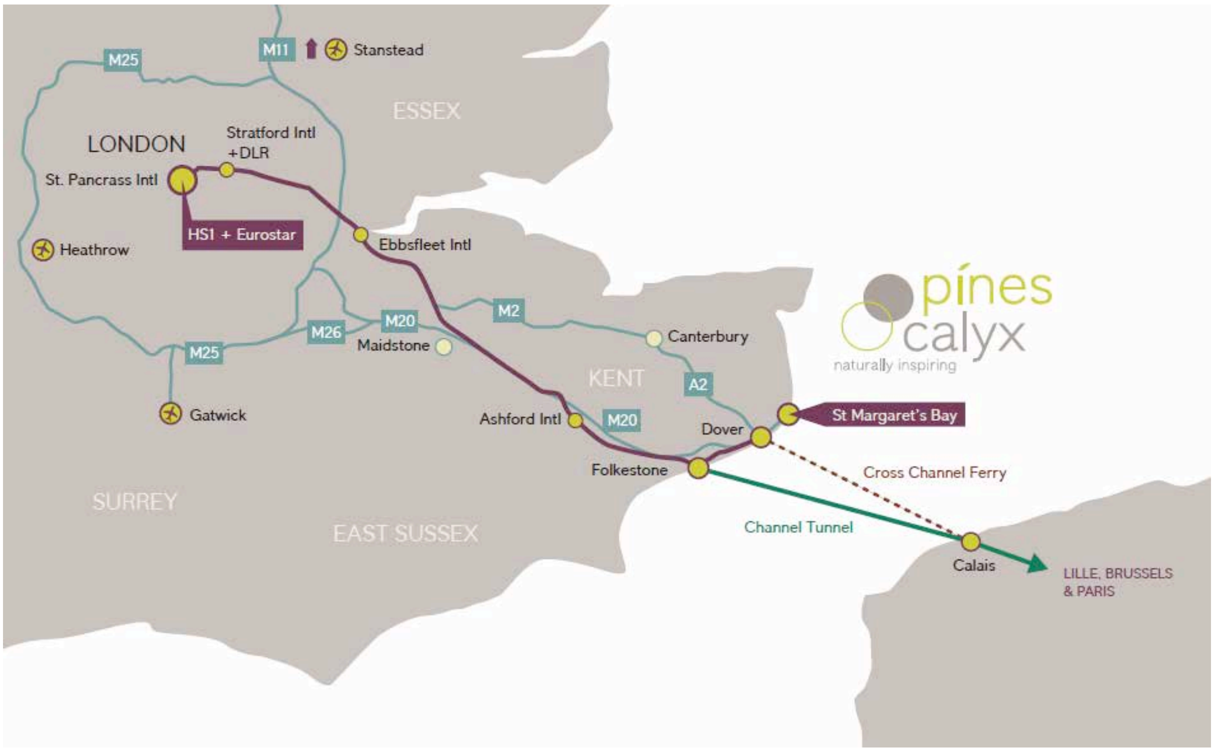


Figure 2.3: Location plan showing UK and European transport links (source: The Bay Trust)

2.3 Design form and outcomes

The building is designed with two cylindrical interconnected spaces constituting three events rooms with a gross floor area of 370m². The size of the Pines Calyx achieves the client's design objective of offering flexibility for a wide variety of events, including: conferencing, learning and creative collaboration, management and staff 'away days', training and workshops.

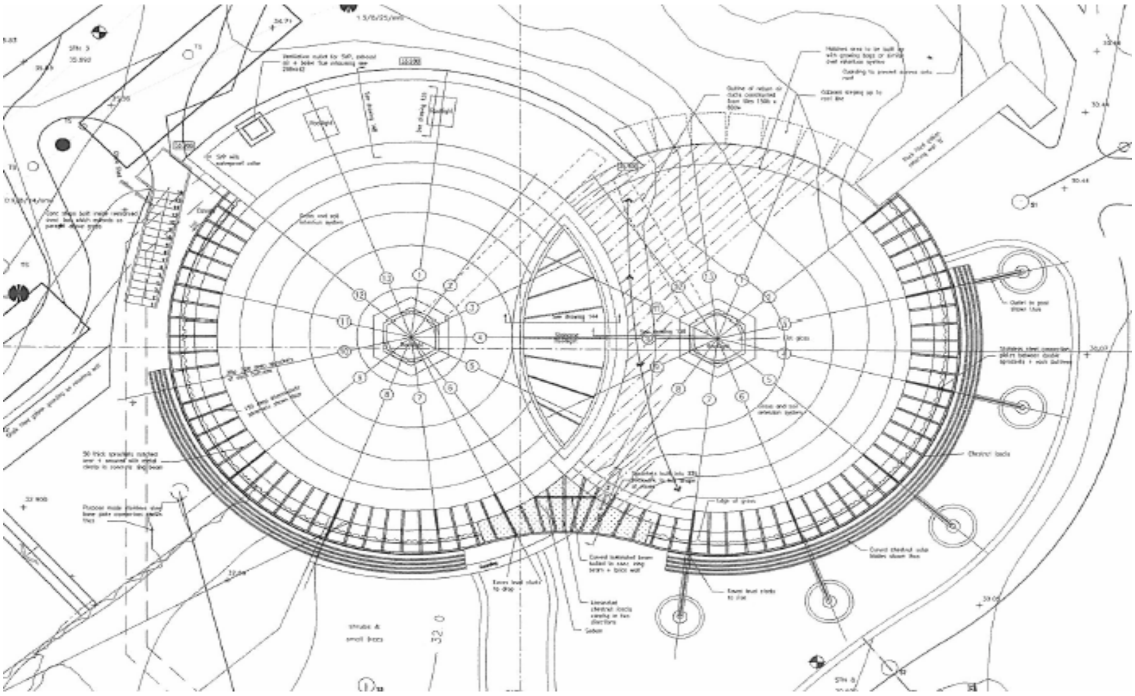


Figure 2.4 above: Plan of the building indicating roof topography

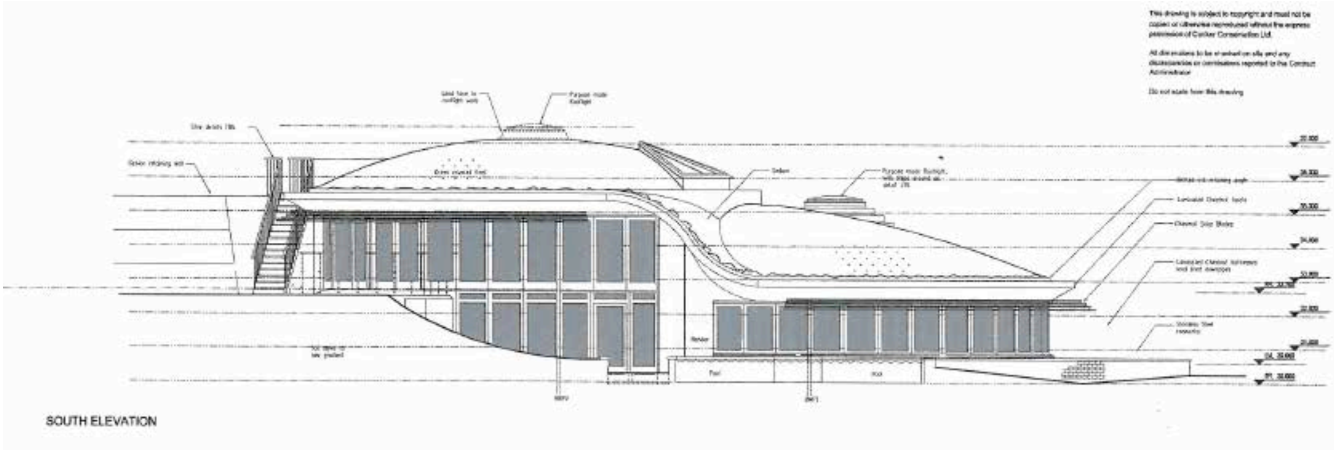


Figure 2.5 above: South Elevation of building

The key features of this building include:

- earth-sheltered construction;
- curved design;
- all the main walls being constructed from rammed chalk.

The circular shapes of the building's upper and lower roundels optimises the available internal usable space and volume, whilst minimising external walls exposed to the elements. Due to this feature it is possible to:

- minimise the heat loss through the walls;
- capture as much daylight as possible in the building, from morning to evening;
- allow for a constant view of the garden, including views to the cliffs and the sea.

The form of construction selected (rammed chalk) meant that waste chalk excavated when constructing the foundations could be used to build the walls. Rammed earth construction has been used for thousands of years for all kinds of construction, and the simplicity of this method of construction helped prevent over-engineering, as well as enabling energy saving and minimising embodied impacts at every stage of construction: from materials extraction, to materials transport to building the walls, heating and cooling the building and even to consideration of minimising demolition impacts. The use of chalk for the walls also would:

- give the building high thermal mass to maintain a more constant temperature inside the building all through the year;
- regulate the relative humidity ensuring a drier and more comfortable indoor environment.[2]

For the roof and ceiling, the designers decided to use 'timbrel-vaulting' – an ancient method of construction that has been revived on this project, which had laid dormant effectively for 80 years. This technique consists of a type of low vault made of plain tiles often used to make a structural floor surface. It is traditionally constructed by laying tiles lengthwise over a wood form or "centering", creating a much gentler curve than has generally been produced by other methods of construction. Though it is popularly called the Catalan vault, this construction method is found throughout the Mediterranean and the invention of the term Catalan vault

[2] Rowland Keable, In situ Rammed Chalk Co., June 2005

occurred in 1904 at an architectural congress in Madrid. The earliest known reference to this type of vault is from Valencia in 1382.

This technique offered a method for creating the two shallow domes for the building on each cylindrical part in an economic and sustainable way, as for example, this method does not require the use of concrete or formwork, and is swift to construct. The round, domed design also provides exceptional acoustic qualities which further enable the building to be specifically suited to its purpose. In terms of environmental performance, the shallow domes:

a) aid in optimising the ratio of the internal volume to the surface area, thereby contributing to the design objective of minimising heat loss ;
b) have a very high strength/weight ratio, therefore allowing great engineering strength to be achieved from relatively low volumes of low impact materials.

The earth-sheltered design, with a roof covered by soil, blends the building into the landscape to achieve the design and planning objective of creating a building that is sensitive to the garden location and the protected landscape designations it sits within. Thus building is designed to be unobtrusive, and to work with the contours and character of the landscape.

As a building designed to optimise benefits to its users, good day lighting was judged to be particularly important in the main functional spaces, i.e. lower roundel, meeting room and upper roundel. This is generally achieved by having daylight from at least two angles and the best possible daylight uniformity. The roundels have both a) side lighting, from windows (on various 'sides' due to the circular form and south-facing orientation), and b) lighting from above from the two round windows in the ceiling (the Oculi), as well as the long crescent moon shaped window above the top of the stairs (the lenticular). Other criteria for good day lighting are: a view of the sky from the working plane and light-coloured internal surfaces.

Figure 2.6: View of upper roundel with reclaimed timber floor, prepared for a catered event

To optimise physiological benefits and energy management for occupants, a sophisticated lighting system was installed, providing programmable artificial lighting to provide different light intensities and colour variations that creates a 'virtual daylight'. This innovation arose in particular from the client's advanced knowledge in this field, having previously been a Director of a market-leading technology company (Clear Vision Lighting Ltd) providing virtual daylight systems, which led the design team to include specialists in the field of integrated health.[3]
In line with the design objectives, the combination of the natural and artificial lighting systems used in the building aim to achieve optimal lighting conditions for users, in functional and health terms, with low energy use.

2.4 Building process, construction management and procurement

Design and construction approach

The delivery of the project has come through the conscious framing of a flat hierarchy between the various professionals and experts, to create a design and construction approach which was a collaborative process bringing together professionals and specialist experts from disparate fields on an international level. All team members, including the owners, architects, engineers, specialist consultants and contractor were committed to the same high standards in health and environmental sustainability, which helped the collaboration to proceed smoothly. Costs and fees distribution were managed more openly than is typical to ensure goodwill throughout the project.

In view of the experimental nature of the building and many of its construction technologies (e.g. rammed earth and timbrel vaulting) a no-fault approach was taken, with all members of the team encouraged to apply their creative thought in delivering onsite solutions to the inevitable daily challenges during the construction programme for what was a highly unusual building, in terms of a) form, b) materials and c) construction systems, with ambitious performance objectives, and with no direct benchmarks to compare with. The levels of commitment and expertise involved allowed a proportion of construction solutions to be developed, tested and applied 'on the hoof' during the construction process, without adversely impacting the construction timetable or overall process.

A list of the individuals and companies involved in the design and construction of the building is included in Appendix A.

The next part of this section presents the materials used for this building and the second part details the construction sequence, from early March 2005 to completion in October 2006.

The materials and methods of construction

One of the important challenges in the construction of this building was to avoid the use of concrete (because of the high CO_2 impacts of cement), which is usually extensively used especially in earth-sheltered buildings[4]. Avoiding the use of concrete within the build was the first motivation for the use of new materials and methods such as chalk and clay tile Catalan vaulting. The designers thus inspired themselves with old ways of construction to meet the

[3] Alistair Gould, "Pines Calyx", *building for a future*, Spring 2007
[4] Production of concrete is responsible for 8% of the worldwide CO2 emissions

modern design and engineering objectives of the project, informed by the small pool of world authorities on these systems.

The Floor Structure

The design and construction of the floor needed to contribute to objectives of achieving low construction impacts and to achieving a high level of thermal efficiency, as well as allowing for the use of innovative construction methods, in terms of the rammed chalk walls. Limecrete was discussed as a slab option, but it was decided not to adopt this option as the development of this material was still in its infancy, with only small scale production at that time – although lime hemp blocks were used in the plant room. A well insulated concrete slab was selected – this was probably the least innovative primary element of the building, although it did include the use of insulation materials made mainly from recycled car windscreens.

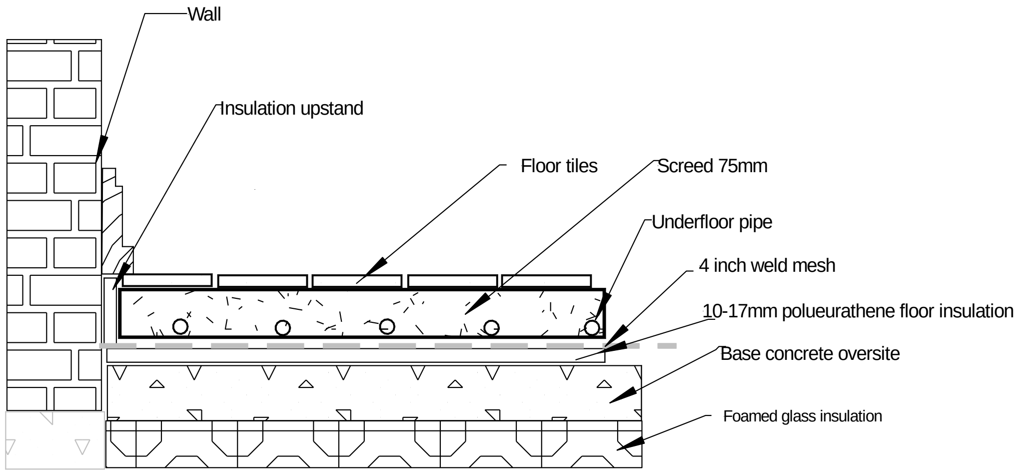


Figure 2.7: illustration of floor construction detail

Underfloor heating was specified early on as the healthiest option for heating the building, as well as being efficient and aesthetically appropriate. The Foamglass insulation below the slab was relatively expensive, but was determined to be the best material in terms of performance, strength and the recycled content.

A number of different types of floor coverings were used, with their selection being largely based on their recycled / reclaimed content – specifically:

- Lower roundel – second hand recycled floor tiles supplied by a social enterprise, to be replaced by Interface floor tiles following the 2014 flood (high recycled content)
- Ground floor lobby and toliets – marmoleum
- Upper roundel – reclaimed maple (from demolished Diaggio social club, London)

It was intended to have a fully or semi-sprung dance floor for the upper roundel floor, however by this point the project was starting to have budget constraints so Marmoleum was being considered. It was relatively late in the day the Edmond Rube discovered the ex-Diaggio social club was being demolished to make way for housing in Park Royal, London, and was able to move quickly to acquire and lift its maple dance floor, as it would have been burnt or gone to landfill within 3 days.

Aluna glass tiles, manufactured from 100% recycled glass, were used around the glazed part of the perimeter of the upper roundel. The original plan had been to use these more extensively, but due to cost and questions over supply the only economic use was to use this in relatively small quantity, through a deal on a 'bin end' job lot from the manufacturer. We believe this company is no long in existence.

Interface Doormats were used for the entrances, with these manufactured from recycled lorry fan belts.

The walls – materials selection and construction technique
The use of rammed chalk for the construction of the walls was the 'greenest' material that could be used because it would have the lowest embodied energy of any masonry material - it required no transportation whatsoever since the raw material came from the excavation of the foundations. Moreover, using this excavated chalk within the construction also minimised exported waste from the construction site, since surplus material could be used in landscaping around the building. This meant avoiding energy use, pollution, waste treatment and transport costs, in both the construction process and in the materials supply chain.

This process of construction involved pouring the chalk into shuttering and then compacting the chalk to create a solid wall. A significant benefit of this building method is that after the compaction is undertaken, the formwork can be taken away instantly and the walls are finished, negating the need of any plastering or painting. The use of rammed chalk creates load-bearing, breathable walls which provide a high thermal mass and maintain constant healthy interior humidity levels.

To construct the chalk walls at the Pines Calyx, loose chalk was placed into layers of around 100-150 mm depth in the formwork and then compacted using a pneumatic (air compressed) rammer. Once the chalk had been adequately compacted, the formwork was removed, leaving a naturally appearing/aesthetically appealing finished wall. Several columns of reinforced concrete were also erected on the south and east side for the areas of glazing and doors, and with the rammed chalk walls these formed a circular support for the concrete ring beam. To complete the surface, the rammed chalk walls were coated with sodium silicate, which is a liquid glass or sand, to prevent the chalk dust from settling on people as they touch or brush past the walls. The walls are load bearing instantly so there was no drying time required like most earth and conventional construction methods where a shrinkage or setting period occurs before loads can be applied.

The walls in the Pines Calyx range from 300 to 600 mm in thickness depending on their load bearing requirements in the building. With uncertainty as to the ability of the rammed chalk to act as a retaining structure for the hillside behind the Calyx, reinforced concrete walls (amounting to approximately 30% of the external wall circumference) were constructed (as the rear wall to the plant room, kitchen and lift shaft) to provide engineering certainty for this function (see figure 2.13). Inside this, 600mm thick internal chalk walls were constructed (e.g. the inner wall of the kitchen and plant room) which also provide an added mass for thermal and moisture control in the building. Windows and doors were easily installed by putting lintels into the rammed chalk during construction.

The 650 tonnes of chalk that was dug out was a greater quantity than needed in construction and landscaping, so the final surplus chalk was given to a farmer who lived a few miles away to increase the pH-level of his land and improve its fertility.

The Roof Vaults

The designers needed a ceiling strong enough to support very heavy loads, since the building is earth-sheltered with a covering of 20-40 cm of soil. They had two possible options available: 1) a concrete roof or 2) a Catalan vault. A Catalan vault was seen as the most appropriate choice. Beside the fact that a Catalan vault gives rise to an aesthetically beautiful outcome which suited the design objective of creating an inspiring space for the building's users, it has the advantage of being extremely economical, quick to build and environmentally sound as it can use locally-sourced materials and a minimal amount of cement. Moreover, the vaults provide excellent acoustic qualities which have impressed musicians who have performed in the Pines Calyx and speakers do not need a microphone to carry their voices.

For the tiles, clay was sourced from the waste 'washings' of a local sand and gravel quarry, 40 miles away, and the tiles were produced by a local company: Robus Architectural Ceramics.

The method of construction that was chosen had been used in various parts of the Mediterranean and dates back more than 600 years. Between the 1870s and the 1930s, through Rafael Guastavino, the method had been successfully used within many large buildings on the Eastern seaboard of the USA, such as Boston Public Library. Today, only a few craftsmen know how to use this method of vaulting, mostly in Spain. The use of this method for a 12 metre diameter ceiling was a real challenge that was made possible with the help of Massachusetts Institute of Technology (MIT) who studied the history and technology of the system. Together, with masons from the Extremadura region of Southwest Spain, they assisted the design and the construction of the first timbrel domes in the UK, at the Pines Calyx.

The timbrel technique involves using tiles laid on edge and built up in layers to produce the necessary structural thickness. In this case, three layers of tile were used with a waterproof cement screen covering the extrados (the outer curved surface) acting as a fourth layer. The tiles used are approximately 300 x 150 x 20 mm and are held in place with Gypsum mortar which dries very fast. The cement mortar is composed of Sharp Sand, Cement, and Lime.

The master mason simply holds the latest tile in position for a few seconds until the plaster can take its weight, then repeats the operation all the way around. After three rings of the first layer are complete a second is begun, bedded on a mortar base. Then a third layer follows close behind. Each layer uses a different bond pattern for extra stability and strength. A final layer of mortar takes the total thickness to no more than 150mm. The domes were constructed without any heavy machinery, yet were completed in just two weeks. This technique has also been used for the staircase. As a result of the domed roof shape, there is now more grass growing on the site than before original excavations took place.

Figure 2.8 Timbrel vaulted clay tile staircase

Figure 2.9 First vaulted roof section (from above) showing 2nd diagonal layer of tiles and the first row of the 3rd (horizontal) layer

For more information on the timbrel vault's construction, see the youtube video of the time lapsed roof construction : http://www.youtube.com/watch?v=jTBvV6b6LGo

The insulation

The insulation used to provide an efficient and continuous thermal envelope considered the use of natural materials but generally opted for oil-based insulation materials as these were seen as being more reliable at the time in terms of avoiding damp and settlement, and thereby maintaining their thermal performance in the long term.

Examples of insulation materials used are as follows:

- Polystyrene panels around the foundations and concrete retaining wall
- Foamglass for the floor.
- Natural insulation (Hemp/Recycled Cotton) for the eaves and around the ring beam

In making choices on insulation materials it was clear that partly buried buildings will generally require the use of concrete and plastic-based insulation materials much more than buildings above ground.

Table 2.1: composition and thermal performance of key elements of the floor, roof and walls.

ELEMENT	**DESCRIPTION**	**U-VALUE**
Lower ground floor – floor slab	100mm floor finish: 50mm screed and 50mm tiles 300mm reinforced concrete raft 100mm cellular glass insulation (0.047W/mK) 100mm weak concrete blinding	0.332 W/m^{2}K (0.453 W/m^{2}K incl thermal bridges)
Exposed external walls	12mm plaster (where required) 650mm rammed chalk 225mm expanded polystyrene insulation 20mm sand-lime-cement render on mesh	0.13 W/m^{2}K
Roof	75mm clay tile vault 240mm polyurethane slab 200mm topsoil/vegetation	0.12 W/m^{2}K
Windows	Combination of units, all timber framed casement, triple-glazed Vogrum Passivhaus standard.	Average weighted U-value = 0.73 W/m^{2}K
External doors	Door units Vogrum standard units with double glazing (hence higher u-value than windows)	Average weighted U-value = 1.2 W/m^{2}K
Roof lights (kitchen)	Double glazed with safety glass and solar reflective film.	U-value= 1.0 W/m^{2}K This value is not consistent with PHPP figures

Source: PHPP 2007 in use calculations produced by Conker Conservation

Other Construction Materials
Below are some of the materials used in the building chosen for their low embodied energy, all of which are on display in the Lobby 'show and tell' area within the Pines Calyx:

Sycamore
Felled from the site itself and utilised in interior joinery (tables, chairs, etc.)

Reclaimed semi-sprung maple floor - Upper ground level
Japanese maple floor used in the upper roundel which was rescued from a demolition site in London.

Sweet Chestnut
Used in interior and exterior fascia boards, sourced from a sustainably management woodland in East Sussex

Ceiling tiles
Made from waste material from a local gravel pit

Marmoleum - Lower ground floor
Eco-friendly floor covering from waste oil, chalk and hessian

Doors mats
Made from recycled lorry fan belts

Bathroom splash backs and servery paneling
Made from recycled yoghourt pots

Foamglas insulation
Used in under floor insulation and made from recycled car windscreens

Parts of the floor
Used as a floor around the doors, made from recycled glass bottles

Construction Sequence

March 2005 : construction commences

April 2005 : The incline was cut away, and the 300mm initial reinforced concrete layer placed to provide a thoroughly level base. The next layer of reinforeced concrete is 175mm thick, sitting on top of 100mm of "Foamglas"[5] to protect the building from excessive heat loss, 60% of which is recycled windscreen glass. Foamglas is a cellular glass insulation material that's impervious to moisture, inert, resistant to insects and vermin, strong, and reasonably well-insulating (R-3.44 per inch).[6]


Figure 2.9 Chalk excavated from the site **Figure 2.10** Slab drying with insulation part laid

Figure 2.11 Insulation over the lower ground slab

May 2005 : The excavated chalk was put to use as the building's external and internal walls. Some concrete was used to spread the load of the upper floor and the roof : 8 beams and the wall around the kitchen (shown dark grey in Fig 2.13 below).

[5] See page 15 for a picture.
[6] http://www.greenbuildingadvisor.com/blogs/dept/energy-solutions/foamglas-my-new-favorite-insulation-material

Figure 2.12 Lower roundel columns

Figure 2.13 shuttering for reinforced concrete retaining wall and internal rammed chalk walls (Lower roundel rear wall)

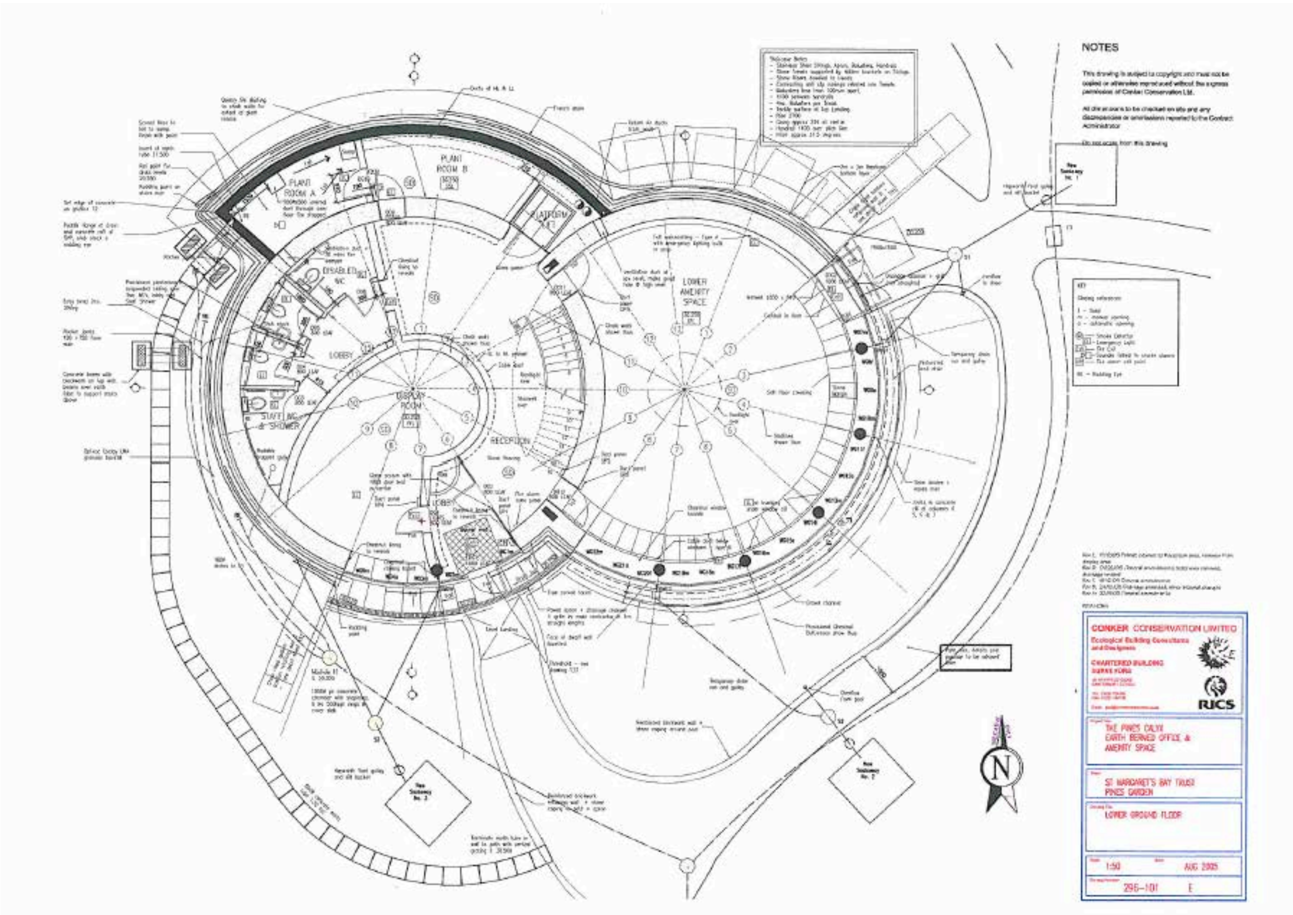


Figure 2.14 Lower ground floor plan showing columns, ring beams and reinforced concrete retaining wall (dark grey) – a 'belt and braces' engineering approach was adopted.

June 2005 : The walls were built with a swift and straight-forward process, only requiring 8 weeks of work. All the rammed chalk internal walls were eventually sealed with a stablishing solution of Calcium Silicate to prevent dusting.

Figure 2.15 First rammed chalk internal wall

Figure 2.16 Rammed chalk internal walls, lower roundel

Fig 2.17 Finishing internal rammed chalk walls

Fig 2.18 First vaulted roof section (from below)

August 2005 : The builders started the timbrel vault ceiling. The inner tiles are lighter and held merely with Gypsum mortar before other tiles are layered over them and held with mortar. The two domes are supported at the perimeter on a reinforced concrete ring beam - see Fig 2.17 and Fig 2.8 in the previous section.

Fig 2.19 Finished roof Oculi (internal view)

Figure 2.20 Finished roof with Oculi (external view)

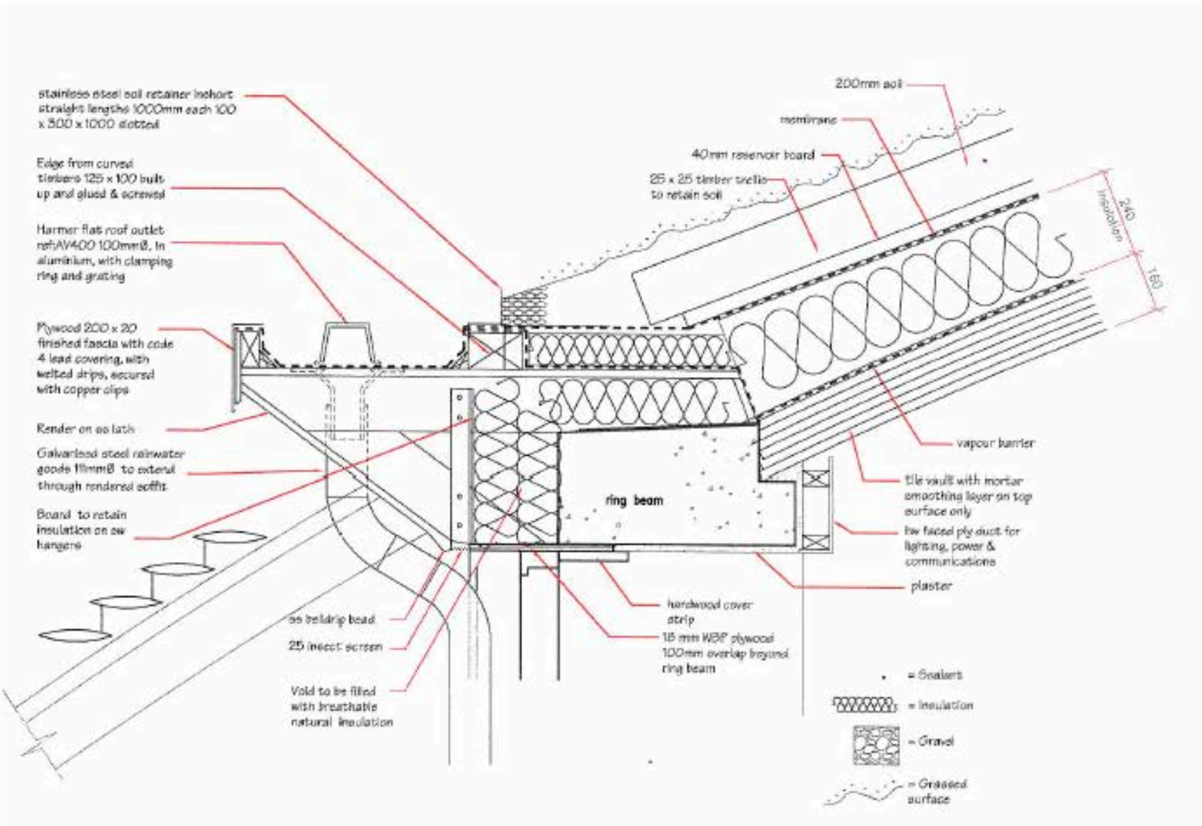


Fig 2.21: drawing for complex wall to roof junction detail, showing continuity of insulation to minimise heat loss through thermal bypass (source: Conker Construction Drawing: 296-136C)

September 2005: The roofs were completed and covered with waterproof coating: bitumen felt membrane by Bauder, over 240mm of polyurethane insulation. The Oculi and the lenticular are in place.

Figure 2.22 Internal view of upper roundel, prior to fit out – shows a) the structurally engineered design adjustment of the vaulted roof curving up to the Oculi (originally planned to be a right angle); b) the very low curve of the vault that was achieved, thereby reducing materials use and space requiring heating.

May 2006: All external works were completed and the building sealed. The process of insulating the chalk walls took place before the landscaping started. Wall waterproofing is Bituthene Liquid Membrane[7], made from synthetic oils and bitumen. Polystyrene panels line the outer areas, followed by a waterproof membrane to protect the polystyrene once the areas around the building were back-filled with earth and chalk. The insulation of the external walls needs to protect from moisture, thus the use of waterproof EPS (Foamglas being too expensive to insulate the floor and the walls). See Fig 2.24.

Figure 2.23 external chalk walls prior to insulation

Figure 2.24 Insulation of earth sheltered walls and render, providing insulated internal thermal mass

September 2006: The Calyx's lighting system[8] and air conditioning system were installed.

October 2006: The wooden floors - made of recycled and reusable materials - were laid. The building and the landscaping was completed, it was then just a matter of waiting for nature to do its work and soften the surrounding and germinate the seeds on the Calyx's domes.

Figure 2.25 The upper roundel at completion

Fig 2.26 South Elevation after landscaping

[7] for more information : https://grace.com/construction/en-ca/Documents/BIT-230%283-26-07%29D_BitutheneLiquidMembraneDataSheet.pdf

[8] For more information : http://www.lightingdesignhouse.com/downloads/PINES%20CALYX%20PROJECT%20STATISTICS.PDF

Figure 2.27: Ground floor lobby at completion of lighting installation

2.5 Knowledge and Skills Development

A number of significant knowledge and skills progressions occurred through the design and construction of the Pines Calyx. Given the highly experiment and innovative nature of the building, all those involved in the project are thought to have benefited in knowledge and skills development, in many cases quite significantly. In terms of structural elements, two areas of significant knowledge and skills development were as follows:

Rammed Chalk knowledge and skills – Rowland Keable, already an expert in rammed earth construction when he joined the Pines Calyx project team, further developed his existing theoretical knowledge and practical skills through applying them to a new material, chalk. He also spread knowledge and skills through his leadership of this aspect of the project, benefiting both the design and construction teams in their knowledge and skills development. This also added to knowledge held within the BRE Centre for Innovative Construction Materials, via Professor Pete Walker's involvement, and CICM's role in testing samples of rammed chalk for strength and other important qualities during the project.

Timbrel / Catalan / Guastavino Vaulting knowledge and skills – this aspect of the project significantly benefited knowledge and skills development, in terms of structural engineering and artisan building skills, with the expertise of Professor John Ochsendorf and his MIT Architecture Dept team applied to the project, including Michael Ramage who later moved to Cambridge University Department of Architecture, thereby embedding this expertise in a UK institution. Sarah Pennal, already an expert in design and construction of arches, vaults and domes, added to that expertise through learning this system from John Ochsendorf and the team of Spanish artisan builders from the Extremadura region who were brought in for the construction of the first (lower roundel) vaulted roof. This included innovating the vault design during its construction to include a curved progression from the main roof up to the Oculi, rather than using a right-angled corner, as was first planned. Both John Ochsendorf and the client were particularly pleased with this evolution in knowledge of how the vaulted roof could be designed / engineered and constructed. A number of the team (Ochsendorf, Ramage and Bellamy) were later involved in the Mapungabwe National Park Interpretive Centre in South Africa, which was inspired in its design by the Pines Calyx project – the Mapungabwe building won a number of international building awards (including World Building of the Year at the World Architecture Festival 2009). Sarah Pennal led the construction of the second vaulted roof (upper roundel).

2.6 Design and Construction Management and Procurement

Initial conceptual design work started in 2002, from the Helionix team, particularly led by Alistair Gould (who was also the client, as Chair of the Bay Trust) and Issy Benjamin, with a design team built around this visionary core. This conceptual design set the form and layout of the building, as well as the core principles as to how it would be constructed and how it should perform. A number of variant designs were worked on, with particular sensitivity to landscaping aspects.

The Helionix team then surveyed the site and produced the detailed drawings for the planning application. Approval was achieved late in 2003.

The building of the detailed technical and engineering design team was critical in developing the specific technical design elements which would conform to the principles and objectives the concept design has set, and included Helionix, Cameron Taylor construction engineers (which became Scott Wilson near to the time the building was commissioned) led by Philip Cooper and Conker Conservation, building surveyors and green building specialists, led by Paul Mallion.

David Olivier of Energy Advisory Associates was also brought into the design process in spring of 2004 as one of the UK's leading energy and buildings experts.
In 2004, other specialists were also brought into the project including Conservation Engineering as M&E engineers, and The Lighting Design House for lighting system design – as Alistair Gould (client) was still a Director of Clearvision Lighting (a market leader in systems mimicking natural light) at this time, the level of client-specialist designer collaboration on lighting design was significant.

These specific expert roles were important for defining the design details of the project, in effect to move from the general objectives 'what would be achieved' to the specific details of 'how it would be achieved'.

In early 2004 the baton for leading the design process was handed over from Helionix Designs to Cameron Taylor. Philip Cooper, supported by the level of expertise being built within the technical design team, grew in confidence in the engineering approaches through non-standard design forms.

During 2004 working drawings were developed by Cameron Taylor, informed by regular design workshops. In January 2004 Alistair Gould and Paul Mallion attended an earth building conference at Bath University in January 2004 where contacts were made with Professor Pete Walker (head of the BRE Centre for Innovative Construction Materials at Bath Uni) and others. This led to a rammed chalk workshop at the Pines Garden, St Margaret's Bay in spring 2004 which helped Cameron Taylor and other team members have confidence in the viability of rammed earth construction for the project. During late 2004 Rowland Keable was introduced to the project, providing the enabling group for the rammed earth sub contract.

In relation to the innovative roof design, it was known from 2004 what was wanted i.e. a Catalan vaulted roof – the difficulty was to find out how this could be constructed and by whom. Research in this area led to contact with Professor John Ochsendorf at the department of architecture at MIT in early 2005, which progressed rapidly, leading to a team from MIT coming over to build the first vaulted roof of the lower roundel in July 2005, led by John Ochsendorf. The difficulties in identify the 'how' and the 'who' for the vaulted roof, had meant that the project had come close to adopting the option of a reinforced concrete roof, having also considered a reciprocal frame roof. So there was a great deal of enthusiasm behind the roof element of the project once the how and who had been identified, with significant level of confidence naturally arising from the fact that MIT were leading this element.

During 2004 Cameron Taylor continued to lead the evolution of the design, with regular meetings held in London. During this period Conker Conservation started to develop drawings of construction details, with the specialists such as Conservation Engineering and (later on) MIT providing detailed drawings of their elements of the project. Also through this process, a number of construction options were reviewed by the team, essentially researching and exploring recycled materials options 'on the hoof', which was aided by Alistair Gould of Helionix being London-based at the time, thereby having easier access to the emerging field of recycled construction materials and products. Some materials options failed on site tests and were thus replaced with other more conventional options.

In summer 2004 the project was put out to tender for contractors, and Ecolibrium Solutions was selected (from effectively only two credible options) and Andrew Bassant of Ecolibrium was then brought into the latter stages of the design sessions, which is seen as having been important and very beneficial to the project. The contract with Ecolibrium defined their role as main contractor for the project as a whole, with the exclusions of the rammed chalk wall construction, for which Rowland Keable was contracted, and the vaulted roof construction, for which MIT was contracted.

PCM Safety were also brought in once Ecolibrium were selected, to manage site H&S elements of the project.

As main contractor, Ecolibrium Solution's flexibility and commitment were crucially important in the construction process, as this ensured they had tolerance for 'on the hoof' design solutions being generated for certain technical issues, and where some of the construction products and materials were also being identified as the build progressed.

In early 2005, at the commencement of the construction phase, the baton for leading the project was effectively passed over to Conker Conservation, who in addition providing precise project design drawings to various elements of the structure were also tasked with the building contract management.

A trial project to test and prove the rammed chalk wall system and the vaulted tile roof system was planned for the spring of 2005, with the walls constructed in March/April, and the roof in April. This trial project also brought in the expertise of Sarah Pennal, one of the UK's leading experts on design and construction of arches, vaults and domes, as well as Michael Ramage as part of the MIT team (later of Cambridge University school of architecture). As well as her role in roof construction Sarah Pennal also built the vaulted staircase, constructed from tiles to MIT's design..

Three months later the lower roundel dome was constructed, led by John Ochsendorf of MIT who then returned to the USA, and handed on to Sarah Pennal to lead the construction of the upper roundel roof.

The innovative construction methods and materials raised challenges, but also generated a great deal of enthusiasm and personal commitment to the project from all the members of the now emergent 'design and build collective' – for example, James Bellamy joined the team for the construction of the rammed chalk walls only, but then stayed on as part of the roof construction team, then working on the fit out followed by the commissioning (James stayed on for a year after the completion of the building).

Bauder were subcontracted by Ecolibrium to provide a Bauder guaranteed green roof system, which because of the curved shape of the roof raised more challenges for than a standard flat green roof. This created the only main delay in the construction process, as Bauder had confidently stated they could deliver an appropriate green roof solution when contracted, but then realised the project required a non-standard approach to be used for their system. They did provide an effective solution, but it took significantly longer than planned and at a higher cost.

Therefore, from footings being complete in April 2005 the construction process proceeded smoothly and effectively to the completion of the main roof structure in August 2005, notwithstanding the fact that some construction solutions were being developed 'on the hoof' during this time. Also some new significant design modifications were also effectively implemented 'on the hoof' (including the curved design to the oculi in the lower and upper roundels). From this point the project took a further year to complete with the teams undertaking the internal fit-out, installation of M&E and lighting systems, bespoke areas (e.g. the earth tube and initial solar thermal panel installation). The complexities surrounding the design and installation to the green roof system put a break on getting to practical completion which was eventually achieved in September 2006.

Whilst the formal opening of the building took place in October, a number of elements of the building were left uncompleted, some through design and others through necessity.

The design of the earth tube heat exchange system came from Richard and Anne Walker of Conservation Engineering Ltd, once they had been identified as the right M&E engineers for the project and were brought into the design team. This was because the Walkers thought in terms of design solutions rather than a technology led approach, and as a result they proposed the earth tube heat recovery system that proved to be a relatively low cost, effective solution, which was simple system to install, using a reclaimed heat recovery unit.

For the buildings waste water and sewage system, a reed bed system was seen as desirable but not a priority at the early stages of the design process, so was not given significant attention until later in the design process when it became clear that grant funding might be available. Grant funding was successfully secured via Kent Downs AONB (Defra funding) which provided the majority of the funding for the reed bed system. Designed by reed bed specialist Iain Wilkinson, this was the only part of the project where the Trust received a grant. The location of the reed beds at a high point in the Pines Garden was selected to minimise risk to the bore hole and as the most suitable location in the gardens. Whilst this solution requires energy use for pumping, the ecological benefits are seen as significant, and the energy impacts are probably less than if sewage were taken into the mains system and treated at a distance from the site.

2.7 Completion, commissioning and daily operation of building

The Pines Calyx has had several phases of completion of components of the current building over the period of 6 years between the building first becoming operational, and the start of this BPE project. In particular the commissioning of the renewable energy systems in 2012, replacing the heat supply from the gas boiler and heat main was a significant phase of completion and commissioning, 6 years after the building had become operational.

It is clear that there was much less detailed consideration and planning of the commissioning and operation of the Pines Calyx than there was of the design and construction. Also the client, as operator of the building, lacked experienced facilities management staff at the time, particularly in the area of experimental green buildings and renewable energy technologies. If the Soft Landings framework had existed at the time of the building was brought into operation, or prior to that during the design and construction process, then given the level of expertise across the design and construction teams it is very likely that such an approach would have been implemented. However, as the Soft Landings approach did not exist at the time, the handover lacked the insights that soft landings provides, and as a result the building has suffered from a number of the challenges that the soft landings approach seeks to plan for and avoid.

At the start of the BPE process in 2012, a number of components and systems still remained to be completed. These included:

- Installation of the actuators for the opening Oculi (circular roof lights) in each of the roundels
- Proper commissioning and balancing the mechanical ventilation system i.e. checking the correct functioning of the systems, ensuring key staff understand the correct operation of its components and controls, etc.
- The final glazing system for the lenticular roof light (above the staircase) replacing 'interim' polycarbonate glazing with high performance triple glazed units with low thermal bridging frames

The first two of these items are now underway. The third item is not critical to the BPE process, although it will help improve the building's thermal efficiency when complete and is planned for installation in 2015.

Completion of these items has been complicated by a lack of information and knowledge by the Estates Team, which was initiated with the employment of the Estates Manager in April 2012. This knowledge and information gap relates mainly to the building services systems and the fact that they are all non-standard, innovative or experimental (see section 3 for details of the services and section 8 for recommendations to avoid this situation on future projects). It is primarily through a) establishing the Estates Dept and b) the implementation of this BPE project that this knowledge and information gap has been significantly filled, and now has a pathway for aiming to completely fill these gaps during 2015.

Airtightness testing of the building has not taken place either prior to first-fix, or at completion. This is justified by the fact that the final lenticular glazing element has not yet been installed. The intention has been to test airtightness when this final glazing element is complete.

Some of the window actuators in the roundels have been damaged and are inoperable - this is believed to be the consequence of some users forcing windows open or shut to achieve comfort conditions. This highlights the need for clear guidance on the building and its systems to building users (see section 8), which as yet has not been provided, although is now being planned.

In relation to the building services and energy systems, the completion, commission and operational problems were far more significant than fabric related issues, and are discussed in the following chapter.

The commissioning of the building included no centralised building management system. With the installation of the monitoring system this provides opportunities to use that data in a building management system, which is currently being designed, with the value of this system being made very clear by this BPE project.

In terms of the operation of the building, again there have been major gaps. There was no substantial training system for the building's main user groups i.e. events staff and clients. Also because there was a significant lack of information and knowledge within Estates team on optimum functioning of the building's various systems (because monitoring data on systems had not been gathered), there would not have been the knowledge base to allow effective training for building users anyway. This BPE programme and the monitoring system has provided a very sound basis for addressing this gap.

2.8 Conclusions and key findings for this section

It is clear that the Pines Calyx is an experimental building in virtually every one of its major elements – building form; materials; wall construction system; roof engineering and construction system; energy supply systems (from 2012); ventilation; lighting system and lighting controls.

Specific findings are that:

- Very ambitious design objectives were set by the client and design team;
- Very well selected design and construction teams meant that realistic approaches to achieving the ambitious design objectives were identified;
- Unusually open and collaborative design and construction processes were highly effective in helping achieve the design objectives;
- Excellence in design and construction was not matched by excellence in commissioning, maintenance and operation of the building, although systems are now in place to achieve this;
- There were significant gaps in information being passed on from the project delivery phase to the building operation phase, which led to on-going problems in achieving optimum operation of the building in general, and the energy and building services in particular.

Essentially, many of the classic problems that the Soft Landings framework addresses were experienced within this project, with some aspects of these problems being exacerbated by the experimental nature of the project. As an asset rich, cash poor charity, many of the weaknesses in the operation, management and maintenance of the Pines Calyx have been related to financial and staff resources constraints. However, significant Trustee decisions to strengthen the Trust's management team have since put in place an Estates Manager and Estates Department in 2012. This decision has been crucial for the effective management and delivery of this BPE project, and therefore has been crucial in setting a realistic planned path to:

a) identify and tackle problems;
b) implement solutions;
c) set a target for optimum operation of the Pines Calyx in 2015.

The project has been successful in achieving the primary design intention of creating *an optimum healthy space for creative thinking, learning and working,* as well as in achieving the four more specific key design objectives for the project:

- Low impacts in construction
- Low operational energy in use
- An extremely healthy building for its users
- A beautiful building, internally and externally.

The design process was partly conventional – following RIBA stages A to C for architectural concept design, engineering design and specific technical design of details – and partly unconventional, with a highly collaborative approach adopted so that specific solutions to technical challenges were designed 'On the Hoof' where necessary.

The unique or unusual key design features of this building positively influence its performance including the earth-sheltered construction, curved design and that all the main walls are constructed from rammed chalk. The circular shapes of the building help to minimise the heat loss through the walls and to capture as much daylight as possible in the building, throughout the day. The Rammed chalk walls minimise embodied impacts at every stage of construction, provide high thermal mass to maintain balanced internal temperature and regulate the relative humidity ensuring a more comfortable indoor environment.

The main untested area of performance is airtightness, which will be tested after the final lenticular glazing element is complete. PHPP in-use calculations will also be finalised at this time.

3 Review of building services and energy systems.

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

3.1 Building services and energy systems design intent

The design intention for the building's energy use was to minimise heating, hot water and electrical demand as far as realistically possible for a high quality events venue, with renewable energy supply maximised. In practice this meant that the Pines Calyx is designed to be so well insulated and so well sealed that during cold weather heating will only occasionally be required. Most of this limited heat should be supplied by internal and solar gains – for example, as an events venue with a maximum capacity around 100 people, there would be significant internal gains from occupants and kitchen utilities (cooker, washer, fridges and freezers) during medium to larger events. These gains are backed up by underfloor heating when needed.

With such a well-insulated building, a major emphasis for the design of heating and ventilation therefore has been to reduce cooling loads. The original Electrical Specification included a desire for the solar photovoltaic panels to provide DC for batteries to drive various DC equipment, although this was not implemented.

According to early energy performance specification (circa 2004)[9], the building aims to set an advanced standard in its application of best available energy efficiency technologies. Ideally beating best case energy performance of exemplar buildings (at 2004) - e.g. Elizabeth Fry Building (EFB) at UEA, Norwich. Typical measured energy consumption from such buildings register approx. 28kWh/m^{2}yr gas and 70 kWh/m^{2}yr electricity (total 98 kWh/m^{2}yr).

In relation to energy demand, much of the early specification for the Pines Calyx adopts the German Passivhaus Standard. However, it was recognised that the form chosen for the building design (e.g. without entrance buffer zones) meant that the Passivhaus Standard was unlikely to be achieved, although a very low level of primary energy demand could be achieved compared to commercial building benchmarks at the time. The Passivhaus standard sets no criteria on energy supply, aside from passive energy supply being optimised.

[9] Energy Performance Specification - 16 Nov 2004 - David Olivier BSc MEI MASHRAE

In relation to building services and energy systems therefore, the designed intention was informed by thinking that created the AECB Gold Standard design guidance which seeks to: a) maximise renewable energy supply, whilst b) achieving very low operational energy demand.

The Passivhaus criteria for a central European climate:

Space heating demand ≤ 15kWh/m^2/yr
or space heating load ≤ 10W/m^2

Space cooling demand ≤ 15kWh/m^2/yr
or space cooling load ≤ 10W/m^2

Primary energy demand ≤ 120kWh/m^2/yr
(including hot water, space heating & cooling, fans, lighting, appliances)

Airtightness n50 ≤ 0.6ac/hr

Figure 3.1: Summary of Passivhaus Standard (source: http://www.passivhaustrust.org.uk)

Table 1. **THE THREE ENERGY STANDARDS AS APPLIED TO A TYPICAL DWELLING**

Standard	Useful space heating energy	Primary energy consumption [1]	CO_2 emissions
Silver	40 kWh/m²yr	120 kWh/m²yr	22 kg/m²yr
Passivhaus	15 kWh/m²yr	120 kWh/m²yr	No explicit limit
Passivhaus in a UK context [2]	15 kWh/m²yr	78 kWh/m²yr	15 kg/m²yr
Gold	15 kWh/m²yr	58 kWh/m²yr	4 kg/m²yr

Figure 3.2: Summary of AECB Standards (source: AECB_VOL_3_EnergyStandard_V4c_FINAL.pdf)

This was deemed to be the most robust approach to sustainable design available at the time for non-domestic buildings, with more meaningful energy performance criteria than for example the BREEAM 'Excellent' Standard, which for example, had relatively weak requirements around operational energy use (Note: BREEAM Outstanding was developed at a much later date). It was also recognised that significant cost would be associated with pursuit of the BREEAM Standard, which was seen as not adding sufficient value to the project to warrant its pursuit bearing in mind that a) the design team was constructed from leading UK and international experts in key fields, and b) the client was a Charity, with a limited budget. Whilst the specific performance targets contained with the AECB Gold Standard were not seen as achievable for the Pines Calyx project, the general design philosophy of seeking a) low operational energy, b) maximised renewable supply and c) a very low net level of CO2 emissions for the operation of the building was the driving force behind designing the energy and building services systems.

Lighting Design Brief

The brief for the lighting was extremely unusual; to design an internal environment that was to be beautiful, ecologically sound and as physiologically beneficial as possible. This last goal influenced every decision made and the end result is a unique environment that can change at the adjustment of a virtual slider.

Although there is limited evidence that electromagnetic fields really have a detrimental effect on our bodies, the lighting designer wanted to take as many precautions as possible to reduce any potential risk. How this was achieved is describe in the Lighting section below.

3.2 The Ventilation System

The design intent for the ventilation was to create a naturally and reliably ventilated building, with low energy use and low maintenance for the ventilation systems. This general intention evolved into a specific system design once Conservation Engineering Ltd was identified as providing the right M&E engineers for the project. The intention was that controlled ventilation using forced and natural ventilation would remove excess heat, as there was potential for significant internal heat gains in the well-insulated building from:

- solar gains;
- lighting;
- occupants – particularly during larger and more active events;
- utilities, particularly kitchen equipment during catered events.

The system would need to cater for a building where all of the above could be highly variable depending on the time of year, scale of the event, and whether the event was catered for in-house or not. The gains from lighting were reduced by the choice of efficient light sources set into low loss luminaries coupled with lighting controls. Solar shading from the extended roof overhang minimises summer heating from direct sunlight, with an initial plan for external shades that has not been implemented.

The design adopted introduces fresh air into the building via the windows and an Earth Tube and stale air is extracted through the Oculi and across a heat recovery ventilation system with the fans driven by DC electrical supply for maximum energy efficiency. The heat recovery ventilation is installed to all areas through uninsulated timber ducts leading to room intakes and outlets that are hidden behind low level perforated wooden panels which rise from the floor to a height of around 1metre. Filters to remove particles such as pollen can be introduced as required. More details of this system are provided in the following section.

The main rooms are designed to be naturally ventilated during periods of heavy use using stack ventilation (facilitated by the vaulted roof design with Oculi) by opening windows and Oculi, with automatic controls fitted to minimise the need for user operation of the ventilation system. Any filters will be ineffective during these periods, however this will maintain good air quality and remove excess CO_2.

3.3 The Earth Tube and Heat Exchanger

Design intentions/theory

The design intention was that the earth tube would pre-heat fresh air in winter and pre-cool fresh air in summer. This was based on the knowledge that the ground temperature at a certain depth below ground level is very stable and approximates to the average annual external temperature. The depth at which the ground temperature is stable varies according to soil type and moisture content. Along the south coast of the UK, the average external temperature is approximately 11°C.[10]

As the inlet air passes through the earth tube it exchanges heat with the ground via the wall of the tube. If turbulence within the tube can be achieved (through changes in tube direction and/or surface irregularities in the tube wall and/or baffles to deflect air within the tube) then the heat exchange is enhanced. If turbulence is not achieved then a laminar flow results, with the highest velocities in the centre of the duct and a still layer of air adjacent to the inner wall of the tube - reducing the heat exchange effects.

The following diagrams illustrate key aspects of the ventilation system.

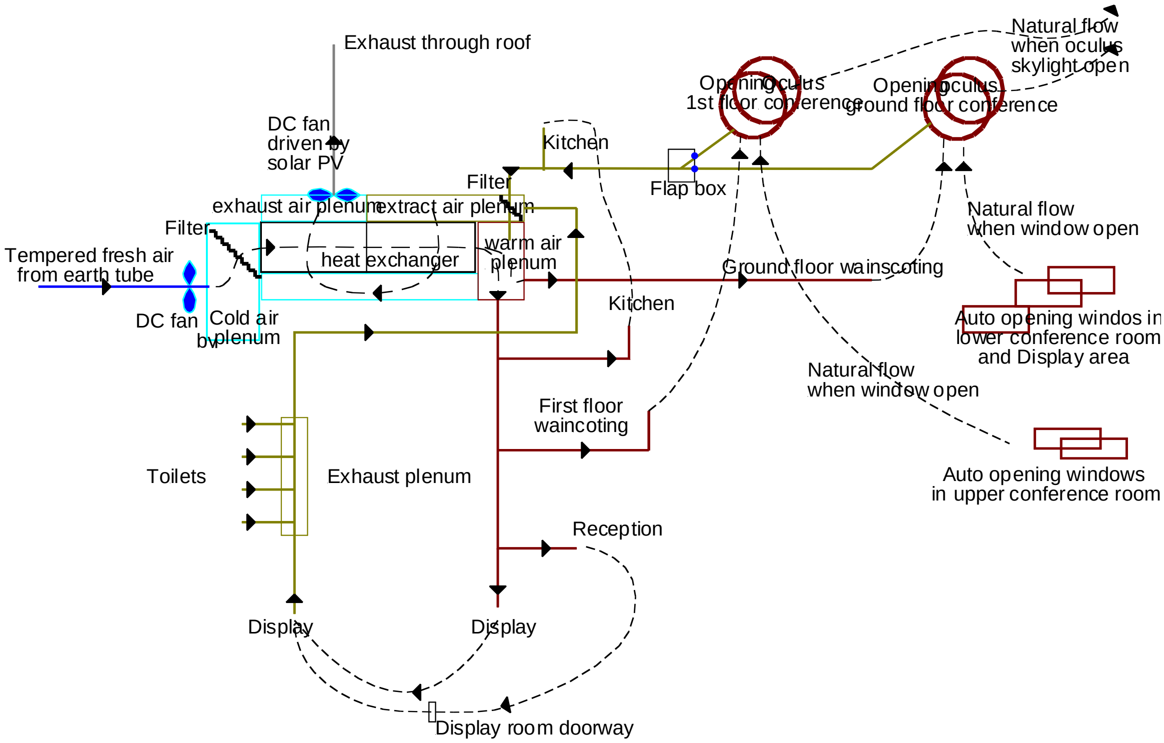


Figure 3.3: ventilation system schematic

Earth tube - general description and how it works

During periods of low use (currently the norm), fresh air is introduced via the earth tube to temper the air by adding heat during the winter and cooling during the summer. During periods of heavy use for instance during a conference, the low use system is overridden. The natural ventilation controller opens windows in each of the conference rooms to let air in and high level opening oculi (circular roof lights) to let the air out. The high level ducts to the heat exchanger may be closed. Further windows can be opened by hand as needed.

The earth tube is a concrete pipe of approximately 16m length overall, with an internal diameter of 0.6m, located approximately 1.5m below ground level. The tube inlet is connected to a manhole, which is capped with a ventilating cowl structure fabricated from timber and

[10] www.metoffice.gov.uk/climate/uk/regional-climate/so

incorporating spiral shaped openings on all sides. Insect mesh covers all the inlet openings. The tube terminates below ground level internally with a fan, which pushes air first through the heat exchanger in the plant room, and then to the building. The heat exchanger comprises a box containing glass tubes and is reused from another building, supplied by Conservation Engineering. It was built into the ductwork by the builder/joiner along the back wall of the plant room and the earth tube connected by an end wall cupboard. The box has a clear plastic face to front, so that the internal arrangement is visible.

The intake air from the earth tube passes through the glass tubes in the heat exchanger and then through distribution ductwork to the building. The extract air passes through the space in the box surrounding the glass tubes, pre-heating the intake air. The extract air is pulled through the heat exchanger by a second fan, located in a duct which extracts through the roof. Intake and extract fan speeds are set independently by two variable speed controllers located in the plant room. These are manually adjusted.

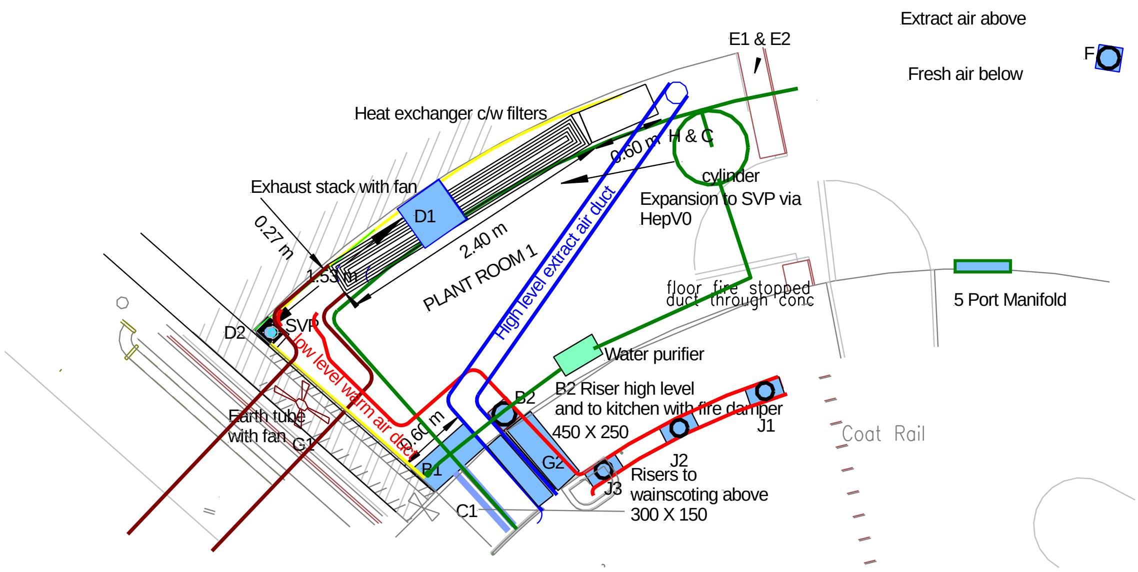


Figure 3.2: plant room plan

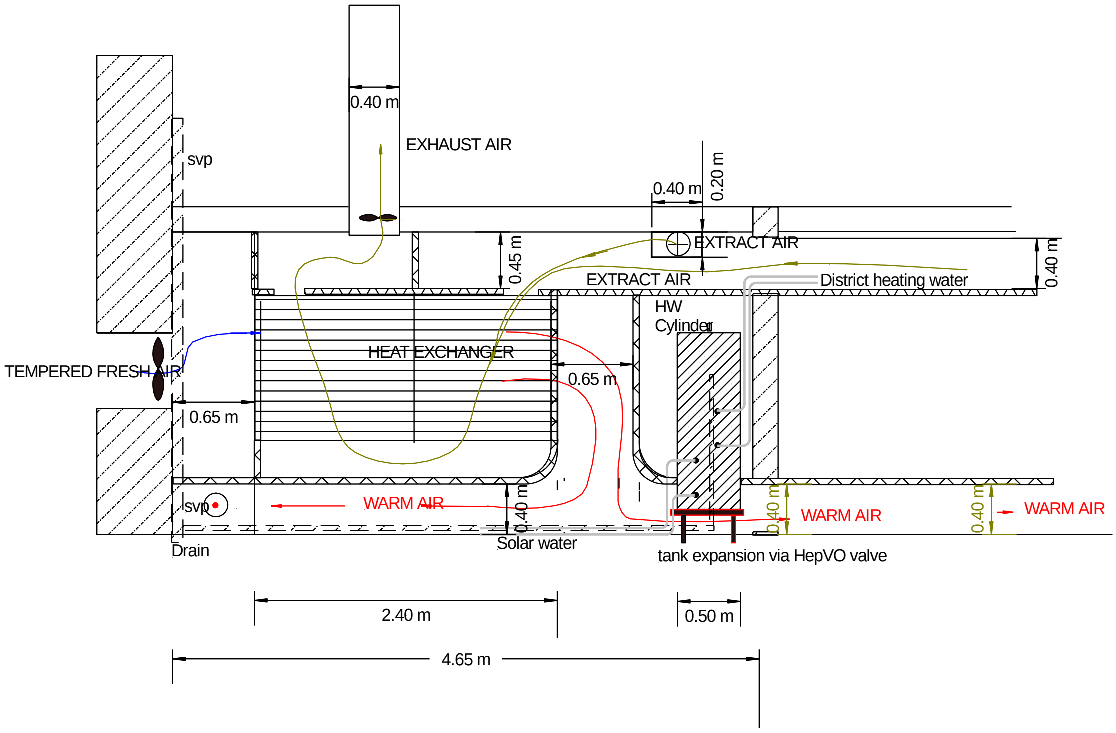


Figure 3.4: Plant Room Elevation drawing

The original design utilised uninsulated ducts based on the understanding of the proposed system and available knowledge at the time. In retrospect it would have been preferential to incorporate some form of insulation into the heat exchanger which was constructed out of WBP FSC ply on 75 x 50 SW studwork and run along the back and side walls of the plant room Dust and pollen filter frames can be installed on the inlet and outlets to allow removable filters to be installed as required. Simple site glasses can be installed to show pressure drops across the filters as the dust build up. The DC extract fan was built into the flue above the heat exchanger - the flue runs up through the kitchen. A warm air vertical riser duct is branched from the floor level duct and routed across the ceiling to serve the warm air ceiling network. In more detail:

a) **The plant room extract duct** runs at ceiling level along the full length of the plant rooms from the lift shaft to the heat exchanger. The extract air from each oculus runs behind the lift shaft and flows into the same duct. The extract form the ground floor also connects into this duct.
b) **The plant room warm air duct** runs at floor level along the full length of the plant rooms from the heat exchanger to the lower conference room. The fresh air to the ground and upper connect to this duct in the plant room
c) **Extract ducts from each toilet and the display area** are built into the false ceiling and terminate in the false ceiling plenum near the plant room. The ducts are separate to remove noise transfer between room outlets.
d) **The extract air from the kitchen** flows from the cooker hood, then drops down via the vertical duct to the plant rooms extract duct.
e) **The extract air from each oculus** runs in tiled ducts already laid below the roof insulation. The ducting was constructed behind the lift shaft to connect to the plenum

adjacent to the lift shaft c/w isolating flap for each oculus extract and sited to allow maintenance access.

f) **Ground floor warm air** runs in the false ceiling to the Reception area and to the Display area. The ducts were built and extended through the walls, with vents set in the walls, and a vent louvre over the entrance to WC's, made by the joiner.
g) **The warm air to the Upper Conference Room** feeds from the plant room to the false ceiling and up into a wainscoting duct via 3 holes in the floor. Ductwork was constructed to marry with these holes, with wainscoting with air vents along its length.
h) **The warm air to the kitchen** rises through the Plant Room ceiling into a 2m high duct onto the floor of the Kitchen, installed with a grille on top.
i) **The warm air duct to the Lower Conference Room** runs along the lower part of the plant room back wall across the lift shaft and through the lower hole in the wall to the Lower Conference Room. It is then distributed via a wainscoting complete with vents.
j) **Automatic opening windows** to let air in are sited in the lower conference room (4 or 2 off), upper conference room (2 off), and display area (1 off) controlled by the ventilation controller
k) **Automatic opening skylights** to let air out through the oculi are sited in the lower conference room (1 off), upper conference room (1 off) controlled by the ventilation controller.
l) **Manual opening windows** to let air in are sited in the lower conference room upper conference and room display area. To let air out the kitchen has 2 Manual opening skylights.

3.4 Heating

This BPE study commenced once a replacement low carbon heating supply source had been commissioned for the Pines Calyx, to feed into the existing heat distribution and management systems within the building that had been commissioned 6 years earlier, with minimal heating supplied by underfloor warm water pipes laid round the perimeter under the windows.

The initial design intention for the heating system incorporated a planned future change of heat energy generation and supply systems once budgets allowed. However, whilst a change of energy supply systems occurred 6 years after the building came into use, the change in energy systems was not that which was initially expected:

- The energy and building services systems were originally planned for a change from a) a gas boiler to b) a wood fuel boiler, both located in the Pines Cottage and supplying the heat to the Pines Calyx as one of 3 buildings supplied by the boiler and a heat main, feeding into an underfloor heating system i.e. a boiler change without a fundamental change in the nature of the heat supply and distribution system;
- The actual change was from the gas boiler and heat main to a highly innovative new ‘Hybrid Solar System’ combining a Photovoltaic Thermal (PVT) panel with a water source Heat Pump, using an existing water bore hole i.e. this involved a fundamental change in the heat supply system, feeding into the existing heat distribution system within the building of underfloor heating;

In practical terms this meant a change in the planned replacement heat supply system from one which was tried and tested, although relatively uncommon, to a system that was highly experimental.

PVT and heat pump

Technical details of heating and hot water system:

PVT is a 20 panel Solimpeks array. Calculated outputs:
Installed capacity: 3800w
Net AC Electricity: 4104kwh
Useful solar thermal: 847kwh

A 12KW Kensa Heat Pump is linked to two heat sources:
- Thermal output from PVT array - Direct
- Borehole open loop collector - indirectly through plate heat exchange.

Heat pump outputs/requirements estimated at:
Available annual heat: 12,165kwh
Electrical requirement for Heat Pump: 2,816 kWh per annum

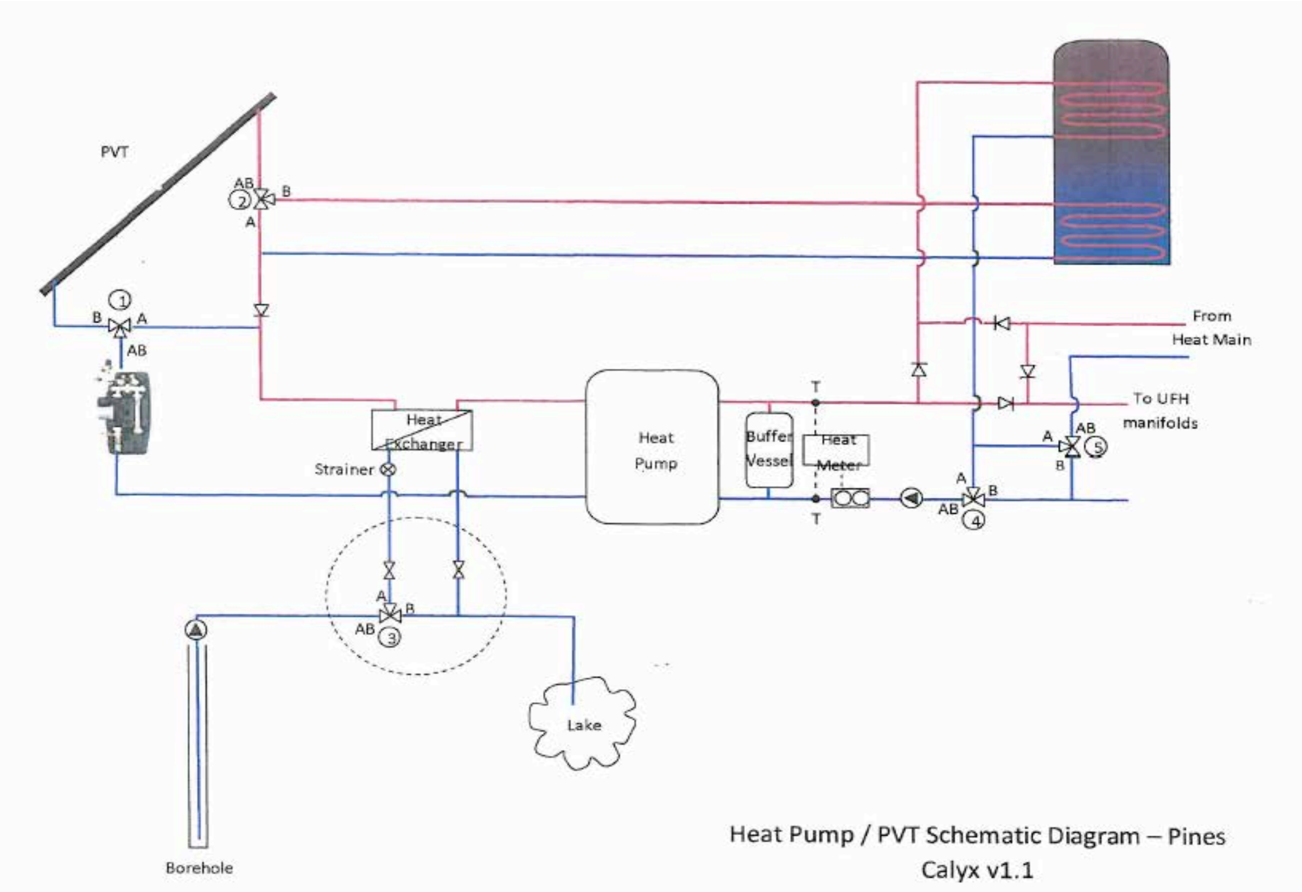


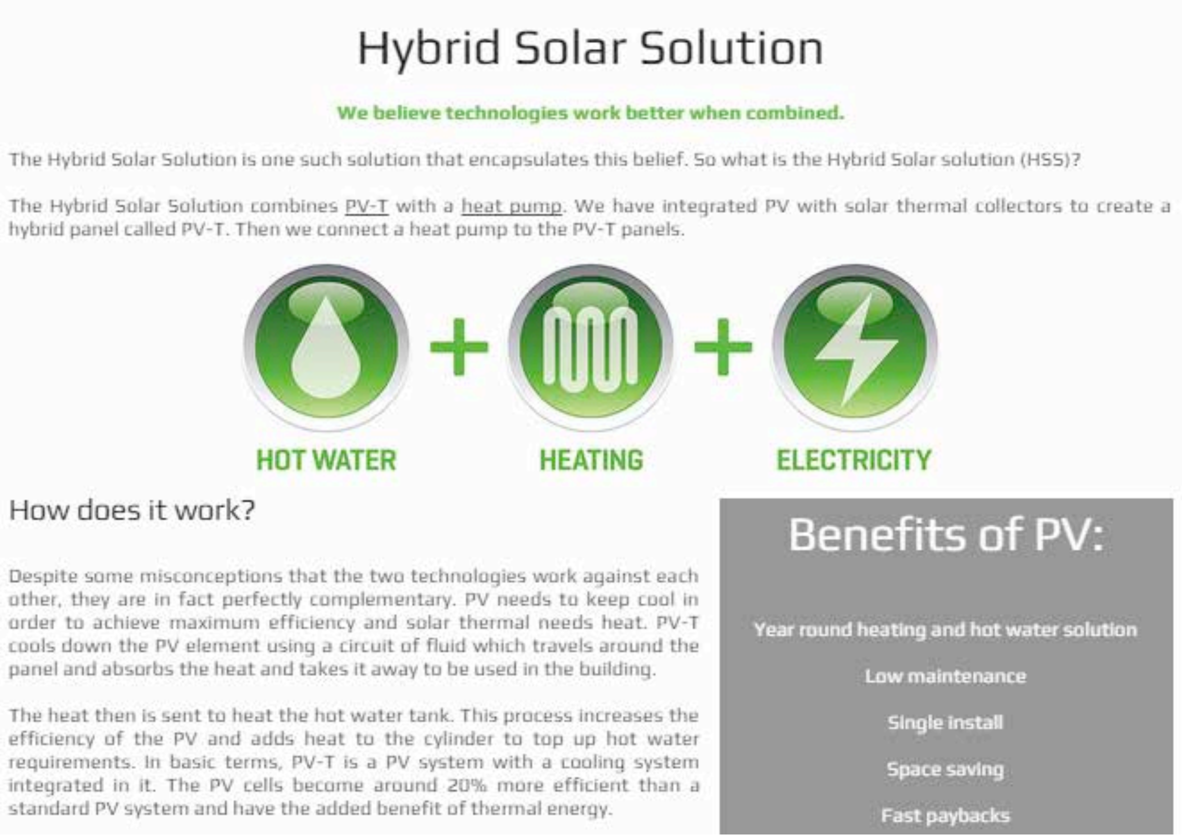
Figure 3.5 Heat Pump / PVT schematic diagram

Water is distributed in a buried pipe around the grounds from a borehole. The borehole currently operates continuously with the return water discharging into a small lake. Heat from the water extracted from the borehole is used to supply the heat pump.

The supply of heat from the heat pump to the underfloor heating manifold has been integrated into this system. The control system gives priority to the heat pump but allows the gas boiler/heat main to continue to be used to provide backup, if needed.

The hot water cylinder has dual heat exchange coils. The heat pump has been integrated with the heat main connection to the upper coil and have the priority. The lower coil is currently directly connected to the thermal output of the PVT array.

The full project design and installation costs for the HSS were £39,996.



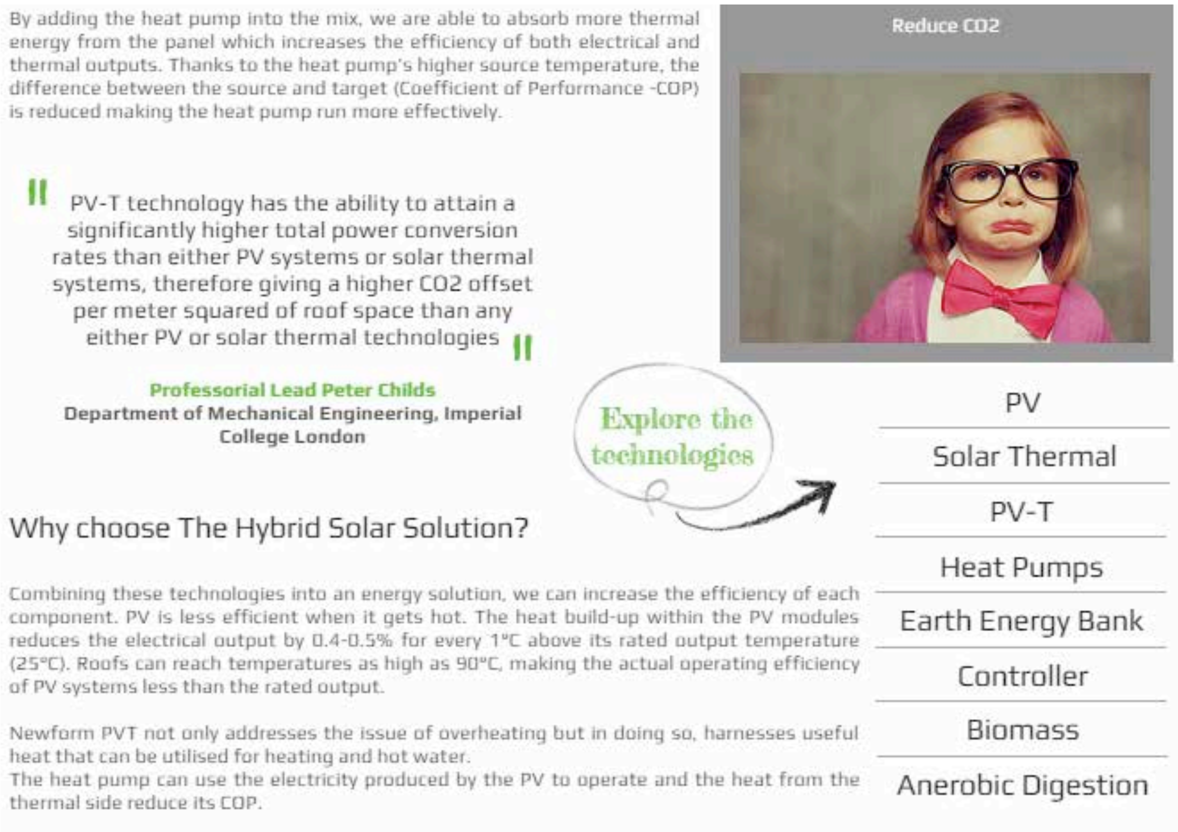


Figure 3.6: Hybrid Solar Solution supplier's description (Source: Newform Energy website - http://www.newformenergy.com)

3.5 Lighting

The lighting techniques in the Calyx are practically glare free. In two key areas, a special polarizing diffuser was used which can be viewed directly by the eye without causing any glare – this particular diffuser also improves contrast and can improve visual acuity.

The colour temperature of the roundels can be adjusted to create varying degrees of stimulating light source. This is achieved by dimming the 3 tubes within the suspended fluorescent fittings - which are red, green and blue – in different percentages so that a variety of whites ranging from cool to warm can be used as well as actual coloured light if desired.

The lighting system has numerous configuration options, including the option for one set of lights to run on a direct current rather than the standard alternating current[11]. The Calyx has one circuit in each of the main rooms that gives a low level of light which can be run on DC. The control system from Dynalite DDNP1501 is a 15V DC 1.5 amp regulated power supply designed to supplement the DyNet network DC supply. The switch mode design allows the device to be used with a wide range of supply voltages without the need for a manual selector setting[12]. Although the facility to switch between AC/DC is available on the system this is still not widely understood. The Estates Team instructed an independent engineer to review and upgrade the system in summer 2014 – phase I works have been completed and it is anticipated that further works will continue during 2015/16[13]

3.6 Non-service loads

As a highly thermally efficient conference and events venue with catering facilities, there can be relatively significant non-service loads related particularly to the kitchen appliances – e.g. fridges and freezer, cooker, dishwasher. These loads have not yet been a significant focus of attention, although they will receive greater attention as the building moves to optimum operation. The original design intent for kitchen services was to supply basic reheat services – i.e. food prepared and cooked elsewhere and then transferred to Calyx for reheating. This design decision mapped the original use plan for the Calyx – Small conference/seminars and office space. However, the Calyx has evolved to become a very popular Wedding and function building with higher needs for catering etc. Whilst this operational development has aided the income requirements of the Calyx, it is not the intended purpose and the Calyx owners are actively looking to revert the building's use back to conference/seminar space.

3.7 Monitoring

The initial specification for the monitoring system was developed by the University of Kent team, and then was refined in consultation with the monitoring system suppliers, Thompson Ellis. Energy monitoring and environmental sensors are in place and logging has been underway since January 2013, the data is being entered into a server database which has been shared with the project team.

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[11] This assumes that DC electricity has less impact on our bodies, if any at all.
[12] Details are available in Evidence Q4 folder
[13] Details in Evidence for Q7 Task 4 folder

The sensors are measuring CO2, temperature and humidity levels in each roundel and in the seminar room. Monitors have been set up to identify the energy use of specific systems like the heat pump, the lighting and the earth tube. Other sub-meters measure the electricity consumption of different items in the building (oven, hob, fans etc.) All of the meters measure data every 15 minutes, and graphs can be seen on the website http://logging.eco-monitoring.co.uk/ [14]

More specific details of the monitoring system are as follows:

- System installed to provide visibility on
  - 14 Channels electrical usage (kWh and Power) – see below for specifics
  - 27 Channels of environmental data – see below for specifics
  - 4 Channels heat input data
- Data is logged at 15 min intervals 24/7
- Data uploaded to Thompson Ellis hosting
- CSV file sent once a day with last 24hrs data
- Web portal available for looking at the data
- Display screen to show some of the data

The details of the electrical and environmental channels are shown below:

Electrical Channels

- Main meter
- Lighting board
- DMC 805
- DLE 405
- DDBC
- Ventilation, Emergency
- Solar Water
- Heating Manifolds
- Solar PV
- Servery Lights
- Immersion
- Servery Hob
- Servery Oven
- Earth tube fans

Environmental Channels

- Upper Roundal
  - Level 1 Temp and RH
  - Level 2 Temp and RH
  - Level 3 Temp and RH
  - Carbon Dioxide
- Lower Roundal
  - Level 1 Temp and RH
  - Level 2 Temp and RH
  - Level 3 Temp and RH
  - Carbon Dioxide
- Outside
  - Temp
  - Relative Humidity (RH)
  - Irradiance
- Conference Room
  - Level 1 Temp and RH
  - Level 2 Temp and RH
  - Level 3 Temp and RH
  - Carbon Dioxide
- Earth Tube
  - Air Speed
  - Entrance Temp
  - Exit Temp
- Heat
  - Heat pump output Energy and volume
  - External heat input energy and volume

[14] Access to data. Username: thepines Password: test

In the latter stages of the project an error has been identified in the labelling of a sensor in the CSV file format – this meant that the captured data provided a confusing picture for Bay Trust staff until the error was identified. This highlights that a level of familiarity with *both* a) energy and buildings issues and b) spreadsheet analysis is needed to make best use of the monitoring data and TM22 analysis tool.

3.8 Completion, Commissioning and daily operation

Completion, commissioning and operation of the building services and energy systems has been complicated by an initial lack of information and knowledge within the Estates team, which has been steadily addressed on an on-going basis since the department was established in 2012, with this BPE project significantly accelerating this process, as well as adding greater depth of technical detail. Issues in this area include:

- Initial handover when Pines Calyx became operational in 2006 with initial relatively simple energy systems, but without any experienced Facilities Management staff;
- Installation and handover of PVT system – was complicated by the innovative nature of the system, poor installation by sub-contracted plumbers, and a lack of technical FM expertise within the Trust at the time the installation was designed and planned;
- Energy management and control systems are still to be completed – currently the Estates Team monitor energy usage and employ a manual recording system. With additional details from the data monitoring the Team will review findings and respond accordingly. Simple housekeeping measures have helped to lower energy use in the building – through careful monitoring of lighting/pumps and fans and adjusting accordingly;
- Information and understanding of optimal operation of systems, maintenance, etc. was significantly lacking.

The energy and building services systems had no natural handover. The building was completed 2006, and an Estates Department was created early in 2012 - the Estates team have worked to collate as much information as possible, bringing in experienced staff and proven protocols for managing systems and relationships with installers/suppliers, none of which were previously in place.

The highly innovative nature of the Hybrid Solar System (PVT + heat Pump), and the fact that when the system installation was designed, planned and commissioned there was a lack of high level technical FM expertise in-house within the Bay Trust meant that:

a) Whilst the installation was more or less experimental in its nature, it was not necessarily managed as an experimental system by the client or supplier either at the time of installation or once it was in operation – if it had been then close monitoring and aftercare of the installation and operation of the system would have been put in place;
b) Design of the system was outsourced to the technology supplier, Newform Energy;
c) The installation of the system by a subcontractor was planned and managed by the renewable energy supplier Newform Energy, rather than by the client (as the newly

formed Estates Department was focused on other early Estates priorities) with a trust that the subcontractor would deliver a good installation.

In fact, the installation of the Hybrid Solar System had a number of faults which have subsequently been addressed following the establishment of the Estates Department in 2012 with appropriate FM expertise, so that the system faults have been properly identified and diagnosed since the new Estates Manager initiated a post-project review in December 2012.

Eventually this resulted in the system in effect being re-installed during 2014, with a commissioning of the re-installed system taking place in June 2014. A significant contributing factor to the system problems was simply poor plumbing installation by the subcontractor employed by Newform Energy. As a result of the experiences of this project Newform Energy have now initiated both: a) tighter control of installation by subcontractors; and b) an aftercare system for clients to observe and ensure proper operation of newly installed systems.

There were also complications with the installation of the PVT/Heat Pump due to a general misunderstanding of the existing Heat Main set up. After consultation with the original designers the Estates team were able to successfully deal with any remaining issues.
The control mechanism for the heating/HWS was designed by Newform Energy - this control system has a number of settings that can be used (profiles) according to type of usage in Calyx. The Estates Team will monitor effectiveness of the profiles and make adaptations to programmes as necessary.

The overall timetable for the system installation was as follows:

- April 2012 project start
- May to July main plumbing installation phase
- June PVT installed
- September Heat pump installed
- Snagging of overall system problems and modifications through to November
- Post project review.

The lighting system was originally designed by the Lighting Design House, in close consultation with Alistair Gould as client with expertise in the field of virtual daylight systems. The technology and controls were supplied by Dynalite Ltd. However after installation the lighting systems were not checked or maintained, and there was no clear understanding of how to set the system controls for the building (i.e. manufacturers default settings used). In addition there was no clear communication regarding the wider benefits of the system for staff and clients, and no proper training in how to use the system. In addition key components failed (i.e. the user-interface touch-screen controls malfunctioning).

Once established the Estates team reviewed the lighting system to identify problems. They had difficulty in finding technology providers because Dynalite had been bought by Phillips, with Phillips engineers then quoting a minimum £600 site call out fee which was not seen as cost effective. Alistair Gould and Marc Carey then contacted Mary Rushton-Beale of the Lighting Design House, who fortunately still had contact with an ex-Dynalite engineer, who was happy to work with us to bring the operation of the system up to scratch under an outsourced service contract – this has led to evolution of the overall system to take advantage of new technologies that are now available i.e. more user-friendly controls are now operated via an i-pad.

The commissioning and operation of the earth tube and heat recovery ventilation system had significant parallels to the lighting system. Again, through a) the establishing of the Estates Department and a range of management, maintenance and operation procedures and b) the implementation of this BPE project, problems and solutions have been identified with a clear plan for how optimum functioning of the system will be achieved.

The natural ventilation system required major review - unfortunately 'operator error' over the years has resulted in a number of broken mechanisms. The Estates Team have embarked on a program of repairs/alterations to rectify the situation:

- Installation of actuators for Oculi
- Review of mechanical repairs for windows
- Review of control system for windows/Oculi
- Discussion regarding new control panel linked to monitoring system

Once all of the mechanisms are working, we plan to create a 'delegate pack' which communicates the unique nature of the Calyx and, hopefully, explains how the building works. This should decrease any potential future 'user errors'.

A monitor has been sourced and is positioned in the lobby of the Calyx. Relevant data from the meters/logging devices is shown onto this monitor and scrolls between additional delegate details. We will update and review outputs according to delegate interest.

A review of the sewage system by an intern in 2014 revealed similar issues to other aspects of building services, such as a lack of clear information amongst staff on the system components and its proper operation, and the impression that the system was not fully operational. This resulted in a visit in 2014 from Iain Wilkinson (Wilkinson's waste and waste water treatment specialists) who originally designed the system, which provided clarity on the optimum operation and management of the system.

As detailed in Chapter 2, the commissioning of the building included no centralised building management system. With the installation of the monitoring system this provides opportunities to use that data in a building management system to establish the complex interactions between the performance of the fabric, the energy systems and building services systems, with the value of this system being made very clear by this BPE project.

3.9 Conclusions and key findings for this section

The challenges and performance weaknesses have been much greater for the energy and building services systems of the Pines Calyx than for its building fabric. In terms of the operation of the building, there have been major gaps:

- a significant lack of information and knowledge within Estates team on optimum functioning of the building's energy and building services systems (because monitoring data on systems had not been gathered);
- no substantial training system for the building's main user groups i.e. events staff and clients;

- prior to the BPE project there would not have been the knowledge base to allow effective training for building users, because of the lack of real data on the building's performance.

This BPE programme and the monitoring system has provided a very sound basis for addressing these gaps.

In addition:
- There has been considerable learning about the Hybrid Solar Solution *in operation* during the life of the BPE project, both for the client/operator and the supplier;
- Poor plumbing installation has been a greater problem than any failings in the technology;
- Technology issues have also contributed to problems;
- Shading of the PVT panels are a significant limitation on the HSS performance;
- There is no measurement / monitoring of PVT thermal output.

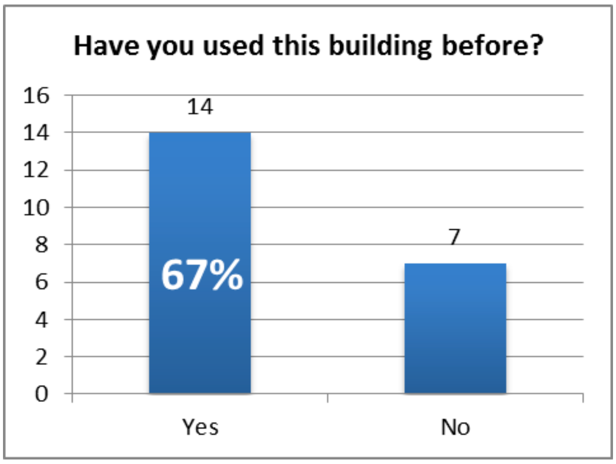
Some unanswered questions are firstly, how we can determine if or when heat supply is exceeding demand in summer, and secondly to what extent this might be giving a 'false' overall picture if that heat is not used. These questions are both in scope to be answered during 2015.

4 Key findings from occupant survey

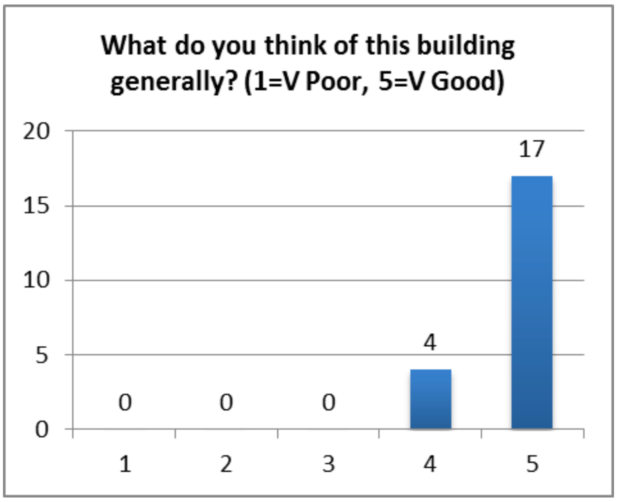
Technology Strategy Board guidance on section requirements:	This section should reveal the main findings learnt from the BPE process and in particular with cross-reference to the BUS surveys, semi-structured interviews and walkthrough surveys. This section should draw on the BPE team's forensic investigations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

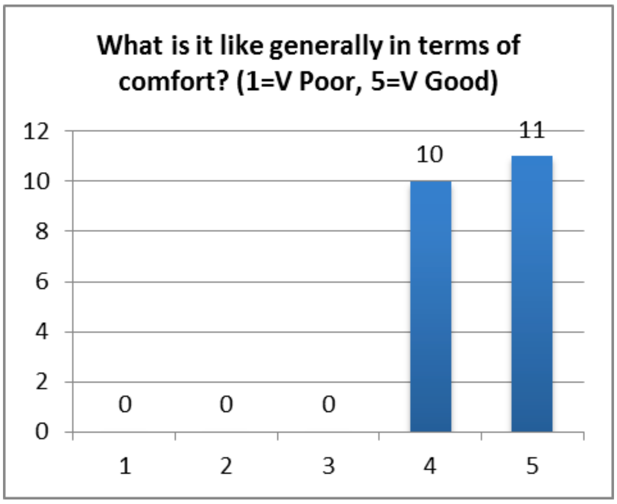
4.1 Findings of the Building User Survey

The Trust did not achieve a high level of responses to the Building User Survey, therefore the findings should be qualified. However, the following graphs illustrate important findings where there is a good indication of Users' experience of the building, although any conclusions will only be robust if we can achieve much higher responses to a user survey in the future.

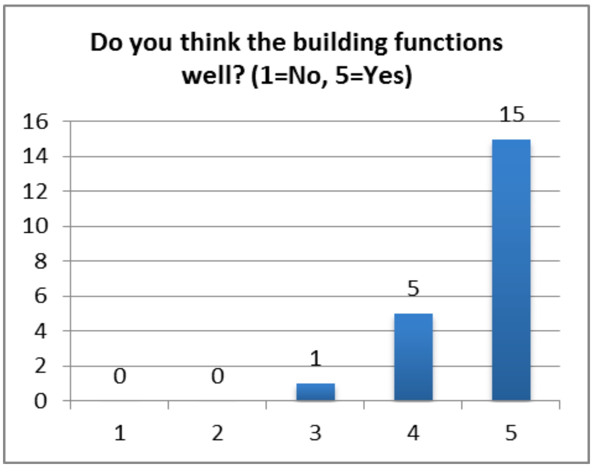


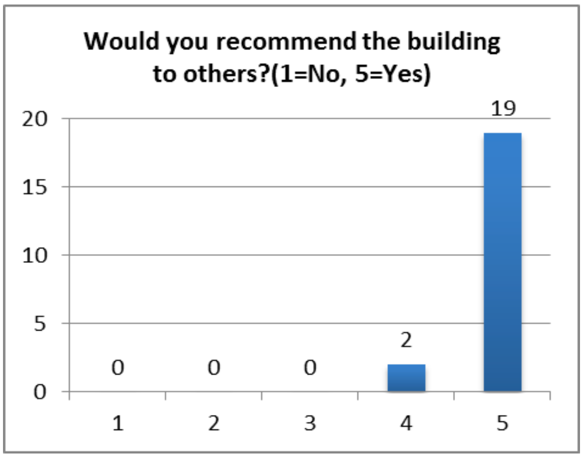
This graph illustrates that the majority of users who completed the survey are repeat users. Records of client bookings will also indicate repeat users, although this is not necessarily a direct correlation as different staff may attend on different occasions, and some users may attend events booked by more than one client. This also suggests that repeat users are more likely to complete user surveys, or are more likely to be asked to do so.

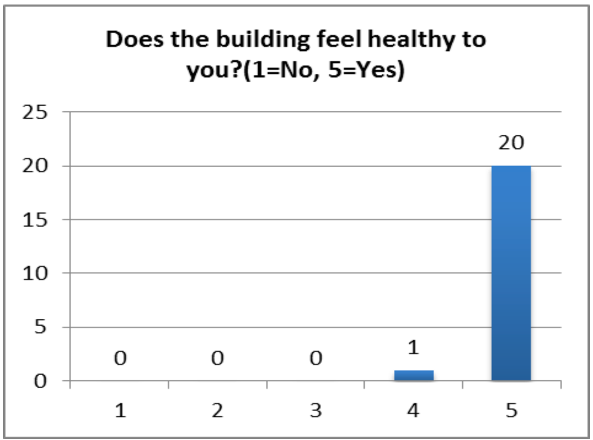




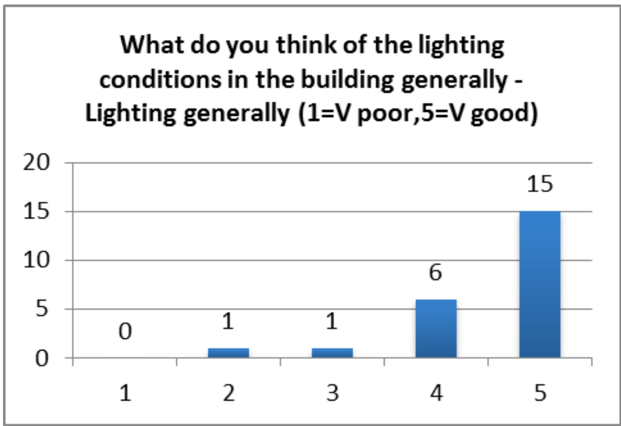
The graphs above generally indicate high satisfaction with the building, and with the comfort levels it provides – although the comfort graph also indicates some room for improvement.

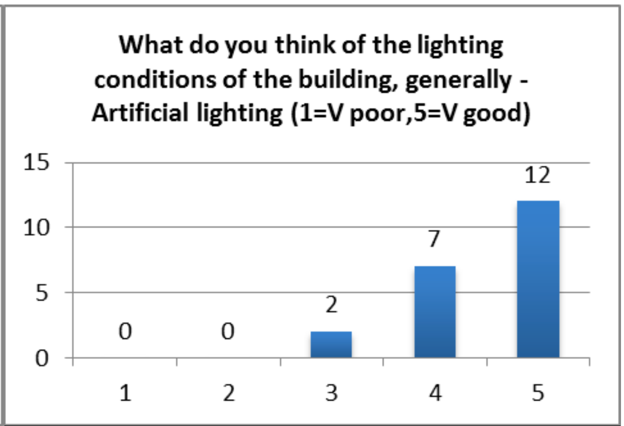


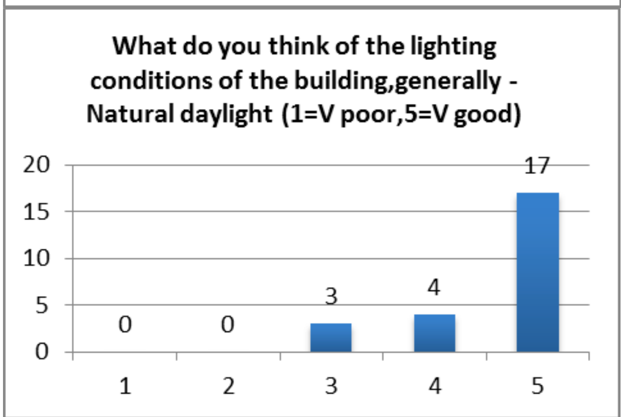




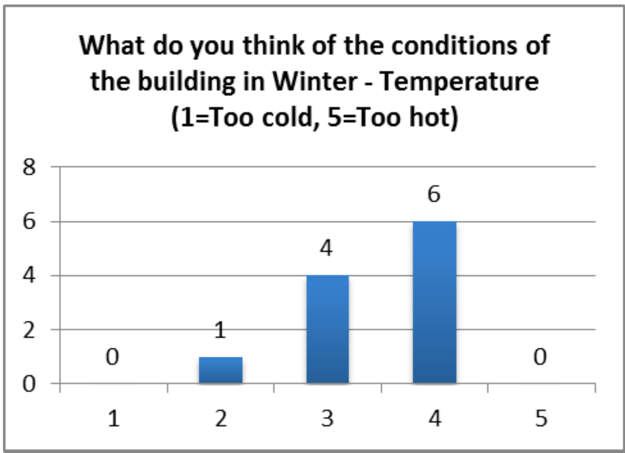
These graphs illustrate generally very high satisfaction with the building in terms of its function, and extremely high satisfaction with how healthy it feels – this is a very positive confirmation of the design and construction teams work in achieving the core healthy building objectives. These findings are confirmed by the high willingness of users to recommend the Pines Calyx to others. These responses are of significant marketing value.

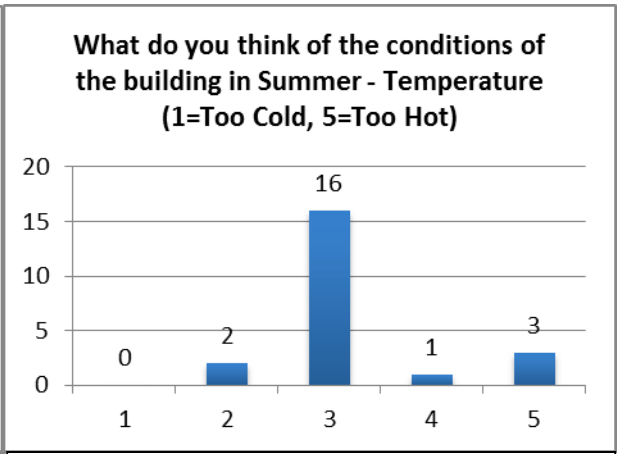


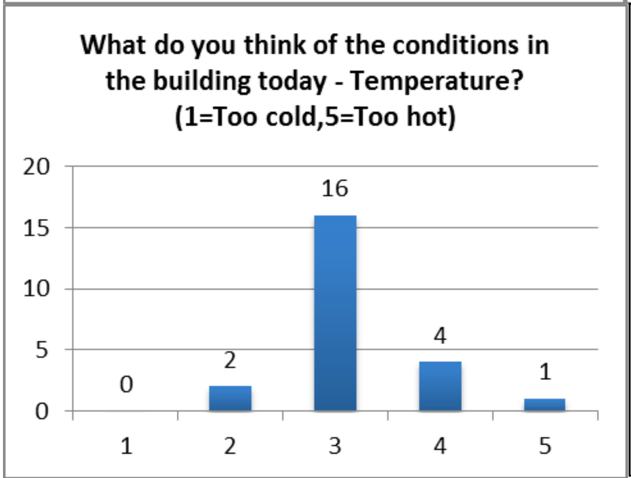




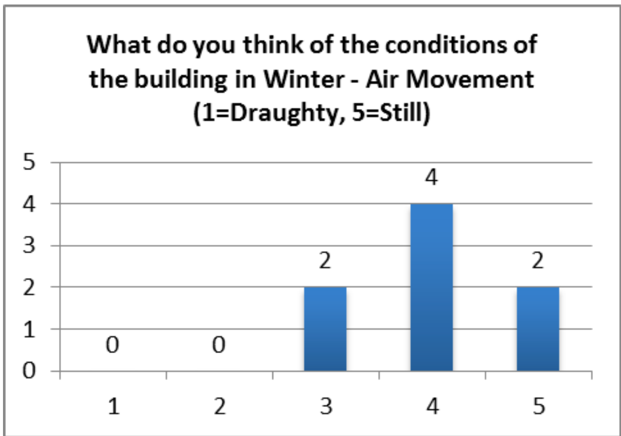
These graphs indicate that lighting conditions are generally considered good, with very high levels of satisfaction for general light conditions and natural daylight conditions in particular, with slightly lower but still high satisfaction for artificial light conditions. Comments indicate that the smaller seminar room is considered dark by some.

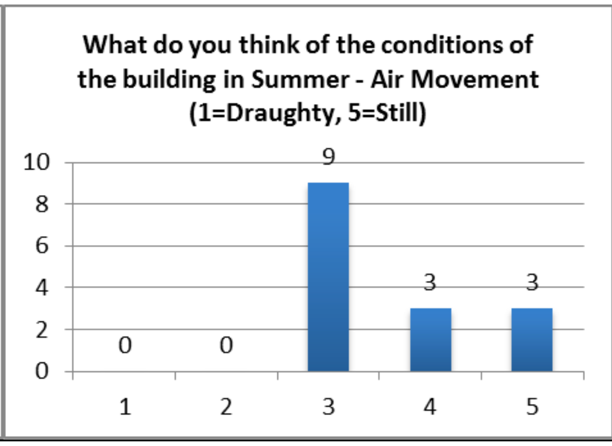


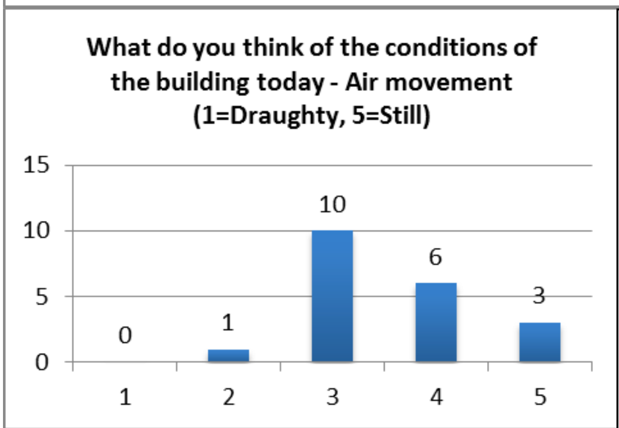




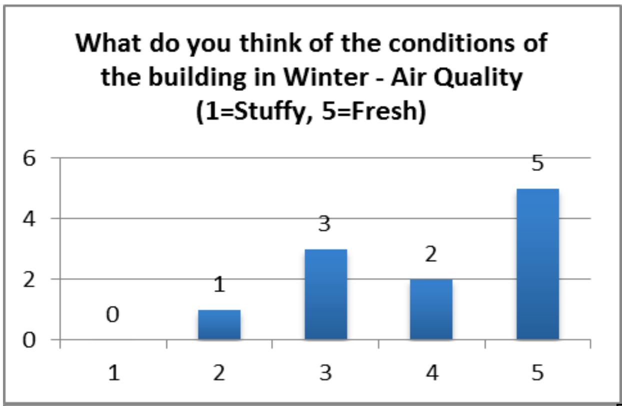
These graphs indicate that temperature conditions are generally considered good, with a small number of users finding the building too hot, but no users finding it too cold. The lower level of responses on winter temperatures reflects the lower level of Pines Calyx bookings during the winter. The level of median responses for 'summer' and 'today' indicate generally that there is a good user satisfaction and comfort in terms of temperature.

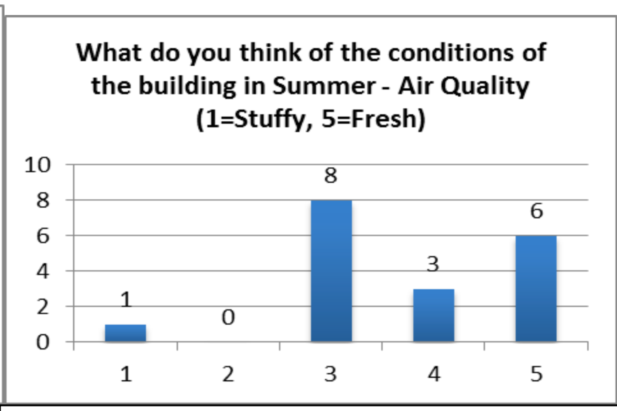


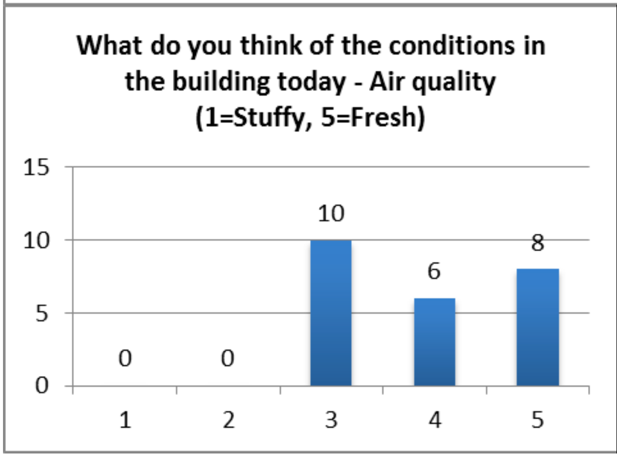




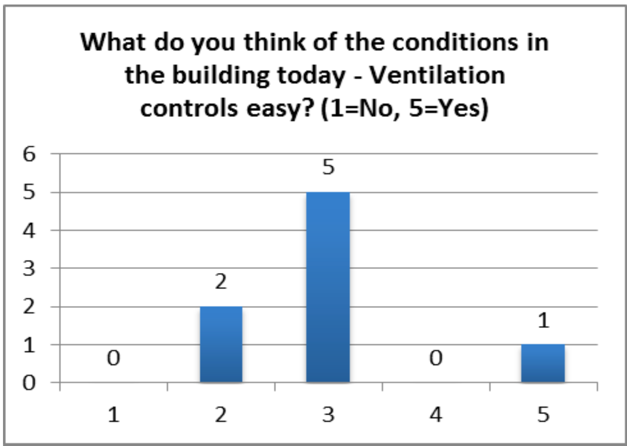
These graphs indicate that air movement is generally is considered balanced with a tendency toward being 'still' more than 'draughty'. The responses suggest that there is probably a good level of satisfaction in relation to air movement, although the question is oriented toward perception of air movement rather than satisfaction. Again, responses reflect the lower level of Pines Calyx bookings during the winter.

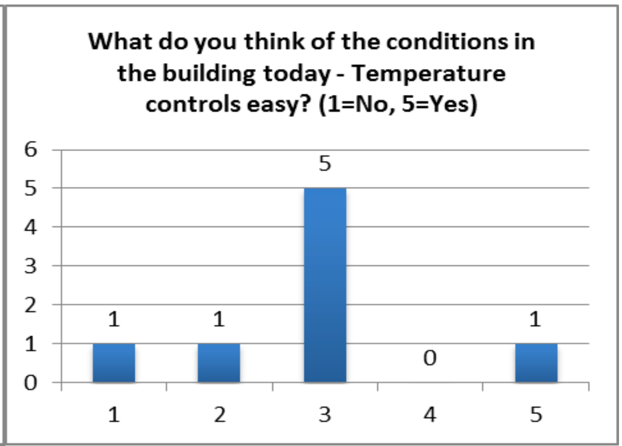


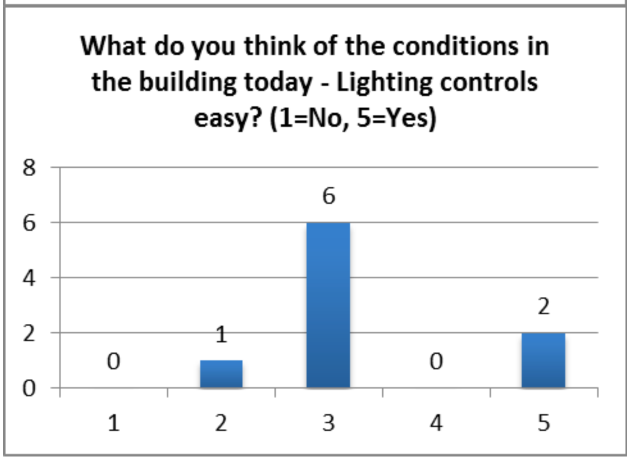




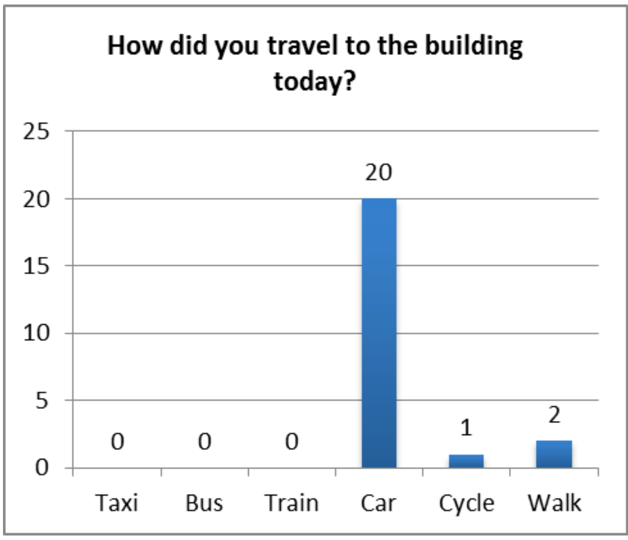
These graphs suggest that air quality is generally good, and tends toward being considered fresh, with only 2 responses indicating any stuffiness - a majority of respondents indicating toward fresh air quality in the 'today' graph (i.e. 58% of 24 responses). Generally, this suggests reasonable satisfaction levels in terms of air quality. Again, the lower level of responses regarding winter air quality reflects the lower level of winter bookings.

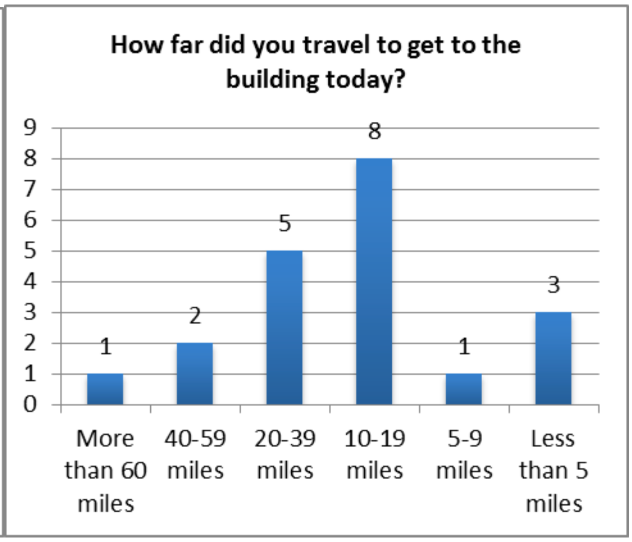






Bearing this in mind the very low number of responses to these questions (8/9), overall the indication is that controls are neither too hard nor too easy to use. The general objective should be that users find the controls easy to use, suggesting there is clear room for improvement to make controls easier to use. Comments indicate that some users did not use the controls, and did not know how to use them.





While the two graphs above do not relate to the performance of the building itself they provide valuable information for the Bay Trust as an environmental charity wishing to encourage more sustainable travel choices. The graph of travel distances may again reflect that those most willing to complete user surveys are more regular, relatively local clients of the Pines Calyx from East Kent. A higher number of responses from a higher proportion of clients would be needed to draw more robust conclusions in relation to travel distances, although it is clear that because of the location the majority of more local users are likely to travel by car for the foreseeable future.

4.2 Key findings and Conclusions for this section

Key findings from the user survey are as follows:

- Survey completion levels were low – 24 only
- Satisfaction levels are generally very high for a) the building and b) comfort
- In particular satisfaction levels are extremely high for the healthiness of the building
- Satisfaction levels are high for lighting
- There is general satisfaction with comfort across the seasons – i.e. temperature, air movement & air quality
- Response rates were low on controls questions – they show ease of use of controls was varied – but generally not considered 'easy'

Conclusions:

- There is real value in continuing with BUS
- Continued BUS should be made much easier to complete i.e. online survey methods, probably with a marketing incentive – both Estates and Events staff need to be engaged in designing an improved BUS, which is of value from both the FM perspective and from the customer engagement and marketing perspective
- Events staff should be considered as subjects for completing the BUS
- Building controls need a) user education and/or b) to be made more user friendly
- For ongoing BUS results, a 2015 target of 250+ completions will be very interesting!
- There is potential for significant value for positive marketing messages arising from more substantial responses to the BUS

5 Details of aftercare, operation, maintenance & management

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

5.1 Introduction to aftercare, operation, maintenance & management

The context for this section of the report includes understanding that the Pines Calyx is part of a larger Bay Trust estate which is largely made up of older educational and residential buildings, with greater needs in terms of management and maintenance.

The building was completed 2006, without any in-house staff with a high level of technical expertise to work on aftercare, operation, maintenance and management, and with no formal procedures for addressing these issues. Therefore the Pines Calyx had no natural handover. Early in 2012 an Estates Department was created, and since that time the Estates Team have worked to collate as much information as possible, overseen by the Estates Manager who has been able to draw on significant his FM experience, alongside experience in the low carbon technologies field. The following table sets out the key differences between operation of the Pines Calyx before the Estates Dept was established in 2012, and after it was established.

Building Operation Pre 2012	Building Operation Post 2012
• Based on ad hoc learning experience of how the building operated • Operated with little understanding of key technical aspects of the building in-house	• Based on developing systematic understanding of the operations of the building as a whole and its individual component systems
Building Maintenance Pre 2012	**Building Maintenance Post 2012**
• Reactive • Little control of supplier relationships	• Proactive, through PPM (Preventative Planned Maintenance) • Management of supplier relationships
Building Management Pre 2012	**Building Management Post 2012**
• No FM experience in house • Building management led by Events Team • Minimal input …	• FM experience in house, through Estates Manager and Estates Dept • Building management led by Estates Dept
Energy Efficiency & Management Pre 2012	**Energy Efficiency & Management Post 2012**
• Energy use was not monitored and was understood from usage on bills, without metering / knowledge of individual heat usage for the building via heat main • No systematic picture of energy use of the building existed	• BPE project is leading generation of data to enable effective energy efficiency management and optimum operation, use and management of the building

Alistair Gould has supported the Estates Department where possible with answers to key questions and there has been a renewed interest from the original design/build team. Connecting the two teams together has been complicated but, ultimately, beneficial to all parties.

From 2012 to the present a series of postgraduate engineering Interns from Nantes University have worked within the Estates Department during the summer each year, undertaking project-focused work which has helped to steadily build technical understanding of building operations issues for the Pines Calyx.

5.2 Building fabric

Some of the key issues relating to the building fabric and its performance are as follows:

Walls

Walls have generally required little maintenance. Where there has been any flaking of the face of the walls the Estates team have identified the following causes:

a) faults in the casting of that part of the rammed chalk wall (i.e. cause in construction);
b) direct damage from users (i.e. tables bashed into walls);
c) humidity effects on chalk surface

Solutions to the above are:

a) Additional treatment with sodium silicate solutions
b) Better education and procedures for events staff and users
c) Humidity effects and their solutions are to be researched more, potentially including additional sodium silicate treatment

Oculi and Lenticular

Oculi controls still to be installed, and lenticular glazing to be installed to replace 'interim' polycarbonate option

Window controls

- No completed control system installed
- There has been a small amount of control available, but with users not educated
- Some contractors and suppliers have gone out of business

Flooring

There have been no concerns about the quality of any flooring – issues have been more about accessing particular contacts within suppliers as original materials were often niche products;

- Marmoleum – was an expensive solution requiring a commitment to long term maintenance or repair costs, which was not necessarily recognised when specified and which needs to be planned for in Management and Maintenance budgets

5.3 Energy and building services systems

Completion, aftercare, operation, maintenance and management of the building services and energy systems has been complicated because all systems are non-standard, therefore operation knowledge and maintenance skills are not widely available. This has been exacerbated by a lack of detailed information and specific technical knowledge within the current building management team. For example:

- October 2006 - initial handover when Pines Calyx became operational with initial energy systems, but without any experienced Facilities Management staff;
- April 2012 - Estates Department established bringing in experienced staff and protocols for managing systems and relationships with installers/suppliers, but also with many other priorities across the Bay Trust estate;
- Oct/Nov/Dec 2012 - Installation and handover of PVT+Heat Pump system, and control systems
- Information on optimal operation of systems, maintenance, etc. has been gathered by correction of faults, trial and error, and through re-installation of the HSS in 2014;

There were complications with the installation of the PVT/Heat Pump due to a general misunderstanding of the existing Heat Main set up. After consultation with the original designers the facilities management team were able to successfully deal with any remaining issues. The control mechanism for the heating/HWS was designed by Newform Energy, and has a number of settings that can be used (profiles) according to type of usage in Calyx. The Estates Team will monitor effectiveness of the profiles and make adaptations to programmes as necessary.

Generally it is clear that in terms of the ability to deliver effective operation and maintenance of the energy and building services systems the Pines Calyx has been challenged by:

- Lack of information
- Lack of staff / user training
- Lack of 'soft landings' type handover and process etc.
- Being a classic example of the performance gap challenges linked to energy and building services systems, with these being to some extent exaggerated by the experimental aspects of the building

Lighting

The sophisticated lighting system illustrates some of the challenges of innovative or bespoke systems in terms of operation and maintenance. Working with a small specialist lighting design consultant led to the use of a Dynalite product in the system, with this supplier later being bought by Philips, who discontinued the range and required a £600 call out charge for the system to be looked at. Personal contacts have fortunately provided a solution to this situation, as an ex-Dynalite engineer is now providing a maintenance service for the system. Lighting controls are now operated by an I-pad, after a number of issues with the lighting controls.

Ventilation System

The natural ventilation system required major review - unfortunately 'operator error' over the years has resulted in a number of broken mechanisms. The Estates Team have embarked on a program of repairs/alterations to rectify the situation:

- Proper commissioning and balancing of the earth-tube and heat exchange system
- Installation of actuators for Oculi
- Review of mechanical repairs for windows
- Review of control system for windows/Oculi
- Discussion regarding new control panel linked to the monitoring system

Despite the ventilation system problems, the technical report indicates that the earth tube has been functioning very well – made possible by its relative simplicity in technological terms.

5.4 The 2014 flood and risk management

The flood resulted from a failed plumbing installation. The post project review identified that nothing like this was planned for e.g. the Risk analysis process had gaps. This unplanned catastrophic event had major impacts both at the time in January 2014 and for 9 months after. This involved an additional cost to rectify the installation of £5,000 and caused over £20,000 of damage, albeit largely payable by insurance (although this will be carefully scrutinised by insurer of course). It has been clear that because the Pines Calyx is a non-standard building (i.e. with chalk walls, and a range of less common materials and features) such events are more complex to manage, will generally take longer to resolve and have a higher cost .

5.5 Overall operation of the Pines Calyx

The major lesson for the Trust from the BPE project has been around the functioning and operation of the building. It is clear that outstanding design and construction needs to be followed by outstanding handover, management and maintenance if the building is to perform to the standards it was designed to. As part of the management of the building the estates team are now regularly reviewing the data from the monitoring systems and a) communicating it to main user groups, b) using it to evolve effective management of the building. Continuing the BPE will help inform decision making and general practices in relation to a) proper operation; b) communication with clients; c) maintenance regimes.

A monitor is positioned in the lobby of the Calyx, with relevant data from the meters/logging devices is shown and switching between additional delegate details. We will update and review outputs according to delegate interest. When the fabric, energy and building services systems are working to their optimum, we will create a 'delegate pack' to communicate the unique nature of the Calyx and explains how the building works. This should decrease any potential future 'user errors'.

In relation to aftercare, operation and maintenance in order to maintain high levels of comfort for building users, the monitoring and the BUS are planned to be continued (with the BUS covering the events team as well as clients). Information on the risks for higher CO_2 levels arising will be communicated to the events team, for example when there are a larger number of building occupants on cooler days when doors and windows are not open, to improve their understanding of how to ensure adequate ventilation during certain events.

5.6 Conclusions and key findings for this section

Most aspects of the structure and energy systems are innovative or experimental, with few tested in-use benchmarks for how they 'should' work i.e. the Pines Calyx is as much an experimental building, as it is a conference and events venue – not surprisingly, this has had major implications in terms of operation, management and maintenance.

Building Element	Experimental / Innovative	Advanced	Standard
Design form	Yes		
Walls system + materials	Yes		
Roof system + materials	Yes		
Materials	Yes (many)	Yes (many)	Yes (some)
Energy systems (phase 2)	Yes		
Energy strategies		Yes	
Ventilation systems	Yes		
Lighting systems		Yes	
Lighting controls	Yes		

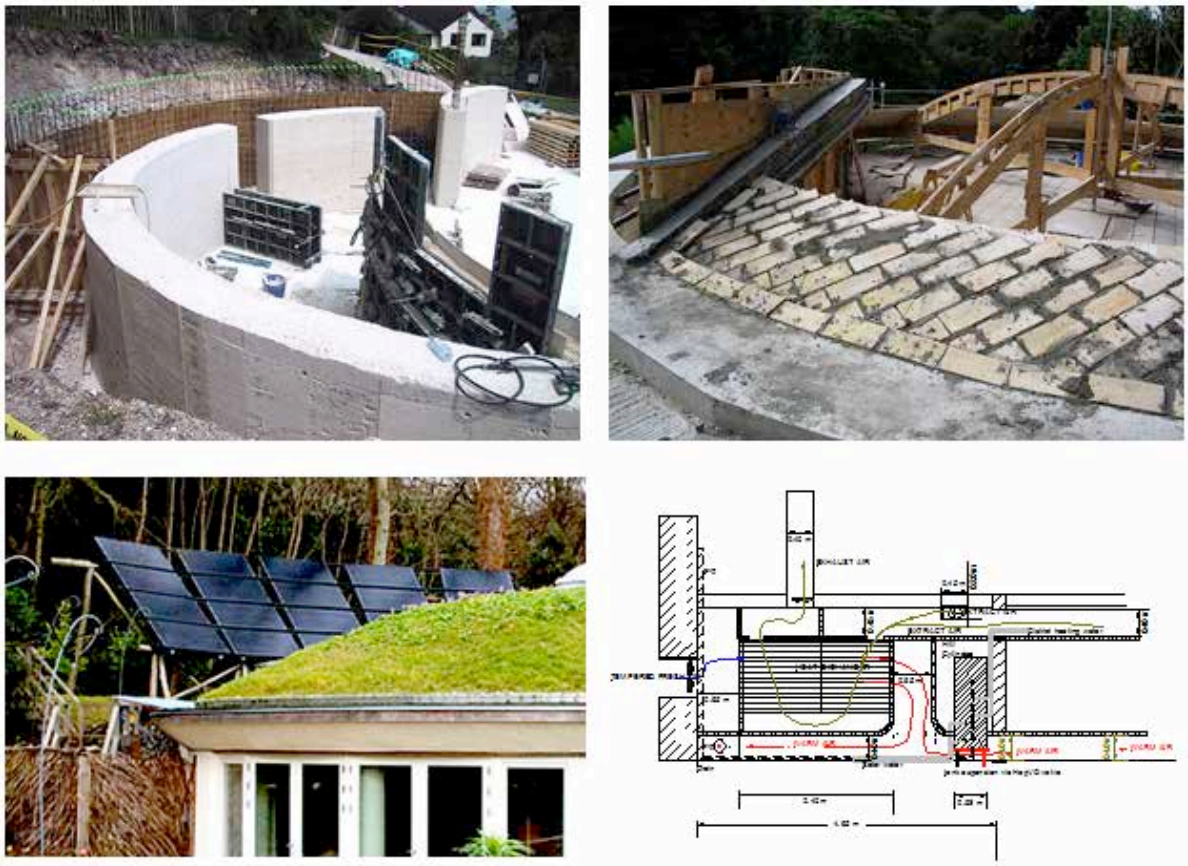


Figure 5.1: some of the multiple experimental / innovative components of the Pines Calyx

Supplier relationships

Relationships were established through the design and construction process, but then dropped off and became sporadic post 2006 to 2012. Supplier relationships have since been re-established and managed by the Estates Dept. The lesson is that if you are going to build an experimental building it is very important to maintain relationships with specialist / niche suppliers – this was only done in a minority instances pre 2012.

Monitoring

There will be significant aftercare, management, maintenance and operation benefits for the Bay Trust and Pines Calyx users arising from continuation of the building monitoring systems, using gathered data in particular to:

a) educate Pines Calyx users / operators;
b) improve and optimise operation of the building.

Phased completion and commissioning of project components

The key elements of the building where design and commissioning has progressed post occupancy are as follows -

- Ventilation Systems – Part commissioned in 2006 (Inc. earth tube system) with full commissioning (with automated controls linked to both temperature and internal CO2 levels) in 2014-15
- Glazing/Fenestration – Main glazing elements completed in 2006, Temporary polycarbonate roof lights replaced with high performance solutions in 2010 (Oculi roof lights) and (central Lenticular staircase roof light).
- Virtual Daylighting Systems – Commissioning of fully automated system underway (2014-15); Upgrading of spotlights to LEDs in 2015-16
- Renewable Energy Generation - Hybrid Solar Solution (Photovoltaic thermal panels + water source heat pump) was commissioned November/December 2012
- Usage of on-site borehole water – Connected to toilets in 2006; Drinking Water treatment commissioned in 2006-07 then decommissioned due to costs of Enviro. Agency monitoring costs (for re-commissioning in 2015-16)
- Waste Water/Sewage treatment – Commissioned in 2007 (back up connection to main sewage system remains for peak loads)
- General Building Management Systems (Inc. real time displays) installed and commissioned in 2012-14

The building will continue to actively managed and optimised for its performance into the future with, in particular, some of the ongoing design and commissioning elements now being linked to design thinking regarding Phase 2 development (which includes a planned major extension to the upper level of the building).

Other key findings and conclusions

Essentially, the strengths have been pre-commissioning, whilst the weaknesses have been post-commissioning, although these are now being solved – in summary:

- Pre 2012 – aftercare, operation, maintenance and management were reactive

- Post 2012 (with Estates Department) – aftercare, operation, maintenance and management are proactive

The time lag between completion and establishing the Estates Department mean there was no effective hand over (no 'soft landing') from design & construction to operation & use – the ambitious design and construction outcomes were not effectively capitalised upon in the early operation and use phase.

Establishing the Estates Department in 2012 and the delivery of this BPE project (2012-14) have both been crucial in creating a path toward optimum operation, aftercare and maintenance of the Pines Calyx as a whole, and its various innovative features and systems.

Communication between the Estates team and the building users – both clients and the events team – will be crucial for achieving optimum operation, although as the building and its components become properly understood, backed up by properly functioning monitoring and control systems, it should be possible for building operation to become increasingly self-managing in terms of day-to-day temperature, ventilation and comfort conditions. It will be worthwhile for the Estates manager to consider the value of developing a member of staff in the role of 'Pines Calyx expert' within the Estates team, although this may be limited by budgets – the more likely option is to establish a building performance expert, covering the Pines Calyx and other buildings in the estate.

More effective supply chain relationships and improved internal technical understanding are creating a path toward optimum aftercare, operation, maintenance and management, with the objective that this will be achieved in 2015.

6 Energy use by source

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

6.1 Context for understanding energy use by source 2010-14

A number of significant changes in the Pines Calyx energy systems are set out chronologically in the table below as this provides important context for interpreting data on energy use by source, and developing an understanding of both a) the energy use by individual elements in the system, and b) the energy use of the building as a whole.

Date	Factor Relating To Energy Use By Source
Oct 2006	Building commissioned with heat and hot water supplied by heat main from gas boiler located in Pines Cottage.
Nov 2012	a) Commissioning of Hybrid Solar Solution: PVT panels + Water source heat pump b) Heat main from gas boiler to Pines Calyx turned off.
Feb 2013	Initial commissioning of energy monitoring systems
June 2013	Energy monitoring systems were optimised
Jan-Feb 2014	Plumbing failure caused flood in Pines Calyx – leading to use of energy-hungry dehumidifiers for during Jan-Feb 2014
Summer 2014	Hybrid Solar Solution re-installed and re-commissioned.

6.2 Installation and operation of the energy monitoring system

To evaluate the performance of the Pines Calyx over a period of time, historical energy data has been gathered to assess performance prior to, as well as during, this BPE project.

Prior to 2013 energy use information has been gathered from invoiced estimates and meter readings, as the Pines Calyx energy monitoring system became operational early in February 2013. Due to the relative complexity of the installed systems however, it was only in June of 2013 that we consider the monitoring system to have been properly ‘tuned’ to the energy supply systems, and therefore to be providing robust data suitable for detailed interpretation in this BPE study. Therefore we have to recognise that the conclusions we can draw regarding energy use by source are of a different order post June 2013.

Nevertheless some useful general interpretations are made within this chapter for the period prior to June 2013, as this period provides valuable insights into energy use in the Pines Calyx, that are of significant relevance to this study. Data from the period June 2013 to June 2014 has been used in the TM22 model, and is discussed later in this chapter.

The following table shows the monitored energy uses in the Pines Calyx:

Description of Monitored Energy Uses	
Lighting board	Use of lights in reception, stairs, lift, WC and WC lobby
DMC	Use of spot lights in the lower roundel
DLE	Use of spot lights in seminar room
DDDBC	Use of RGB fluorescent lights in upper and lower roundel.
Venti, Emergency lights	Use of emergency lights
Heat Pump	Electrical energy used by the heat pump
Heating Manifolds	Use of heating manifolds
Servery lights	Use of neon light in kitchen
Immersion heater	Energy of the immersion heater in the plant room
Servery Hob	It measures the use of hob in the kitchen.
Servery Oven	It measures the use of oven in the kitchen.
Earth tube fan	Energy used by the fans at the building entrance

6.3 Weather data and energy consumption

Considering energy consumption alongside weather data provides context on potential peak periods of demand, specifically in relation to heating and cooling. This is particularly relevant for the Pines Calyx as it was designed from a philosophy of 'bioclimatic' design i.e. as a building that responds to and works with varying climate conditions. For example, whilst it is approximately 20 miles from St Margaret's Bay Met Office data for Manston weather station is useful for considering general climatic variations in East Kent and shows:

- Jan-March 2013: total 176 sunlight hours / average temp: 1.4
- Jan-March 2014: total 340 sunlight hours / average temp: 4.3

  Note: timing of installation and fine-tuning of the monitoring system means we do not have irradiance data for these specific periods, when we know sunlight hours we very different.

This indicates that that in Jan-March 2013 sunlight hours were roughly half those of the 2014, and 40-50% less than might normally be expected, whilst the average temperature was also 1-2 degrees C below the average. For a building designed to take advantage of low angle sun during the winter, this is a significant factor. It will have limited passive solar gain to levels well below those expected on average for those months. With lower than average external temperatures, this would have created higher than average demand for heat energy for the Pines Calyx for those months, although the semi-earth sheltered design and high levels of insulation mean that the Pines Calyx will be less effected by low external temperatures than most buildings.

6.4 Gas

Gas was used by the Pines Calyx as the main fuel source for heat energy until November 2012, when the hybrid system of PVT (Photovoltaic Thermal) panels combined with a Water Source Heat Pump became operational, and the heat main from the gas boiler was turned off.

Gas Consumption to November 2012

The gas meter measured the gas consumption of a) the Pines Cottage, b) the Pines Office and c) the Pines Calyx as one figure to November 2012, with no details on the proportional use of gas between these three buildings.

Simple methods to estimate usage proved inaccurate: firstly, because many of the meter readings were estimates until late 2012, not measured, which may have been significantly inaccurate; secondly, because overall gas use patterns varied considerably as the Pines Cottage was occupied by different people and families at different times which could explain the conservative consumption of gas in 2011 in particular, compared to the consumption of 2012, 2013 and 2014.

Pines Cottage Occupant(s) & Number of occupants	From:	To:
Alistair Gould (1)	December 2008	April 2011
Jerome Dutton & family (4)	June 2011	March 2012
Marc Carey & family (3)	June 2012	Now

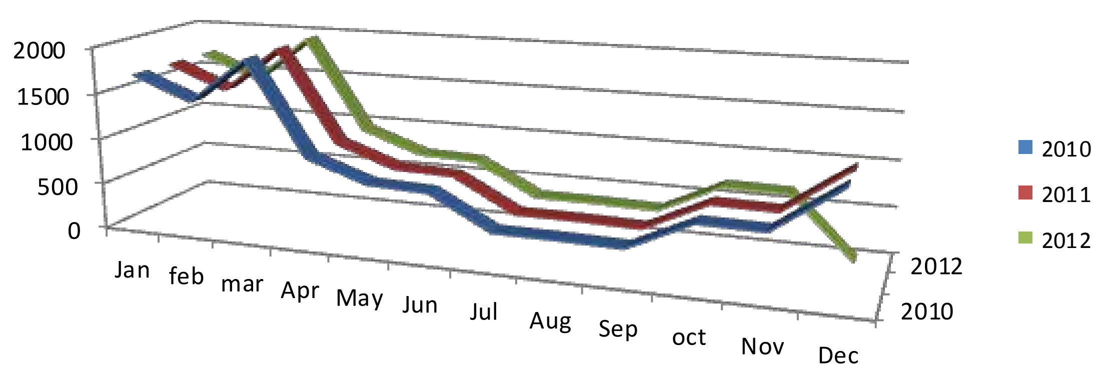
Gas consumption Pines Cottage, Office & Calyx (kWh) – showing different periods of occupation shaded					
	Estimated Readings Only			Excluding P. Calyx	
	2010	2011	2012	2013	2014
January		2254	10051	7689	5893
February		1925	9403	6901	6681
March		2584	10051	8319	5074
April		1265	2085	4948	4412
May		725	2085	2427	2773
June		702	2085	2427	1449
July		356	653	1198	
August		356	653	1292	
September		344	653	1355	
October		742	6181	3057	
November		954	3876#	4664	
December		1279	5357	5893	
TOTAL	0	13485	53133	50170	26282

Estimates of gas usage data for the Pines Calyx should be considered generally inaccurate although better informed estimates are shown in the table below, to help generate an overall energy use picture for the Pines Calyx for the period 2010-2014. Based on an understanding of variations in Pines Calyx occupancy, we are therefore making the following assumptions to arrive at reasonable estimates of Pines Calyx gas use:

- Figures for Jan-April 2011 provide a reasonable basis for approximating that at least 90% of total consumption was for the Pines Calyx's and Pines Office, and at least 80% of that consumption was for the Pines Calyx i.e. on this basis we are estimating 75% of total gas consumption for Jan-April 2011 to be Pines Calyx consumption.
- May-Sept 2011 we are assuming 100% of gas estimated usage was for the Pines Calyx;
- Oct-Dec 2011 we are assuming 90% of gas estimated usage was for the Pines Calyx.
- Dec 2012 figure assumes installation of new HSS and therefore no need for gas use.

Estimated Gas consumption of the Calyx (kWh)			
	2010	2011	2012
January	1690	1690	1690
February	1444	1444	1444
March	1938	1938	1938
April	949	949	949
May	725	725	725
June	702	702	702
July	356	356	356
August	356	356	356
September	344	344	344
October	668	668	668
November	659	659	659
December	1151	1151	0
TOTAL	10982	10982	9831

Fig 6.1: Estimated Monthly Pines Calyx Gas Consumed 2010-12



6.5 Electricity

There are several significant factors in understanding Pines Calyx electricity use variations:

- The Hybrid Solar System, including the Heat Pump became partially operational in November 2012, and fully operational in December 2012, therefore creating a major rise in electricity consumed;
- The energy monitoring system became operational in February 2013, therefore data before this date is less accurate and more generalised;
- Figures from February to June 2013 are prior to the energy monitoring system being 'tuned' to optimum operation;
- From June 2013 the energy monitoring system was operating at its optimum although two significant problems / anomalies occurred, which greatly increased electricity use during the BPE project – these are explained in this section.

Mains electricity consumption

As the Pines Calyx energy monitoring system became operational during February 2013, the following table of monthly Pines Calyx mains electricity use, draws on two sources:

- January 2010 to February 2013: invoiced metered energy use from electricity suppliers
- February 2013 to present: data from the monitoring system via Thompson Ellis website

The following table and graphs represent all the electricity that the Calyx consumed a) annually and b) each month in kWh, and do not include the electricity produced by the solar panels as it is supplied to the grid for sale, although generated electricity is accounted for later in this chapter as a relevant energy output.

Fig 6.2: Annual electricity consumption (kWh)

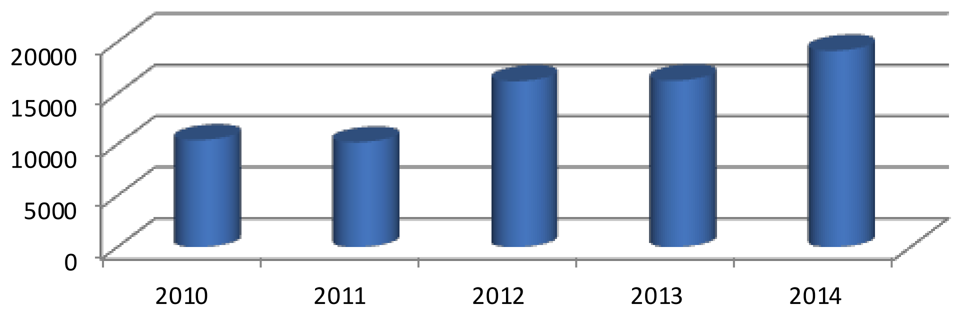
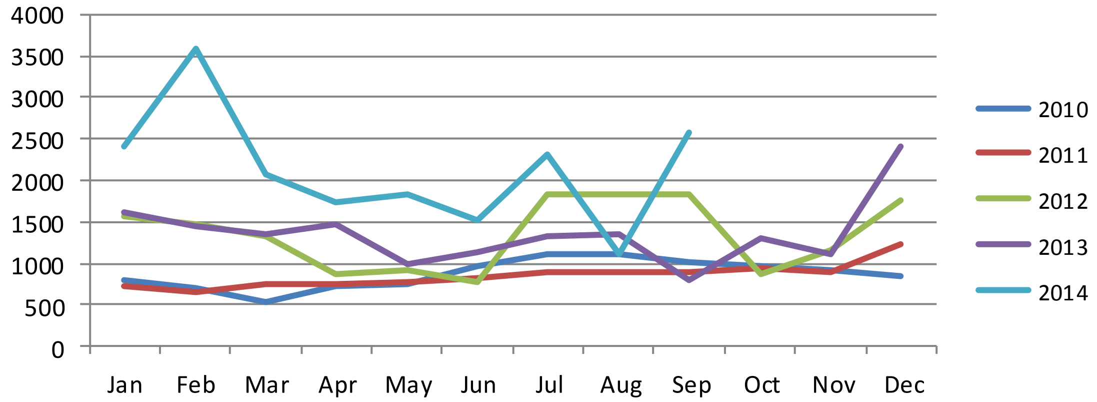


Fig 6.3: Mains electricity Pines Calyx by month (kWh)



Mains electricity (in kWh)	2010	2011	2012	2013	2014
January	800	724	1569	1622	2406
February	700	654	1468	1438	3598
March	528	758	1314	1347	2067
April	721	749	879	1473	1726
May	745	774	909	988	1831
June	972	811	762	1129	1522
July	1116	888	1834	1316	2303
August	1116	888	1834	1351	1119
September	1006	884	1834	785	2588
October	953	933	868	1305	
November	923	903	1149*	1099	
December	842	1241	1767*	2406	
TOTAL	10422	10207	16187	16259	13194
Note : * Hybrid Solar System became operational November (partially) and December 2012 (fully)					

General observations from the above data are as follows:

- 2010 and 2011 show consistent low mains electricity use, relative to the overall 2010-14 picture, as gas was the energy source providing space heating at that time;
- January-March in 2012 and 2013 show significant rises (around 100%) compared to the same months in 2010 and 2011;
- In 2012, following a steady January-June decline in line with seasonal demand, there is a sharp rise (140%) during June to September with exactly equal consumption shown over those 3 months (assumed as an averaged estimate), before falling to typical levels in October, with a rise in November and December above historic levels in previous years – the point at which the HSS was operational, with heat from gas turned off;
- 2013 is broadly similar to 2012 but without a significantly summer anomaly, although July and August figures are relatively high, with a very sharp rise in December;
- 2014 figures are significantly above previous years for the first half of the year, with a major spike in January, February and March, as well as peaks in July and September.

These observations are discussed in more detail in the following sections, with explanations for major variations being provided.

Total Electricity Consumption in 2012

Jan-March 2012 temperatures were lower than average (not as low as 2010 or 2013), with February 2012 was particularly cold at an average temperature of just 0.6 deg C. The below average external temperatures may clearly be a factor in higher energy use in early 2012 compared with 2010 and 2011.

We do not have information to explain the rise in consumption during the summer 2012 since there is no data on electrical consumption from specific uses at that time, as the monitoring system had not been installed. However, comparison with March to May 2014 data shows similar consumption levels, suggesting there may have been consistent use of the immersion heater during this time in 2012 (as happened in 2014), to provide consistent hot water for the summer wedding season – however this is speculation.

The consumption is significantly higher from late in 2012 because the heat pump was installed during the summer of 2012 and became operational in November 2012. From then on the use of gas was made obsolete and heat was created solely by the use of the HSS. A 65% rise in electricity consumption from November to December 2012 reflects the fact that the HSS was only operational during part of November because system modifications were made between 5th and 13th November after initial commissioning, with final snagging of the HSS system on 30th November 2013. Therefore from December 2012 we can consider the HSS system to be fully operational, although more light will be shed on this later in this section.

The speculative element of assessing electricity use in 2012 provides contrast with the more detailed and accurate data provided by the monitoring system – and emphasises the value of the latter.

Total Electricity Consumption in 2013

January to March 2013 was consistently very cold, and with very low sunlight hours, which for a building designed to take advantage of passive solar gain is a significant factor. This provides a reasonable partial explanation for higher in electrical demand during this period compared to previous years, followed by a significant fall off in demand.

There was in a rise in the electrical consumption in December 2013 which is explained by the heat pump coming fully into operation during this month: the Heat Pump consumed 1050 kWh of 2406 kWh in total for December. This is double the 552 kWh that was used by the heat pump in November 2013 as only one out of two pumps had been working in November, so some snagging of the newly installed system took place in November.

Monitored Energy Uses	
December 2013	**kWh**
Lighting board	33.9
DMC (LR spotlights)	5.1
DLE (SRm spotlights)	22.7
DDDBC (Flourescents)	34.8
Venti, Emer	73.5
Heat Pump	1050.0
Heating manifolds	19.2
Servery lights	23.6
Immersion	0.9
Servery Hob	28.2
Servery Oven	33.8
Earth tube fan	10.0
Total of Monitored Use	1335.7
Main Power	2406
Unmonitored Use	1070

External-Internal Temperatures	**November 2013**	**December 2013**
Average external temperature	8.71°C	8.70 °C

Average temperature in lower roundel	18.24°C	18.74°C

Of the 2406 kWh consumed in December, 55% (1335.7 kWh) is from monitored sources. This suggests that 45% (1070kW) of consumption was a) due to other activities or non-monitored appliances/uses, or b) that there is some anomaly in the monitoring equipment, or c) possibly both.

In Dec 2013 the heat pump appears to have consumed half of the amount it should consume in one year. We also noticed that the output of the heat pump never exceeded 6 kW whereas it is supposed to have a capacity of 12 kW – this indicates that one of the two heat pumps was not working, which explains the lack of performance of the system. Subsequently repairs and alterations to the heat pump were carried out with the system effectively re-installed in August 2014.

Total Electricity Consumption in 2014

A large rise in electricity consumption in January and February 2014 was due to a flood caused by a plumbing failure in the building on 14th January, which required energy-hungry dehumidifiers to be used to remove the excess damp in the walls and floor from the 14th January until the 21st February. As all other activity was stopped in the building from the 14th of January until the 7th of February (because the building was not fit for use for conferences etc.), the electricity consumed during this period was therefore dominated by the unmonitored consumption of the dehumidifiers.

The March to May 2014 consumption was still very high. Our search for an explanation led us to conclude that the heat pump had not been working correctly since February 2014, therefore the system was turned off in April. As the heat pump system is also responsible drawing on the thermal outputs of the panels, the panels also did not provide hot water during this period. As a result, the immersion heater, which was supposed to be a back-up support for hot water supply, had in fact been the sole source of all hot water supply in the building from the 11th of April 2014 - hence the high consumption. This explanation was confirmed in August when Newform Energy investigated the functioning of the heat pump. As a result they have also initiated a follow-up and aftercare programme for all their new installations.

From the consumption data (shown on the following pages) it is clear that the immersion heater was the most energy- hungry device in May 2014. In February, only 650 kWh was consumed by the main devices (a confirmation that activity was halted) and we can reasonably assume that the dehumidifiers consumed the majority of the 2948 kWh difference (i.e. 3598-650), with a small amount of usage from other appliances that month. In May 2014 the 740kW for unmonitored usage is mainly from appliances etc. i.e. fridges, freezer, dishwasher, cleaning, projector, laptops etc.

The following graphs show a major difference in the use of the immersion heater in May 2013 and May 2014 (note the difference of the immersion heating scale on the right).

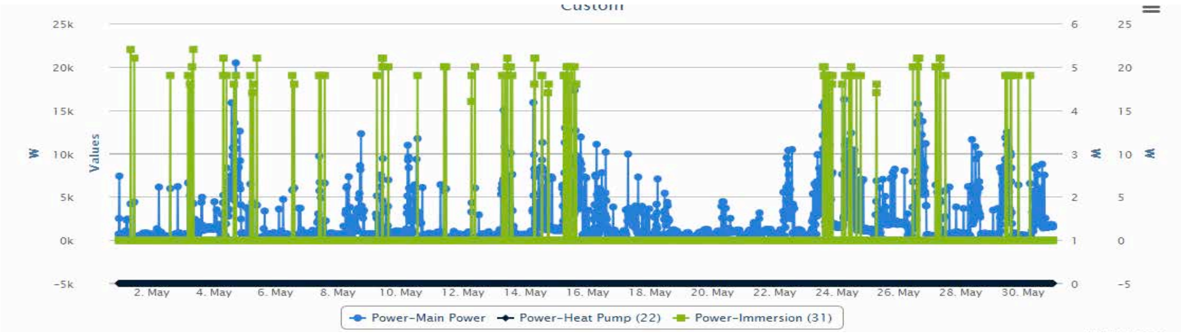


Fig 6.4: May 2013 mains Power (light blue) and immersion (green)

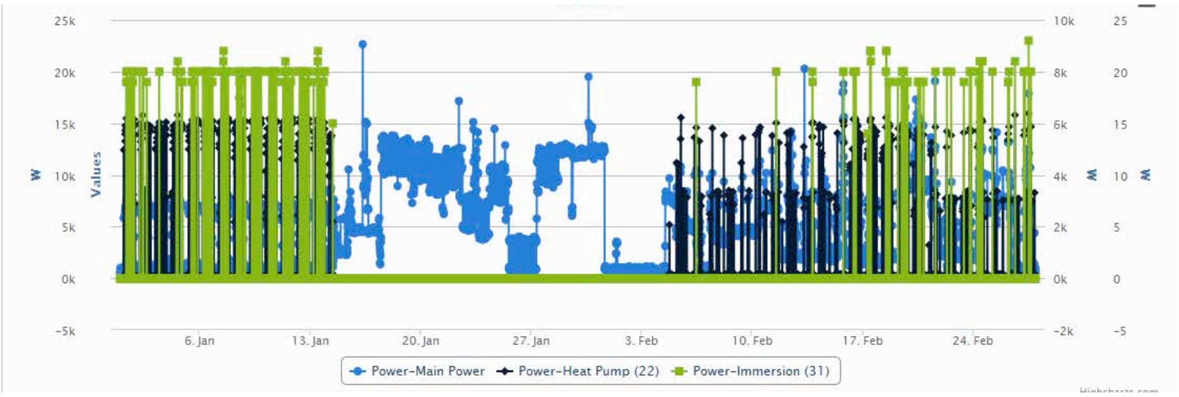


Fig 6.5: January and February 2014 Mains Electricity (light blue), Power Immersion (green) and Power Heat Pump (dark blue)

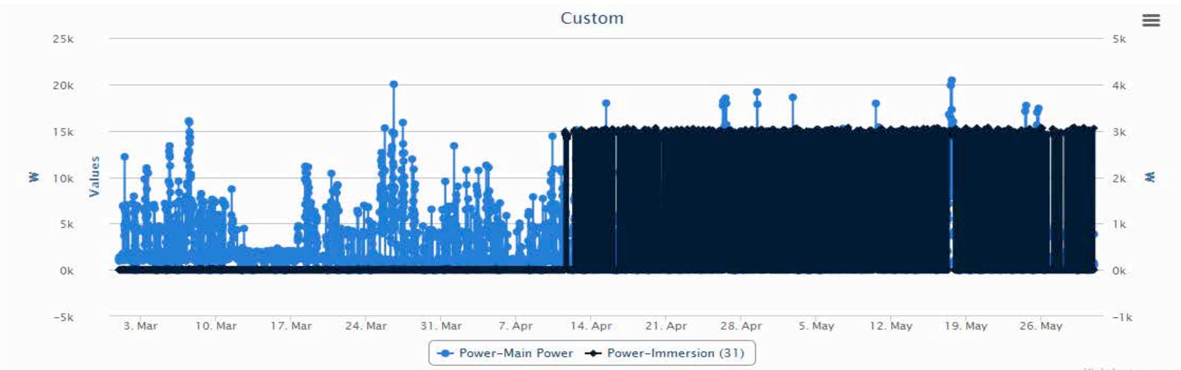


Fig 6.6: March to May 2014 Mains Power (light-blue/left scale) and Immersion (dark blue/right scale) – with constant use of immersion from mid-April (i.e. Heat Pump was off).

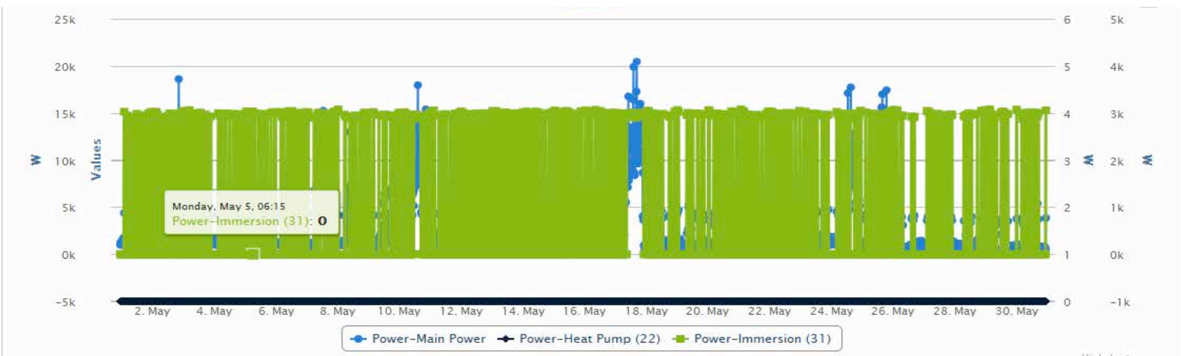


Fig 6.7: May 2014 Mains Power (light blue) and immersion (green)

February 2014	(kWh)
Lighting board	66.8
DMC (LR spotlights)	3.0
DLE (SRm spotlights)	4.2
DDDBC (Flourescents)	93.6
Venti, Emer	36.7
Heat Pump	356.0
Heating manifolds	9.2
Servery lights	31.7
Immersion heater	0.3
Servery Hob	15.0
Servery Oven	25.0
Earth tube fan	9.0
Total	650.5
Main Power	3598
Unmonitored use	2948

May 2014	(kWh)
Lighting board	120.0
DMC (LR spotlights)	8.8
DLE (SRm spotlights)	17.8
DDDBC (Flourescents)	154.0
Venti, Emer	53.0
Heat Pump	0.0
Heating manifolds	0.0
Servery lights	59.4
Immersion heater	492.9
Servery Hob	45.7
Servery Oven	46.0
Earth tube fan	11.0
Total	1008.6
Main Power	1748
Unmonitored use	740

Above: distribution of the consumption between different devices in February and May 2014

A potential lesson here, is not monitoring each individual element which would prove costly, but a common point such as a plug in power distribution board, similar to the lighting board. This would account for a significant portion of the unmonitored load found.

Further analysis of electricity and overall energy use follows later in section 6.10 where TM22 data is assessed.

6.6 Solar Panels Outputs

Since the monitoring system was installed we have accurate data of the solar panels' electrical output since February 2013, with less reliable data from its installation in July 2012. These figures of course do not take into account the thermal contribution of the panels (estimated at 847kWh).

The 12 months from June 2013 to June 2014 shows an output of 2343kWh, compared with the predicted output potential of 4104kWh[15] i.e. 57%.

This difference is primarily explained by the siting of the panels, which includes significant shading of the array during the afternoon - this is the result of sensitive location and planning restrictions in the Kent Downs AONB in which the Pines Calyx is located. Obviously this limitation on the PV element of the system has a significant influence on payback[16], although the Heat Pump element of the HSS provides greater net benefit when the HSS is considered as a whole system.

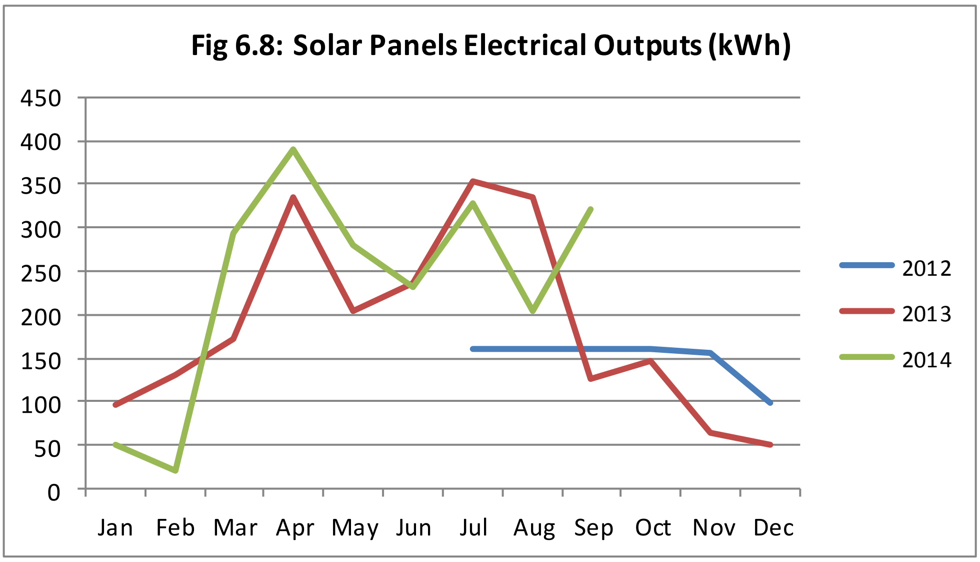
[15] Post-Project-Review HSS word spreadsheet

[16] The initial assessment for HSS did not account for this shading – the consultant assumed that trees would be crowned or felled. However, a later assessment carried out by the Estates Manager illustrated three scenarios acknowledging the possibility of 15/20 and 35% losses – PVT Estimate (1).xls

The considered exported energy is taken as 50% in line with export guidelines from Department of Energy and Climate Change. Once Smart Metering is in place the export of energy from PV element of PV system will likely change.

PVT Electrical Outputs (kWh)	2012	2013	2014
January		97	51
February		130	20
March		173	293
April		336	389
May		204	281
June		237	232
July	#161	353	327
August	#161	334	205
September	#161	127	321
October	#161	146	
November	156	64	
December	98	51	
TOTAL	898	2252	2119

Note: # averaged figure from 4 months output



Clearly any possibility of improving the siting of the panels to increase their output should be considered if feasible within a planning context.

Currently the thermal contribution of the panels is not measured in terms of the volume and temperature of the hot water used in the building – this is clearly an important consideration for future improvements in our energy monitoring systems i.e. it needs to be measured and monitored.

6.7 Heat Recovery Ventilation System

The objectives of the monitoring exercise relating to the earth tube included to determine the cooling and heating effects of the earth tube itself, and to compare the power of these effects with the power being used to drive the fans.

In terms of energy consumption, the design intention was that the earth tube would be a core component of an energy efficient ventilation system to pre-heat fresh air in winter and pre-cool fresh air in summer. The heating and cooling effect of the earth tube can be calculated as follows.

Mean velocity x Area = flow rate:

- 1.5m/s x 0.28 m^2 = 0.42 m^3/s

Density x flow rate = mass/sec (Density of air = 1.2kg/m^3):

- 1.2 x 0.42 = 0.5kg/s (Specific heat capacity of air = 1.0 kJ/kg K)
- If dt = 3 degrees K, then 3 x 0.5 = 1500 J/s = 1500 W of cooling (when dt = 3 degrees K).

Each DC fan has a power rating of 21W. Allowing for both intake and extract fans the total power rating is therefore 42W. However, measured power levels from the CT meters indicates a maximum power consumption by the fans of 16W and an average of 14W.

The net energy gain from the earth tube is therefore highly significant and the power consumed by the fans negligible in comparison: 500W for each degree K raised or lowered, compared to an average of 14W of power expended. This is a significant finding, enabling us to conclude that despite the fact that the system has not been properly commissioned or balanced it has been working extremely well. Although this detail is relatively theoretical at this time, based on current data, it is proposed that further research will be undertaken to provide details on actual performance.

6.8 Total Energy Consumption

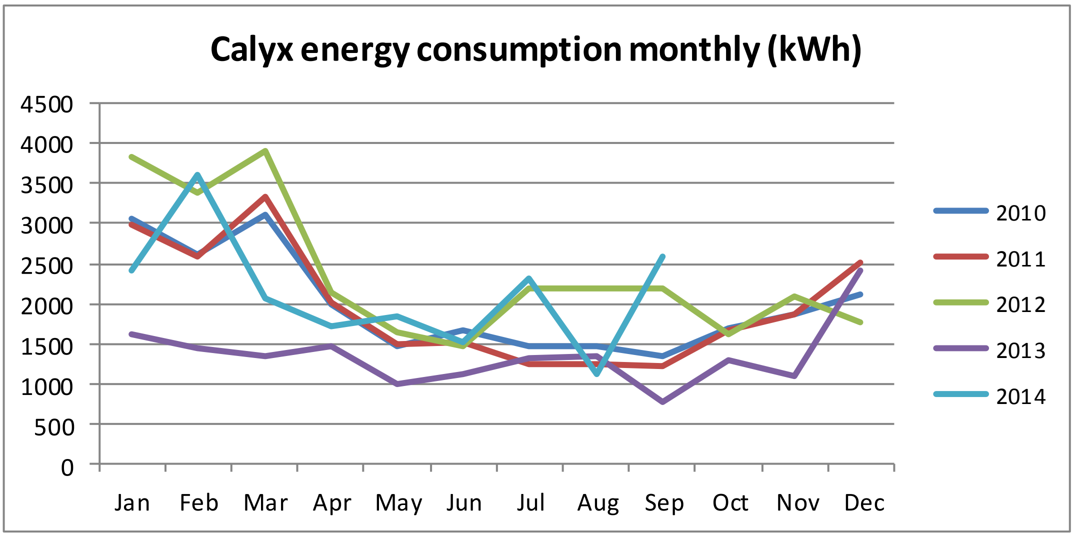
To calculate the overall consumption of energy of the Pines Calyx, we are considering two periods to generate: a) an historical picture (starting pre BPE project and monitoring) for 2010-2014; b) a recent picture for the year June 2013-June 2014 (during BPE project and monitoring), with the latter period considered in the subsequent section using TM22 model.

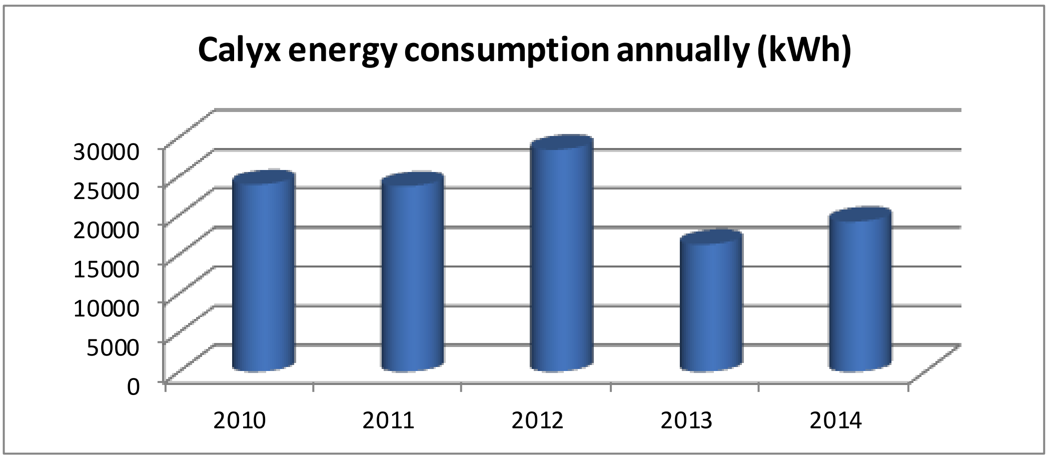
Total consumption (kWh)	2010	2011	2012	2013	2014
January	3054	2978	3823	1622	2406
February	2625	2579	3393	1438	3598
March	3112	3342	3898	1347	2067
April	1986	2014	2144	1473	1726
May	1470	1499	1634	988	1831
June	1674	1513	1464	1129	1522
July	1472	1244	2190	1316	2303
August	1472	1244	2190	1351	1119
September	1350	1228	2178	785	2588

October	1695	1675	1610	1305	
November	1877	1857	2103	1099	
December	2121	2520	1767	2406	
TOTAL	23908	23693	28394	16259	19160

The historical picture to November 2012 is generated by adding the gas and the electricity consumption together. The data below does not include the solar panels outputs as it is not part of the consumption.

Fig 6.9: Total energy consumption





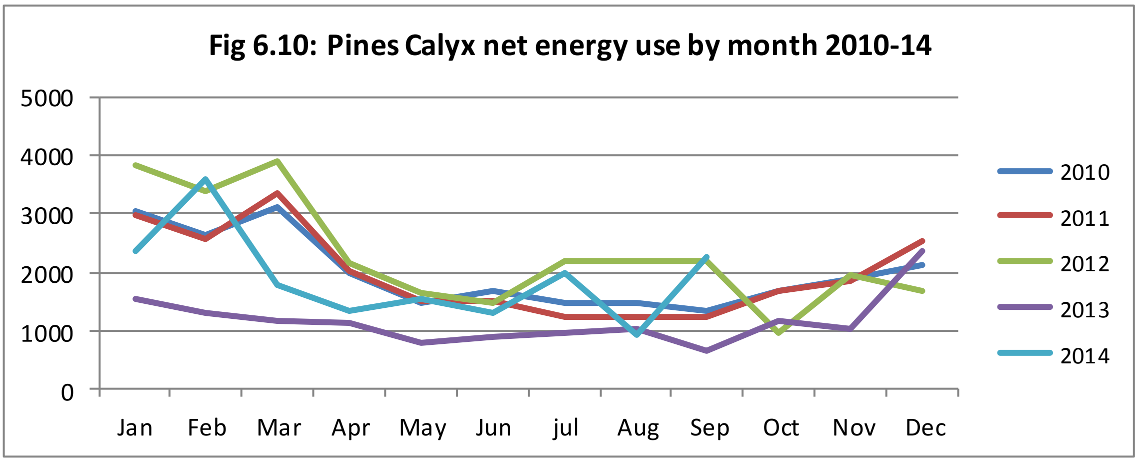
6.9 Net Energy Consumption Including Generation From PVT Panels

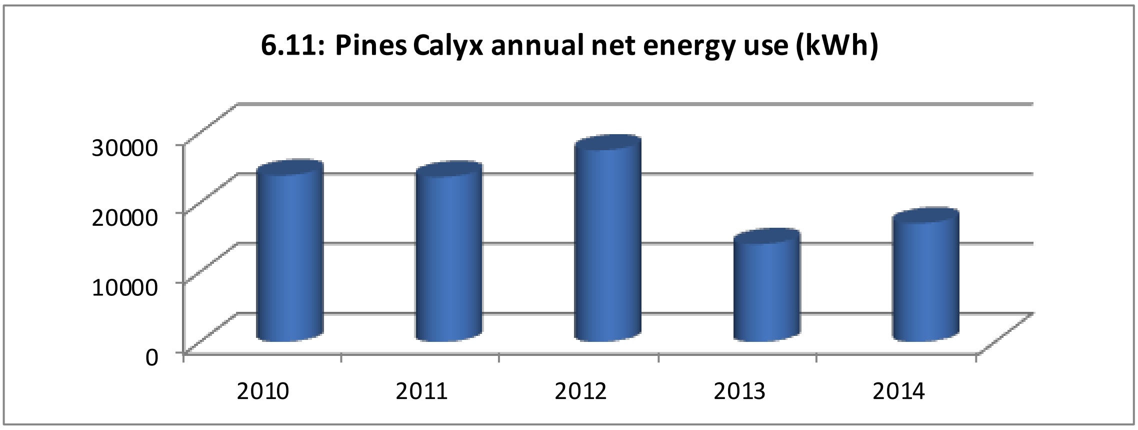
To show the impact of the PVT system we have subtracted the electricity produced by the Solar Panels from the overall energy consumption of the Calyx. We still cannot take into account the thermal contribution as it is not currently measured.

The following table and graphs show a significant reduction in overall energy consumption from 2012 to 2013 and 2014, although the figure for 2014 is significantly above 2013.

We cannot reasonably assess 2014 as a whole unless we a) have additional data, or b) can make reasonable estimates of consumption for the rest of the year. To generate estimates we can take account of HSS working properly post May 2014, when the Immersion was not being used continuously – although data for September 2014 indicates high usage again, due to use of the immersion heater again whilst the HSS system was being recommissioned.

Net energy use of the Pines Calyx (kWh)	2010	2011	2012	2013	2014
January	3054	2978	3823	1525	2355
February	2625	2579	3393	1308	3578
March	3112	3342	3898	1174	1774
April	1986	2014	2144	1137	1337
May	1470	1499	1634	784	1550
June	1674	1513	1464	892	1290
July	1472	1244	2190	963	1976
August	1472	1244	2190	1017	914
September	1350	1228	2178	658	2267
October	1695	1675	966	1159	
November	1877	1857	1947	1035	
December	2121	2520	1669	2355	
TOTAL	23908	23693	27496	14007	17041





6.10 TM22 Data and findings

There has naturally been a significant learning curve for Trust staff, and a volunteer, in terms of inputting, interpreting and taking advantage of the data that TM22 provides. We are still on that learning curve and plan to continue to use TM22, to generate a deeper understanding of the Pines Calyx energy use, energy efficiency and carbon emissions using this tool.

Data has been input to TM22 for the year from 1/6/2013 to 1/6/2014. The following pages set out key TM22 outputs of the Simple and Detailed Assessments, namely:

- Energy consumption and carbon emissions excluding renewables (Simple Assessment);
- Building energy efficiency, with fossil fuel equivalent energy consumption and generation, and carbon emissions (Simple Assessment);
- The breakdown of energy demand by use, and overall building energy use (Detailed Assessment);
- The breakdown of carbon emissions by use, and building carbon emissions (Detailed Assessment);

It should be noted that:

- *there are differences in the headline figures provided by the Simple and Detailed Assessments as follows:*

	Carbon Emissions (kgCO$_2$/m^2/yr)	***Energy Use (kWh/m^2/yr)***
Simple Assessment	*38*	*75.2*
Detailed Assessment	*47.9*	*87*

- ***we have a high degree of confidence in the accuracy of the Simple Assessments in terms of headline electricity usage, heat energy usage and renewable energy generated;***

- ***we have less confidence in the figures in the Detailed Assessment due to difference between metered energy use and total energy use, and the estimation of usage profiles of energy using items in the 'In-use' section of TM22, when the usage of the Pines Calyx and those energy using items was very variable during the year.***

- *with limited time and expertise to understand the divergences in figures, and the need to prioritise completion of this report, we have not had the time or staff capacity to understand the differences at this time, although we plan to do so in the future. Our intention is to deepen our understanding in all areas, including the use of the TM22, in order to further improve both Pines Calyx energy use / carbon emission and the accuracy and value of our use of the TM22 tool and the energy monitoring system.*

The key outputs from the Simple Assessment provide a good overall picture of actual energy use and carbon emissions for the Pines Calyx for the year to 1/6/2014. We know that these in-use performance figures include two specific anomalies in energy use during this 12 month period – namely:

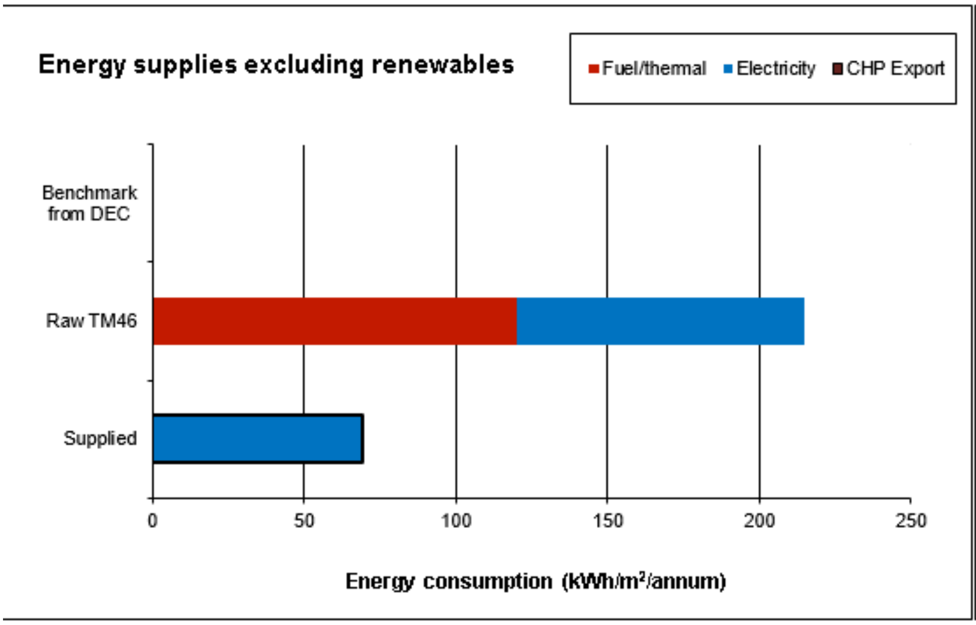
a) the extended use of dehumidifiers to dry the building out after the flood;
b) the extended use of the immersion heater when the heat pumps were not working and turned off.

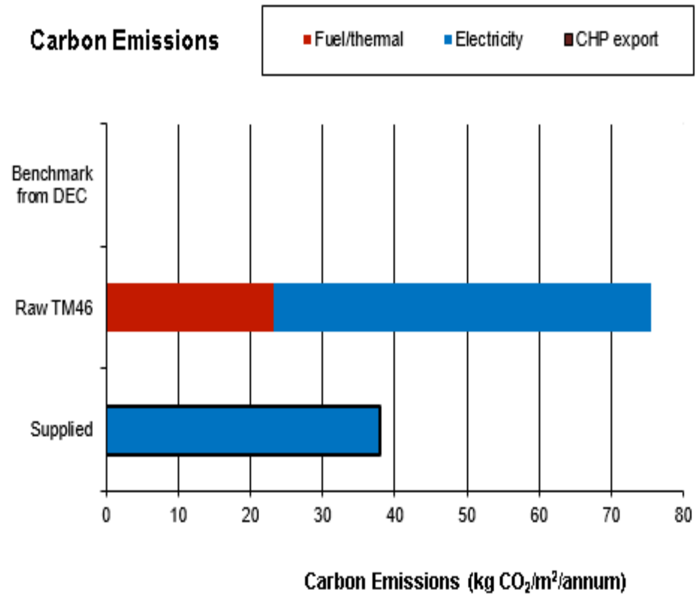
We know that this does not represent optimum energy use and carbon emissions, and that we have to work to reduce energy consumption in order to fully judge the success of the building design. In the meantime the TM22 model provides a very valuable analysis tool.

ASSESSMENT ACCOUNTING FOR SEPARABLE ENERGY USES

Absolute values	Energy supplied (kWh)		Carbon dioxide emissions (kg CO_2)		
	Fuel/thermal	Electricity	Fuel/thermal	Electricity	TOTAL
Separables	0	0	0	0	0
Supplied less separables	0	21,183	0	11,651	11,651
Exported CHP	0		0		

Unit values	Energy supplied (kWh/m^{2}TADA)		Carbon dioxide emissions (kg CO_2/m^2 TADA)		
	Fuel/thermal	Electricity	Fuel/thermal	Electricity	TOTAL
Separables	0.0	0.0	0.0	0.0	0.0
Supplied less separables	0.0	69.1	0.0	38.0	38.0
Raw TM46	120.0	95.0	23.3	52.3	75.5
User Specified	0.0	0.0	0.0	0.0	0.0
Exported CHP	0.0		0.0		
Benchmark from DEC	0.0	0.0	0.0	0.0	0.0





CO_2 factors used in assessment:	kg CO_2 /kWh
Electricity (grid)	0.55
Renewable electricity	0
Solar thermal	0.1447

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

These tables and graphs indicate the simple assessment of energy supplied to the Pines Calyx at 69.1kWh / m²/year (of grid electricity) and related carbon emissions, excluding the Pines Calyx's renewable energy systems.

This does not give us an overall picture of the building's energy use as heat energy supply from the heat pump and solar thermal element of the PVT is not included as it is not externally supplied.

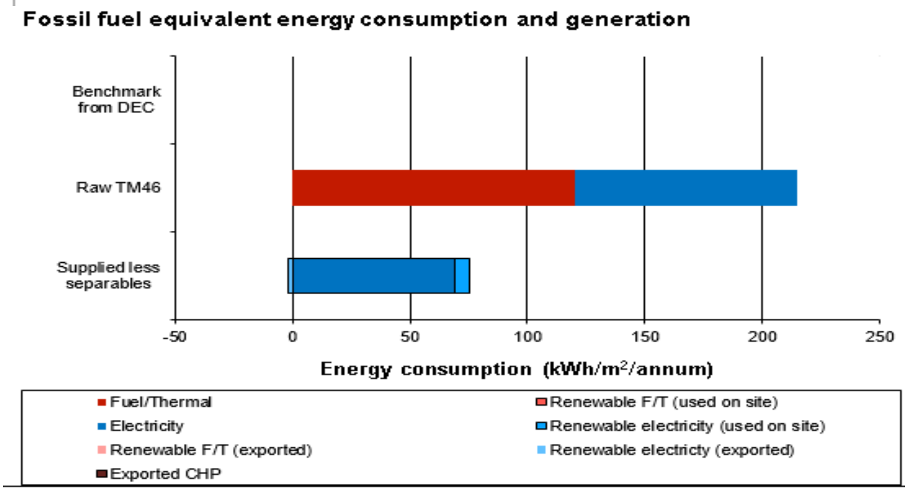
They indicate a carbon emissions figure for the building of 38 kg CO_2 /m²/year

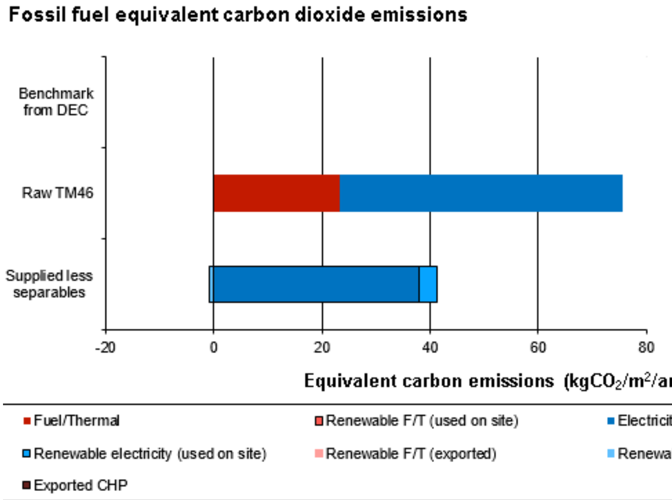
The building has not had a DEC. It has a CEPC – so data from DEC is omitted.

BUILDING ENERGY EFFICIENCY

Absolute values	Fossil Fuel Equivalent Energy supplied (kWh)		Fossil Fuel Equivalent Carbon dioxide emissions (kg CO_2)		
	Fuel/thermal	Electricity	Fuel/thermal	Electricity	TOTAL
Supplied less separables	0	21,183	0	11,651	11,651
Renewables (used on site)	0	1,857	0	1,021	1,021
Renewables (exported)	0	-506	0	-278	-278
Exported CHP	0		0		

Unit values	Fossil fuel equivalent energy (kWh/m^2TADA)		Fossil fuel equivalent CO2 (kg CO_2/m^2 TADA)		
	Fuel/thermal	Electricity	Fuel/thermal	Electricity	TOTAL
Supplied less separables	0.0	69.1	0.0	38.0	38.0
Renewables (used on site)	0.0	6.1	0.0	3.3	3.3
Renewables (exported)	0.0	-1.7	0.0	-0.9	-0.9
Exported CHP	0.0		0.0		
Raw TM46	120.0	95.0	23.3	52.3	75.5
User Specified	0.0	0.0	0.0	0.0	0.0
Benchmark from DEC	0.0	0.0	0.0	0.0	0.0





CO_2 factors used in assessment:	kg CO_2 /kWh
Electricity (grid)	0.55
Fuel use	0
Heat use	0.000

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

These tables and graphs indicate the simple assessment of the Pines Calyx's energy performance taking into account renewable energy generation.

Totalling the heat and electrical energy used by the Pines Calyx gives a total figure of 75.2kWh/m^2/year (69.1 + 6.1) - an important headline figure for Pines Calyx energy use, in terms of energy efficiency targets.

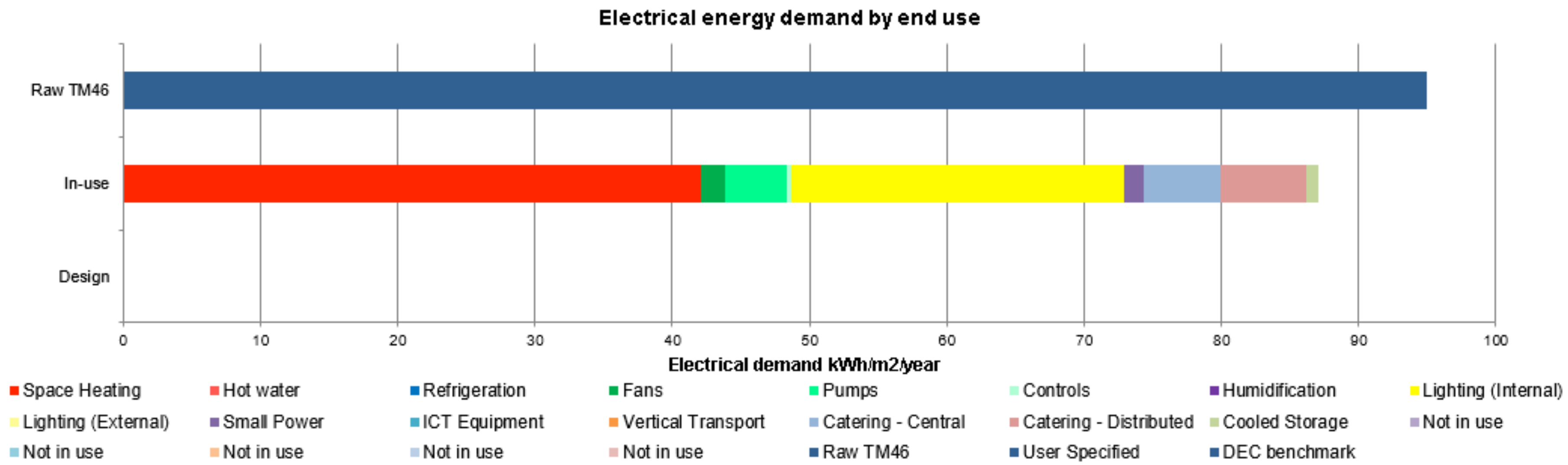
The associated headline carbon emissions figure is 41.3 kg CO_2 /m^2/year, (38 + 3.3).

ENERGY DEMAND (kWh/m²/year)

System	Description	Heat demand (kWh/m2/year) Design (kWh/m2/year)	Heat demand In-Use (kWh/m2/year)	Electricity demand (kWh/m2/year) Design electricity (kWh/m2/year)	Electricity demand In-use electricity (kWh/m2/year)	Additional metrics for electricity demand In-use electricity (kWh/year)	In-use % of total	In-Use Full load W/m2	System hours/year	Utilisation
Space Heating		0.0	0.0	0.0	42.1	12,895	48.3%	12.0	3,504	40.0%
Fans		0.0	0.0	0.0	1.8	561	2.1%	0.5	3,504	40.0%
Pumps		0.0	0.0	0.0	4.4	1,359	5.1%	2.2	2,022	23.1%
Controls		0.0	0.0	0.0	0.3	93	0.3%	5.5	55	0.6%
Lighting (Internal)		0.0	0.0	0.0	24.3	7,439	27.9%	69.3	350	4.0%
Small Power		0.0	0.0	0.0	1.5	452	1.7%	10.5	141	1.6%
Vertical Transport		0.0	0.0	0.0	0.0	6	0.0%	0.2	117	1.3%
Catering - Central		0.0	0.0	0.0	5.6	1,706	6.4%	20.1	277	3.2%
Catering - Distributed		0.0	0.0	0.0	6.2	1,911	7.2%	18.5	337	3.9%
Cooled Storage		0.0	0.0	0.0	0.9	263	1.0%	0.1	8,760	100.0%
Total		**0.0**	**0.0**	**0.0**	**87.0**	**26,683**	100.0%	**138.9**		
Metered building energy use			0.0		75.2	23,040				
Variance TM22 versus metered total			0.0		11.9	3,643		**Building GIA:**	307	
Variance TM22 versus metered total			#DIV/0!		16%	16%				

Whole building benchmarks

	Energy demand (kWh/m²GIA) Heat	Electricity
Raw TM46	96.0	95.0



We are not yet confident that this detailed assessment provides an accurate picture of the breakdown of Pines Calyx energy use, although we are confident that it provides a reasonable general picture, which can be refined to be more accurate as we develop more expertise in working with the monitoring data and the TM22 tool.

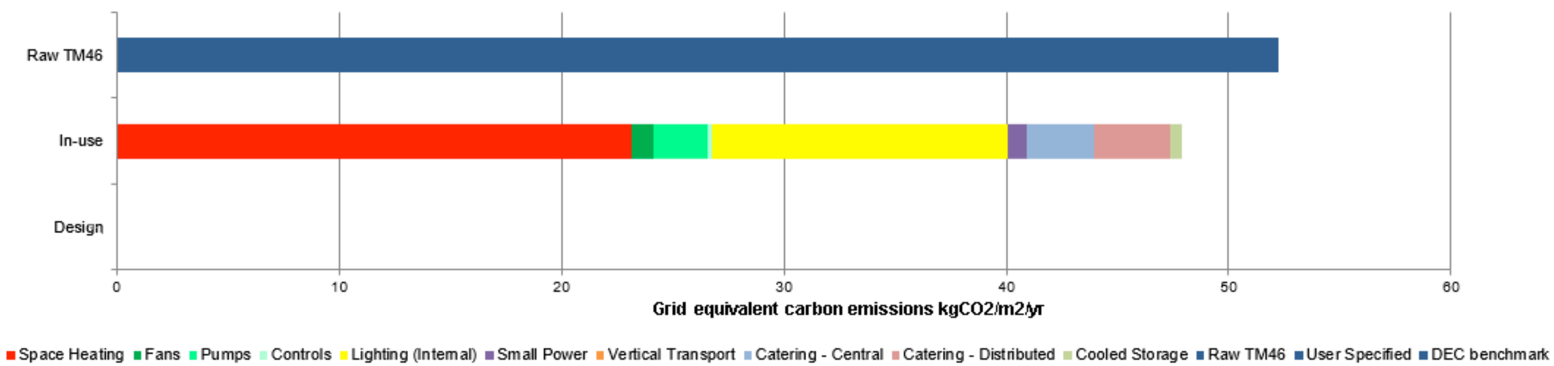
CARBON EMISSIONS (kgCO_2/m^2/year)

System	Description	Fuel /Thermal (kgCO2/m2/year) Design Fuel/Thermal equivalent emissions	Fuel /Thermal (kgCO2/m2/year) In-use Fuel/Thermal equivalent emissions	Electricity (kgCO2/m2/year) Design grid equivalent emissions	Electricity (kgCO2/m2/year) In-use grid equivalent emissions	Total carbon emissions Design total equivalent emissions	Total carbon emissions In-Use total equivalent emissions
Space Heating		0.0	0.0	0.0	23.1	0.0	23.1
Fans		0.0	0.0	0.0	1.0	0.0	1.0
Pumps		0.0	0.0	0.0	2.4	0.0	2.4
Controls		0.0	0.0	0.0	0.2	0.0	0.2
Lighting (Internal)		0.0	0.0	0.0	13.3	0.0	13.3
Small Power		0.0	0.0	0.0	0.8	0.0	0.8
Vertical Transport		0.0	0.0	0.0	0.0	0.0	0.0
Catering - Central		0.0	0.0	0.0	3.1	0.0	3.1
Catering - Distributed		0.0	0.0	0.0	3.4	0.0	3.4
Cooled Storage		0.0	0.0	0.0	0.5	0.0	0.5
Total		**0.0**	**0.0**	**0.0**	**47.9**	**0.0**	**47.9**

Whole building benchmarks

	Fossil fuel / grid equivalent carbon emissions (kgCO_2/m^2 GIA) Heat	Fossil fuel / grid equivalent carbon emissions (kgCO_2/m^2 GIA) Electricity
Raw TM46	23.3	52.3

Grid equivalent electrical carbon emissions by end use



We are not yet confident that this represents an accurate picture of the breakdown of Pines Calyx carbon emissions, although we are confident that it provides a reasonable general picture, which can be refined to be more accurate as we develop more expertise in working with the monitoring data and the TM22 tool.

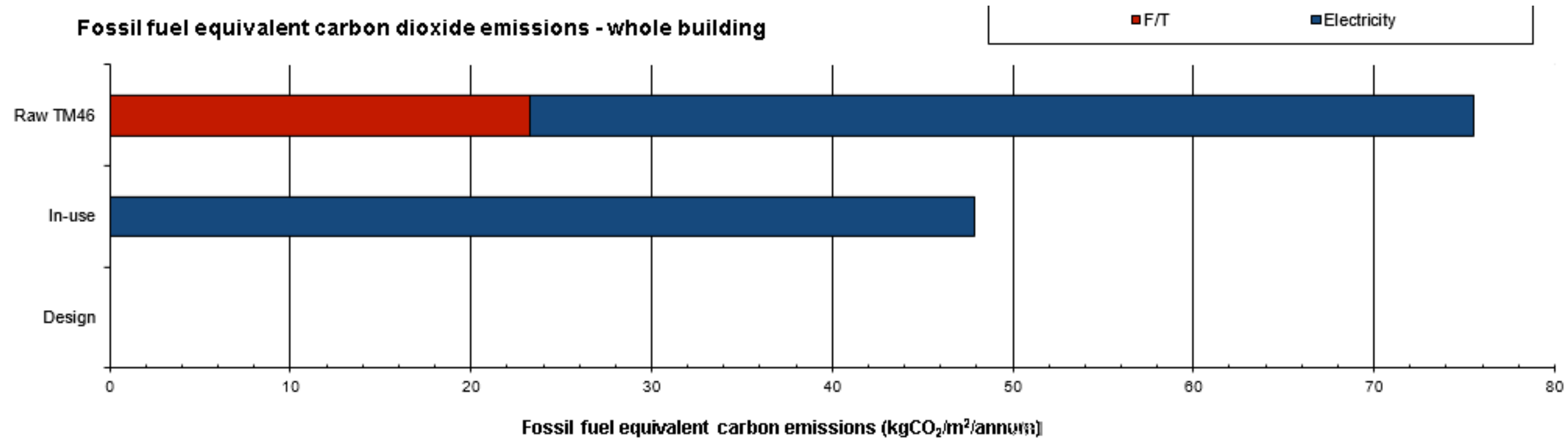
WHOLE BUILDING FOSSIL FUEL EQUIVALENT CARBON EMISSIONS (kWh/m^2/year)

	Carbon dioxide emissions (kgCO_2/m^2 GIA)			
	Design		In-use	
	Fuel/thermal	Electricity	Fuel/thermal	Electricity
Total	0.0	0.0	0.0	47.9

Information about TM22 methodology:

These results present the fossil fuel and grid electricity equivalent carbon emissions of the whole building.

The data represents the total energy demand of the building - energy supplied by renewables or CHP which is used in the building is therefore included in the totals



We are not yet confident that this detailed assessment provides an accurate picture of the Pines Calyx fossil fuel equivalent carbon emissions, although we are confident that it provides a reasonable general picture, which can be refined to be more accurate as we develop more expertise in working with the monitoring data and the TM22 tool.

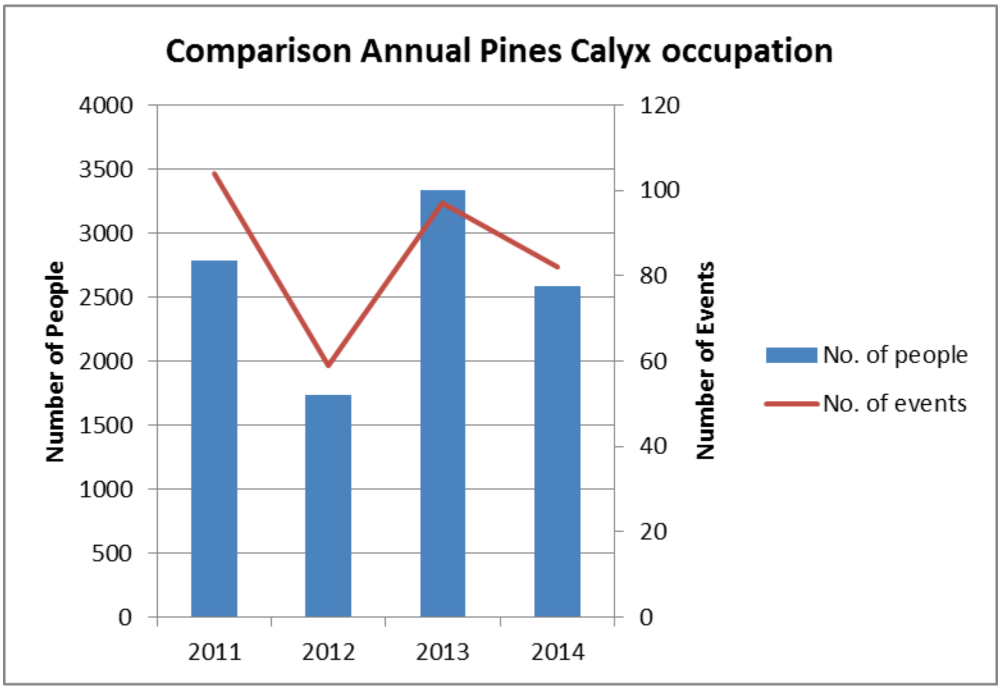
To take full advantage of a) the data provided by the monitoring system and b) the outputs of the TM22 model, we know we need to do more work in two particular areas:

1. We need to improve the efficiency of the building's energy use by tackling:
    a. technical issues;
    b. user understanding to improve operation of the building;
2. Improve our familiarity with the monitoring data and TM22 tool in order to generate more detailed and more valuable understanding and interpretation of the data to know:
    a. how the building and its elements are functioning;
    b. how to further improve the building's performance.

To provide ourselves with a realistic target for 2015, and to attempt to judge the in-use performance of the Pines Calyx compared with the as designed performance objectives, *without* the anomalous energy uses, we can work with these tools to estimate the net additional energy consumption associated with these anomalies, and take that off actual energy use to produce an estimate for the year to 1/6/2014 of what energy use would have been without the anomalies. This approach to estimating Pines Calyx energy without anomalous energy use, alongside referring back to 2013 energy use, will give us a clear target for improving energy and carbon performance in 2015.

6.11 Energy use compared to events and user numbers

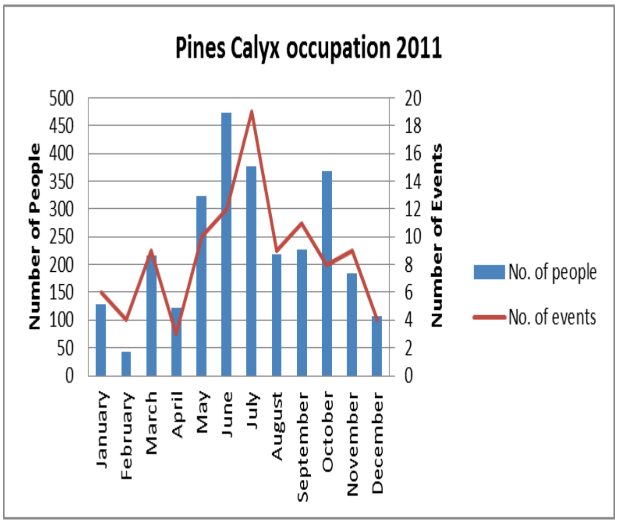
Additional context comes from considering the correlation between the energy consumption of the Calyx and the building's occupation, because a) the building is a conference and events venue, and b) it was designed to take account of significant variations in heat gains from occupants.

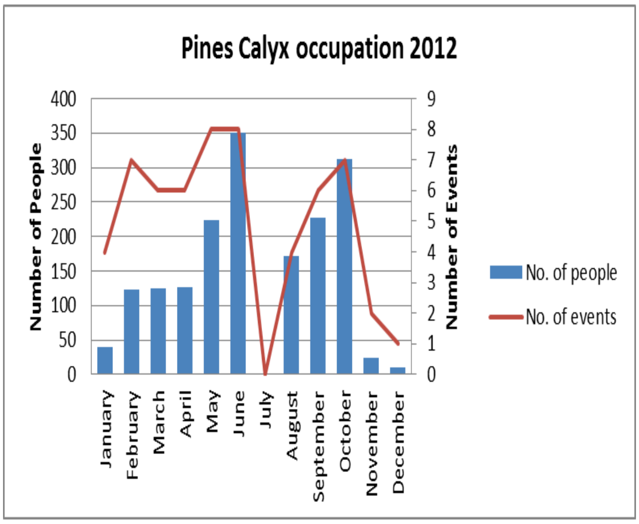


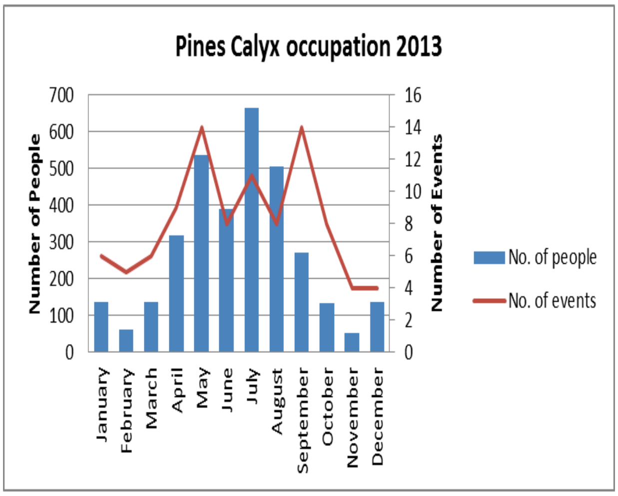
The graph above shows higher event and occupant numbers in 2011 and 2013.

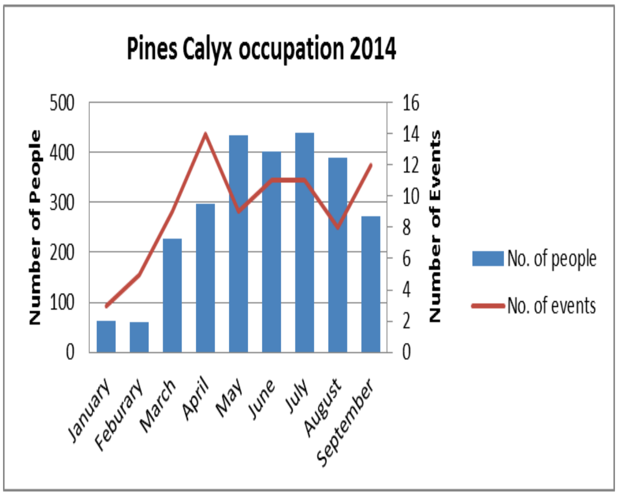
The events of 2013 were also on average larger events, with a rise in the number of people attending the Calyx to nearly 3500 people for approximately 95 events, whereas in 2011 there were more events with a lower overall attendance than 2013.

The data for the year 2014 is clearly partial – it indicates a relatively busy year to September, with 80 events from January to September (the events planned for the end of the summer have been taken into account), that is to say for the three quarter of the year.





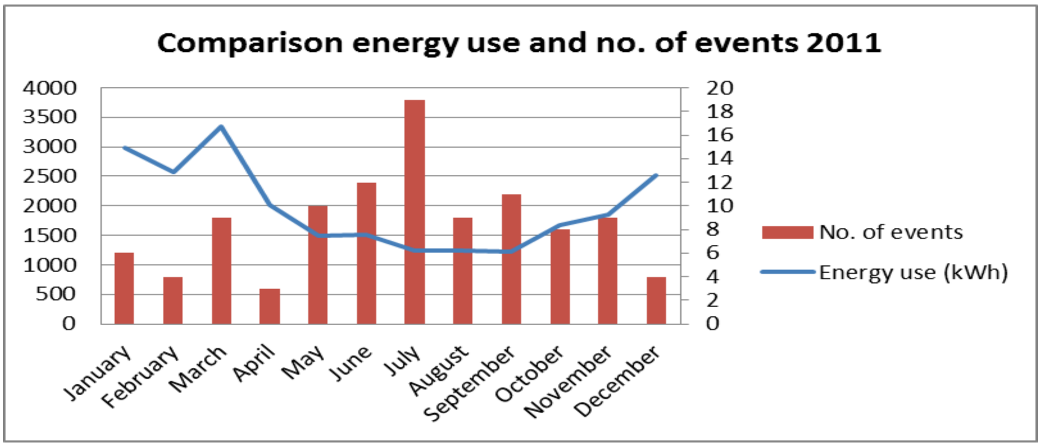


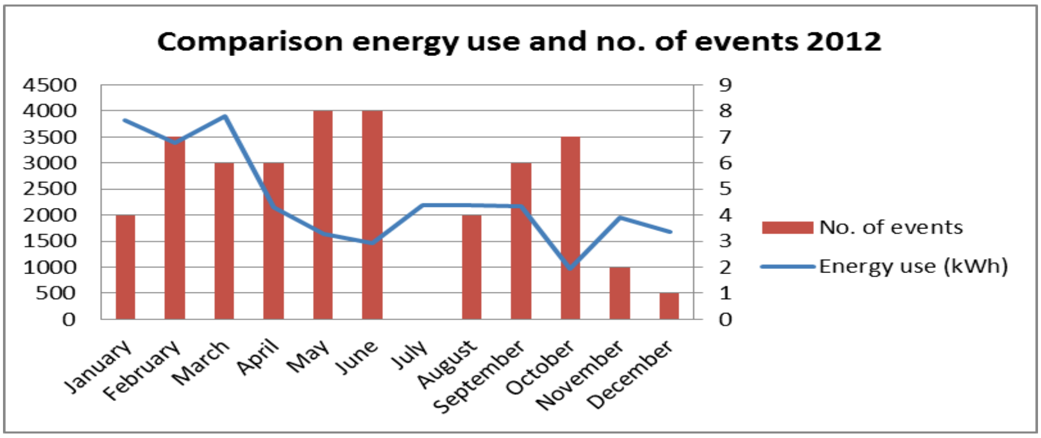


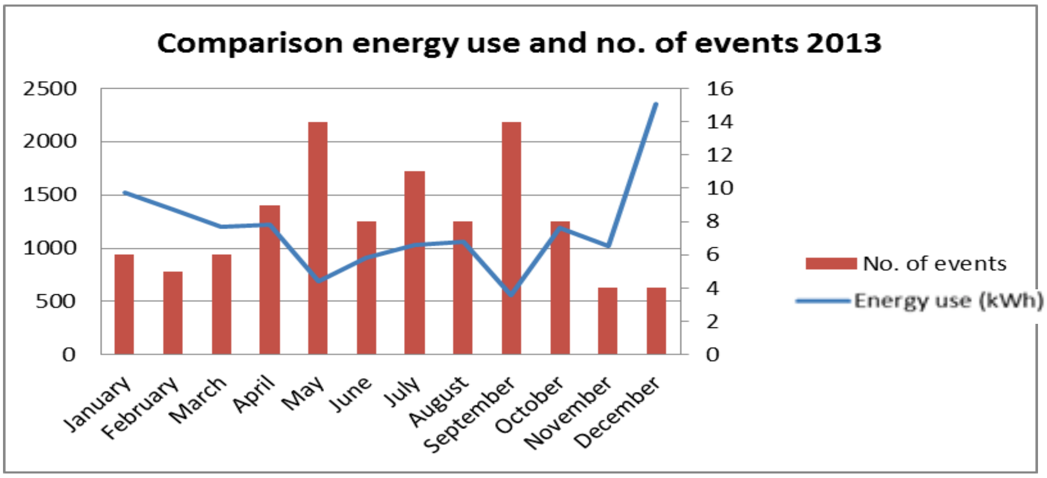
NOTE: from August, the graph represents planned / expected events

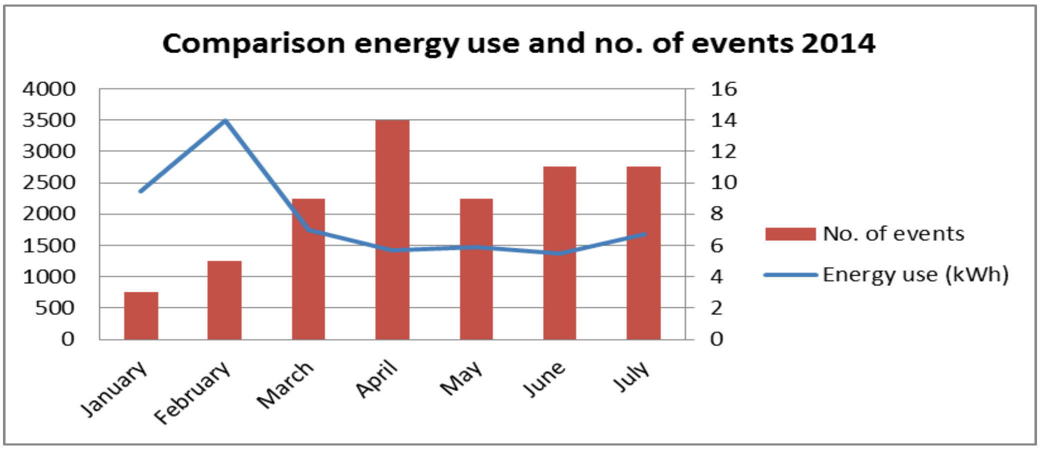
The graphs on the following pages represent the correlation between the number of events and the energy use of the Calyx.

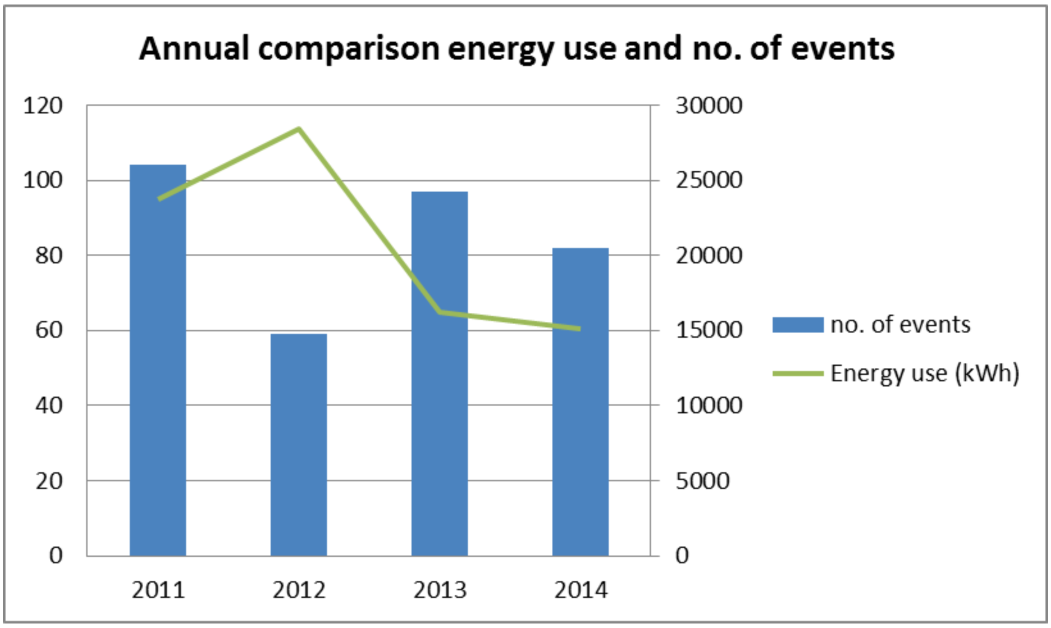
We know that the energy consumption of 2013 was the lowest – this shows that energy consumption in the Pines Calyx stayed low despite an increased level of activity – which is a very significant finding. Clearly this is mainly linked to the installation of the HSS system, which had a very positive effect on the net energy consumption and carbon emissions.


Comparison energy use and no. of events 2011
4000
3500
3000
2500
2000
1500
1000
500
0
20
18
16
14
12
10
8
6
4
2
0
January
February
March
April
May
June
July
August
September
October
November
December
No. of events
Energy use (kWh)


Comparison energy use and no. of events 2012
4500
4000
3500
3000
2500
2000
1500
1000
500
0
9
8
7
6
5
4
3
2
1
0
January
February
March
April
May
June
July
August
September
October
November
December
No. of events
Energy use (kWh)


Comparison energy use and no. of events 2013
2500
2000
1500
1000
500
0
16
14
12
10
8
6
4
2
0
January
February
March
April
May
June
July
August
September
October
November
December
No. of events
Energy use (kWh)


Comparison energy use and no. of events 2014
4000
3500
3000
2500
2000
1500
1000
500
0
16
14
12
10
8
6
4
2
0
January
February
March
April
May
June
July
No. of events
Energy use (kWh)



The figures for 2012 show up as an anomaly because it was the most inactive year but had the highest energy consumption. The summer 2012 saw the creation of the estates department and the start of a definite management program of the estate, including the Pines Calyx. This graph very clearly reflects the benefit of the Estates Dept in energy terms, alongside a sharp rise in the events bookings in the Pines Calyx – this indicates that energy consumption is on target to be almost halved in two years from the high of 2012, and also reduced by a third on 2011 figures – when taken on a 6 monthly basis, we expect the energy monitoring data to verify this for the 2nd half of 2014.

Based on the analysis above, given the Pines Calyx's use as a conference and events venue, and the Trust's objective for the Pines Calyx to be recognised as the lowest impact conference and events venue in Europe, in addition to measuring and monitoring net energy use and carbon emissions totals, and figures per m2 per year, it will also be highly beneficial for the Trust to measure and monitor net energy use and carbon emissions a) per event and b) per user – with the objective that the Pines Calyx becomes the European best practice benchmark in its sector.

6.12 Conclusions and key findings on Energy Use By Source

When we consider on-site energy production, the net energy consumption of the Pines Calyx was roughly halved in 2013 against 2012 due to the introduction of the Hybrid Solar Solution.

However for 2014, in the first half of the year to June consumption is almost as much as in the complete year of 2013. We know the causes of this:

1. In January and February 2013 energy-hungry dehumidifiers were used to dry out the building following a flood caused by a plumbing failure.
2. March to May - constant use of the immersion heater, significantly raised energy use – this arose from the heat pumps apparently not functioning properly.

The Events Team oversaw the operation of the building at the time, however the monitoring data led to this being changed to the Estates Team overseeing the operation of the building until a) all systems are properly functioning, and b) the Events Team is trained in proper operation of the building, with clear protocols for communication with the Estates Team if any element of the system is changed in its balance of use, or does not appear to be functioning properly.

Following repairs being made to the heat pump system, and significant improvements being made to the operation of the building's energy systems, we can predict that energy use for the 2nd half of 2014 should be considerably less that was consumed in the first half. However, we have seen high usage again in the latter part of August and much of September 2014, caused by high usage of the immersion heater whilst the HSS system was being reinstalled, snagged and recommissioned i.e. with the Heat Pumps turned off.

With energy roughly halved from 2012 to 2013 indications on payback are positive, although we are not yet in a position to estimate payback accurately, as the HSS system is only now operating at its optimum. In 2015 when the HSS is operating at an optimum level on an ongoing basis, we will be able to accurately assess its performance and therefore the payback on the £39,996 system design and installation cost. The target for improving energy performance by at least 30% in 2015 indicates a saving of around £815 based on projected total energy costs for 2014 of £2717.

All the findings of the monitoring programme and TM22 evaluation have been of great value to aid the Trust's understanding of the functioning and malfunctioning of the Pines Calyx, and to identify a clear pathway for improving its performance. The Trust is committed to continuing is monitoring programme, and to use TM22 to better understand and improve the performance of the Pines Calyx.

To close the Pines Calyx's performance gap the biggest gains will be secured by tackling:

- technical issues with the energy and building services systems;
- implementing user education measures, amongst both staff (from Estates and Events teams) and clients;
- some improvements can also be made to building fabric performance.

As the Trust has limited in-house energy and buildings expertise, and the Pines Calyx has a number of relatively complex and innovative energy and building services systems, it is clear that continuing learning and skills development is needed within the Trust in relation to the understanding and interpreting a) the data outputs from the monitoring system, b) the data inputs and outputs to TM22. The Trust in general, and the Estates and Education managers in particular, are clear that this learning will have significant value for the Pines Calyx, the rest of the Trust's estate, and for future projects, as well as in its sustainability education work.

Known anomalies in energy use mean we are setting a target to reduce Pines Calyx energy use and carbon emissions in 2015 by at least 30% in comparison with June 2013-June 14 energy use and carbon emissions.

It is clear that the Pines Calyx does not perform to a level that can be considered 'zero carbon'.

The objective is now that the following action is taken during 2014-15:

a) Work is undertaken to ensure all systems are properly functioning;
b) The Estates and Events teams are trained in proper operation of the building, with clear protocols for communication with the Estates Team if any element of the system is changed in its balance of use, or does not appear to be functioning properly.

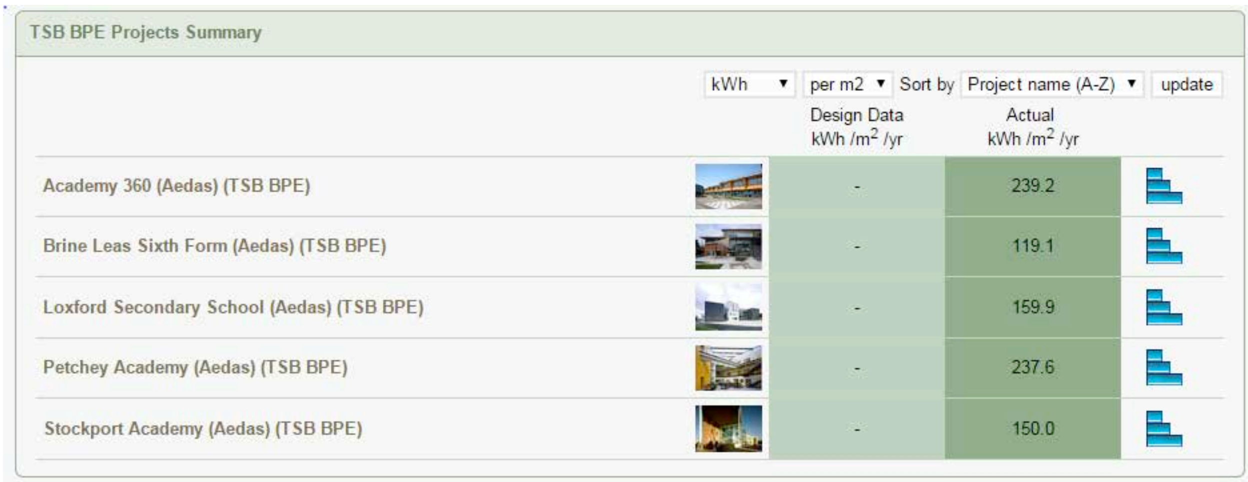
Conclusions:

For the year to June 2014, the Pines Calyx performed very well in comparison to DEC benchmarks as follows:

	Pines Calyx	**DEC benchmark**
Energy use:	116.7 kWh / m2 / year	177 kWh / m2 / year
Carbon emissions:	42.8 kg CO_2 / m2 / year	79.9 kg CO_2 / m2 / year

Given the known anomalies that raised 2014 energy use, this compares reasonably favourably with the design stage (2004) best practice benchmark of 98 kWh/m^{2}yr for the Elizabeth Fry Building at UEA.

The above figures also compare favourably with other buildings within the BPE programme, as indicated by the details provided on the CarbonBuzz website, an example of which is shown below:


TSB BPE Projects Summary

kWh | per m2 | Sort by Project name (A-Z) | update

	Design Data kWh /m^2 /yr	Actual kWh /m^2 /yr
Academy 360 (Aedas) (TSB BPE)	-	239.2
Brine Leas Sixth Form (Aedas) (TSB BPE)	-	119.1
Loxford Secondary School (Aedas) (TSB BPE)	-	159.9
Petchey Academy (Aedas) (TSB BPE)	-	237.6
Stockport Academy (Aedas) (TSB BPE)	-	150.0

From the BPE project as a whole we can conclude:

1. Building fabric energy performance is largely successful – given what we know about 'the performance gap' in the industry, for such an unusual building, this has been a significant achievement. Some improvements can be made and are planned to be in place within the next 12 months – this will ensure the Pines Calyx maintains a track record as a building with very low operational energy use.

2. The energy systems include multiple complexities, and therefore multiple risks, which have led to several key failures. Some failures were related to the technologies, however the greatest failures have simply arisen from poor plumbing design and installation. All

the known failures and weaknesses have now either been remedied or are in scope for been tackled, which will ensure the Pines Calyx maintains a track record as a building with very low carbon energy systems.

3. The ventilation system has maintained very good performance in energy terms – there is some scope to further improve this with effective ventilation controls, improved user education, and the potential for innovations to help increase the earth tubes cooling effect.

4. The lighting has maintained good performance in terms of its core function – controls are better understood by users with a change to the use of an iPad, with the expectation that there may be scope for further improvement – the energy performance of the lighting system has not yet been fully analysed as greater priority has been placed on the energy systems and the ventilation system. The data suggests there is likely to be scope for reducing lighting related energy use, particularly through user education. It will be important to assess and allow for increased lighting related energy use in relation to levels of Pines Calyx occupancy, particularly during the winter and for evening use.

5. Post 2012, through the creation of the Estates Department, systems have been put in place to understand energy use by source in terms of:
    a) the functioning of the building and its components;
    b) how to improve energy and comfort performance.

6. It is only at the point of this BPE study that the building has been studied and analysed in a form that has generated detailed data to coherently learn about and understand the functioning of:
    a) the building
    b) its component systems;

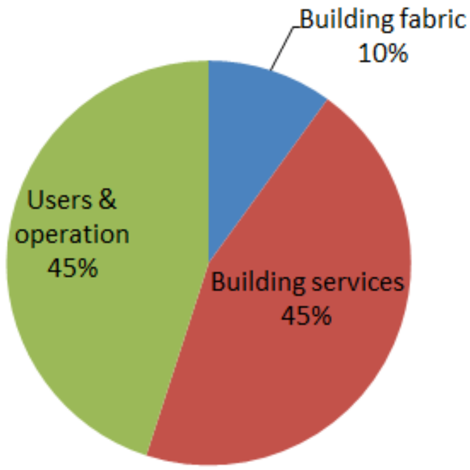
7. The monitoring and BPE methods have to be continued into 2015 to obtain a picture of energy use & CO_2 emissions with all systems functioning well

8. Systems for improved collaboration and communication between Events and Estates teams are expected to bring improved energy performance through improved understanding of the building's technical aspects, and how to operate them properly.

9. An estimate of the breakdown of the contributions to the performance gap for the Pines Calyx is roughly as follows:
    - Building fabric – appears to be minor gap (e.g. 10%)
    - Energy systems & buildings services – a significant gap (e.g. 45%)
    - Operation of the building & its systems – a significant gap (e.g. 45%)

    Further detailed analysis will confirm or adjust these estimates.

Fig 6.12: estimated contributions to Pines Calyx performance gap



10. Whilst the Pines Calyx has a significant performance gap:
    a) the gap can be closed significantly;
    b) the building's success in achieving low energy demand means its kWh/m2/yr and CO2 impacts are very low for comparable events buildings, even whilst it is not operating at optimal levels.

7 Technical Issues

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

7.1 Introduction to technical issues

This section sets out the main technical issues that have been identified through this BPE project, or prior to the project. It is supported by a number of Technical Reports, which are included as Appendices to this report[17], and which provide a great deal more detail on the technical issues they address, as well as the methods of assessing those technical areas.

7.2 Thermography

Appendix B includes the full Thermography Report on the building, based on a survey carried out on 3 April 2012. The main building fabric itself (walls and roof) is generally very sound with no recorded weaknesses, except via the lift pit. Weaknesses and cold spots occur around openings (windows, roof lights, and doors) and where ducts connect inside to outside.

Specific findings of the survey and report were as follows

1. Ventilation diffusers in roundels are dislodged.
2. Windows left open in upper roundel - initially it was thought that there was a lack of coordination within the BMS between set temperature and ventilation controls - however, subsequently it was established that the windows have been forced manually, damaging the window actuators.
3. Plant room ducts not insulated or sealed.
4. Incoming air causes significant cooling even when building temperature is lower than optimum and the building is unoccupied. (Data from BPE indicates that fan power constant at 140W)
5. Water boiler in kitchen appears to be on continuously.
6. Disco lighting ball motor running.
7. Lighting controls are using energy - even when the lights are off.
8. Possible cold bridging in lift enclosure.
9. Possible water leak or air path leak below the basin in disabled WC.
10. Roof lights may not be sealed fully.
11. Perimeter seal to lenticular may be faulty.

The recommendations of the thermography report were as follows:

1. Re-fix ventilation diffusers in roundels – to ensure wider distribution of incoming air, and to avoid leaks

2. Check window actuators and BMS to ensure that windows closed when ventilation not needed, especially in cold weather. Provide clear instructions to users on automatic and manual controls and clear labels for each.
3. Seal ventilation ducts in plant room and insulate ducts to reduce heat losses and gains.
4. Ensure that fans set to low speed or switched off when building unoccupied, to reduce energy use, and reduce heat losses and gains. (also see also the recommendations of the Earth tube performance report).
5. Switch off kitchen water boiler when building not in use.
6. Disconnect disco lighting ball motor when not needed.
7. Consider changing lighting controls so that they do not consume energy when lights are switched off.
8. Check lift enclosure specification and drawings to identify possible cause of lower temperatures.
9. Check duct in disabled WC for air path to plant room or water leak.
10. Check and repair/renew roof light seals.
11. Check/replace lenticular seals. Ideally this should be done prior to the air-tightness test.

7.3 Daylighting

A daylight survey undertaken in June 2013 showed that the daylighting in the building is generally very good. Appendix C includes a full report on the daylighting following a survey of the building. The design intentions for the building were 'that most habitable rooms, i.e. excluding circulation areas and WCs, have daylight from at least two sides, or from a side and the top' and that 'rooms should be designed for the best possible daylight uniformity'. These aims have been met in the roundels with both side lighting from windows (on various 'sides' due to the circular forms) and from roof lights, and are consistent with the recommendations of the British Standard Code of Practice for Daylighting 2008.

Other criteria for good daylighting are: a view of the sky from the working plane; and light-coloured internal surfaces. Good daylighting is particularly important in the main functional spaces: the lower roundel, the meeting room/bar and the upper roundel. Although good daylighting is also beneficial in other areas, these are less critical.

Average daylight factors have been calculated for each of the four spaces and are as follows:

- Upper Roundel 3.9%
- Lower Roundel 1.9%
- Lobby 1.8%
- Meeting room / Bar (front part only) 1.5%

The findings of the Daylight Survey can be summarised as follows:

1. The mean illuminance levels represent good daylight levels, especially in the Upper Roundel, and achieve a 'predominantly day lit appearance', as recommended by the British Standard.
2. However, the average daylight factor is not at the level of 5% in any of the spaces, which is the level recommended for interiors where artificial lighting is not generally required for most of the day.
3. The distribution of light appears to be most uniform in the Lower Roundel. However this is not consistently reflected in the calculated uniformity ratios,

4. Uniformity is a beneficial characteristic because even when the average daylight factor is 1.9%, the uniformity of the light means that it is less likely that the artificial lights will be switched on during the day.

No particular recommendations are made for this building. However, for the design team when designing future buildings, the following comments arise:

- The central Oculus combined with perimeter glazing is a good general principle. If the central Oculus or other roof lighting, were larger this would help to raise daylight levels to achieve the ideal average of 5% DF, resulting in significantly reduced requirements for artificial light during the day.
- Locating roof glazing toward the back of the space, away from windows in the walls (rather than centrally) is likely to improve the uniformity of illumination further.

7.4 Earth tube

The design intention was that the earth tube would pre-heat fresh air in winter and pre-cool fresh air in summer. This was based on the knowledge that the ground temperature at a certain depth below ground level is very stable and approximates to the average annual external temperature. The earth tube is approximately 16m in length overall and comprises a concrete pipe with an internal diameter of 0.6m. The pipe is located approximately 1.5m below ground level. The tube terminates below ground level internally with a fan, which pushes air first through the heat exchanger in the plant room, and then to the building.

Appendix D includes a report on the performance of the earth tube.

The temperature differences at inlet and outlet of earth tube itself were compared to the temperatures inside the building and related to the velocity of the air within the tube. Results from the earth tube temperature sensors in April and May 2013 demonstrate a strong correlation between external and internal temperatures that swing around the assumed ground temperature of approximately 11-12 ° C. In hot weather the earth tube is shown to have a damping effect, reducing the extremes.

However the cooling effect of the earth tube itself is not consistently translated into a cooling effect within the building itself. The reasons for the reduced cooling performance may be attributable to a number of factors:

1. The effects of the heat exchanger: in the absence of clear instructions to the building operators, or automatic controls, to switch off the extract fan in hot weather, the heat exchanger will be pre-heating incoming air in summer, using the outgoing warm air from the building. This is counteracting the effect of the earth tube.
2. Solar gains may be swamping the cooling effects of the earth tube.
3. Casual gains may similarly be swamping the cooling by the earth tube.

The electrical energy consumed by the fans is minimal compared to the energy gained by heating and the potential for cooling - 500W of cooling or heating for each degree Kelvin raised or lowered in the earth tube, compared to 14W of electrical power.

Recommendations for optimising the performance of the earth tube system can be summarised as follows:

1. The Oculi opening vents should be made operational as soon as possible to achieve natural ventilation in summer, by venting off hot air.
2. The extract fan should either be switched off in summer, or a means of by-passing the heat exchanger incorporated to avoid the unwanted and counter-productive warming effects from the extract air.
3. Either a) automatic controls should be introduced to control the fans, or b) regular (weekly) monitoring should take place by the facilities management (FM) team, to ensure that fan speeds are appropriately set, with c) a guidance note prepared to inform the FM team on what are appropriate fan speeds for both the intake and extract fans, under various weather conditions and use patterns.
4. Explore setting the fan to lower speed to increase heat exchange between inlet air and the ground.
5. On future projects employing earth tubes it is recommended that the following are considered to improve the performance:
    a. Employ a longer tube, to increase the heat exchange between air and ground
    b. Locate the tube deeper underground to obtain a more stable ground temperature

Future research on the earth tube system
A future small scale research project has been broadly identified to explore the potential for an additional or enhanced cooling effect to be created by applying moisture to charcoal at the earth tube outlet, with additional cooling achieved through the effect of evaporation. This would be particularly valuable for future cooling demand in the Pines Calyx as it is planned that there will be high levels of kitchen use and dining in the upper roundel in the future e.g. 2016 onwards.

7.5 Rammed chalk walls

Spalling has been occurring in some areas of the rammed chalk walls. As stated in Chapter 5, where there has been any flaking of the face of the walls the Estates team have identified the following causes:

d) faults in the casting of that part of the rammed chalk wall (i.e. cause in construction);
e) direct damage from users (i.e. in setting out / moving tables for events);
f) humidity effects on chalk surface

Recommended solutions to the above are:

d) Additional treatment with sodium silicate solutions
e) Better education and procedures for events staff and users
f) Humidity effects and their solutions are to be researched more, potentially including additional sodium silicate treatment

As Helionix has an on-going R&D and commercial interest in low impact building methods using chalk there is expected to be on-going research in to the aftercare, maintenance and repair of rammed chalk and other chalk based building options, some of which may prove to have cross-over benefits for the Pines Calyx.

7.6 Conclusions and key findings for this section

It is certainly the case that this BPE project, which was initiated alongside the newly formed Estates department, has provided the vehicle to fully review the underlying technical issues associated with the performance of the Pines Calyx as a whole, and of its component elements and systems.

In general this is can be considered experimental building, as it includes experimentation and / or innovation in virtually every main technical element of the building, as well as in how those technical elements are combined:

- General form and construction systems
- Key structural materials and construction systems i.e. both walls and roof;
- Building services systems (earth tube)
- Lighting systems
- Control systems
- Renewable energy systems, when installed in 2012

The major lesson and conclusion in relation to these technical aspects of the building is that they were treated as experimental in the design construction phases – however, they were planned for and managed as experimental in the commissioning, operation and maintenance phases, until this BPE project has highlighted them as such.

Whilst the individual technical components and systems of the building have been assessed and solutions to any weaknesses largely addressed, the various sets of controls for those components, and the potential to link those together as much as possible into a single system of controls is probably the main technical area which still needs to be assessed.

In-house technical competence within the Estates team has made a significant difference to the efficiency of the functioning of individual technical systems or elements, which has coincided well with the opportunity to learn that this BPE project has provided.

The critical role of expert design team ensured that whilst the building has not yet achieved all its technical objectives it has nevertheless operated at a level of operational energy efficiency that is well ahead of the norm for commercial buildings in general in the UK, and conference and events venues in particular. In this sense, the technical elements that were selected and designed into the building have contributed to its very good performance, even though they are not yet operating at optimal performance.

The ambitious health and low carbon objectives for the building have been largely achieved, although it is likely that:

a) they could have been achieved earlier and more efficiently if there had been in-house FM expertise;
b) they will be achieved even more fully as a result of the action plans that will address technical weaknesses that remain to be resolved.

8 Key messages for the client, owner and occupier

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

8.1 Design and procurement

The client adopted an enlightened design and procurement strategy for this ground-breaking building, which was a no-blame approach for both the design and construction teams. This strategy was established to encourage innovation in the use of unfamiliar materials and technologies. As a result, systems of construction not seen before in the UK, such as Catalan / Guastavino / timbrel vaulting and rarely used constructions, such as rammed earth, have been adopted and successfully implemented.

This has been a positive lesson for the client, although it has meant that associated risks were higher.

8.2 Fabric and overall building performance

Implement plans for final installations of fabric elements.

Also consider the potential for i) triple glazed doors, or ii) double glazed porches with two-sets of doors, and other potential contributions to fabric improvements which can be integrated into the planned Pines Calyx extension.

When the fabric elements are complete undertake an air-pressure test to assess air-leakage and then complete the PHPP in-use analysis of the building.

8.3 Electrical circuits

The evaluation has shown that it is necessary to adopt a clear strategy for establishing separate circuits for the main areas of energy use: fans, mechanical services, lighting, small power, kitchen etc. A clear policy on circuit design for future projects will enable monitoring devices (such as CT meters) to be easily installed either at the time of construction, or at a later date. If buildings are designed and constructed as either experimental buldings, or very high performance buildings – or both – then there is a clear benefit to designing circuitry to facilitate easy monitoring so that hard data can be gathered both to ensure that the building is functioning properly, and to be able to promote and market the success of the building in achieving its ambitious design objectives.

8.4 Services systems

Problems have been encountered with incorrectly specified and sized mechanical equipment. For example, for example, once the HSS system is functioning properly it will be important to assess if the heat pump system is properly sized for the requirements of the building or oversized – and if it is over-sized, the extent to which this will cater for any additional heat demands associated with the planned Pines Calyx extension needs to be assessed.

It is recommended that strictly separate contracts are used for design/consultancy services and supply/installation contracts. If the suppliers or installers of systems are involved in specifying them, they are not likely to offer the most impartial advice. A traditional building contract, where design and construction are kept separate is more likely to result in the consultant providing the best advice to their client.

Consultants' contracts should continue through the entire commissioning phase and should ideally extend through at least one if not two annual cycles. This will enable systems to be fine-tuned to achieve optimum configuration. In summary, a soft landings approach should be adopted on any future projects of any scale, for the project overall, and particularly in relation to energy and building services systems, or any other experimental or highly innovative component.

As-built information: delivery of as-built descriptions of how services systems and their controls are intended to operate and as-built drawings should form a compulsory element of all design contracts and construction contracts.

The Oculi opening vents should be made operational as soon as possible to achieve natural ventilation in summer, by venting off hot air.

The extract fan should either be switched off in summer, or a means of by-passing the heat exchanger incorporated to avoid the unwanted and counter-productive warming effects from the extract air.

Either automatic controls should be introduced to control the fans, or regular (weekly) monitoring should take place by the facilities management (FM) team, to ensure that fan speeds are appropriately set. A guidance note should be prepared to inform the FM team on what are appropriate fan speeds for both the intake and extract fans, under various weather conditions and use patterns.

Consider the potential for returning to the original idea of a wood fuel boiler located in the Pines Cottage, to provide low carbon heat and hot water for Pines Cottage, Pines office and as back-up for the Pines Calyx via the existing heat main.

There appears to be value in more specific research and promotion of the findings in relation to the excellent performance of the earth tube, as well as consideration as to how this solution can be more widely used.

8.5 Controls

Very careful consideration should be given to whether controls (such as fan speeds, window opening, lighting, etc.) are manual or automatic. One rule of thumb might be that manual controls should be easy to see and accessible within the main spaces of the building. Controls that are hidden in a plant room should ideally be automatic.

A newly designed Building Manual and User guides will be developed and made accessible to the FM and events teams on how the building is designed to operate under different use/weather scenarios and, where manual controls are used, what settings are advisable under these use scenarios i.e.:

	No Users	**Lightly Occupied**	**Full of People**
Cold Winter Day			
Mild Weather Spring / Autumn			
Hot Summer Day			

Manual controls should be self-explanatory and clearly labelled. An array of switches, each for a row of lamps, is much easier to understand and use by the occasional visitor, than a touch screen with various menu options.

Provide a simpler lighting system on future projects that is easy to understand for casual and occasional users of the building.

The various sets of controls for all the technical and passive components of the building, and the potential to link those together as much as possible into a single system of controls, is probably the main technical area which still needs to be assessed.

8.6 Daylighting

When windows are only located on one side of a room/space, locate roof lights off centre, away from the windows, to achieve a greater uniformity of illumination.

For the design team when designing future buildings, the central Oculus combined with perimeter glazing is a good general principle. If the central Oculus or other roof lighting, were larger this would help to raise daylight levels to achieve the ideal average of 5% DF, resulting in significantly reduced requirements for artificial light during the day. Also, locating roof glazing toward the back of the space, away from windows in the walls (rather then centrally) is likely to improve the uniformity of illumination further.

8.7 Conclusions and key findings for this section

Applying the significant learning from the BPE project:

- Systematic monitoring reaps significant benefits, which are:
    - Technical diagnosis, energy and comfort performance and bottom-line
    - Confirming design objectives and performance targets are achieved
    - Customer / user satisfaction (i.e. incl events Dept)
    - Marketing and sales messages to key client groups

- In-house technical knowledge improves understanding and responses to technical problems / system optimisation i.e. cuts cost and time in solving technical problems
- Continue this BPE monitoring system and use of TM22 to the end of 2019, both for the Pines Calyx and for other significant existing or new buildings alongside:
  - a) completion of Lenticular glazing and other building fabric improvements;
  - b) improvements to energy and building services systems;
  - c) user education.
- Undertake an on-going 'forensic analysis' of building and its components based on the findings and conclusions of each section of this BPE report
- Set a clear target for 2015 for optimum Pines Calyx operation i.e. at least 30% reduction on 2014 energy use and carbon emissions
- Measure and monitor the heat output of the PVT panel, which is currently not measured
- 'Beyond Zero Carbon' should not be used until a 'net zero' position is absolutely clear – a good alternative is 'the lowest impact conference venue in Europe'
- Consider 'off-site' renewable options to achieve 'beyond zero carbon'
- Seriously consider improved location options for the PVT panels to raise electricity and heat outputs – think creatively about this as part of the planned Pines Calyx extension
- Think creatively about how particularly the Pines Calyx extension, as well as Pines Calyx phase 2 (lodges) can be used to tackle the weaknesses identified by this BPE project, as well as to further enhance the significant strengths of the Pines Calyx
- When the performance gap is closed and there is data on optimum performance, consider marketing and sales value of well-produced case studies and 'The Pines Calyx Story' book and film, drawing significantly on the outputs of this BPE project

Applying our learning in the Trust's wider existing estate:

1. Invest in BPE for main sites (i.e. Rippledown) to inform operation and management, and energy efficiency measures
2. Continue to build in-house technical understanding / capacity

For new projects:

3. Set ambitious and challenging targets
4. Follow the strengths of client brief, design & construction processes, and tackle their weaknesses
5. Plan for and implement a soft-landings approach
6. Plan at design stage for post-occupancy BPE for all significant new build projects
7. Capture real data, and use it wisely in marketing and sales
8. Plan and monitor energy systems & their use carefully – this will be easier when they are installed at initial time of building completion! Balance the pros and cons of installing a) sophisticated experimental / innovative systems; b) simpler tried and tested low carbon alternatives.
9. If projects are experimental/innovative in design & construction, plan in advance to manage, monitor & maintain them as such, and ideally to secure funding for BPE research to follow on from initial commissioning – in particular, involve experienced building managers at design stage ('soft landings')

Key messages in relation to Pines Calyx users

- Continue to use and improve the Building User Survey, refining this with the Events team to ensure that it can be used as a marketing tool
- Make it much simpler i.e. online survey

- Work on making controls easy to use
- Target 100% user satisfaction in all key areas
- Recognise staff as users and improve their satisfaction levels
- Integrate the outcomes of this BPE project with the work to achieve and maintain the ISO20121 Sustainable Events Management standard
- Use the planned Pines Calyx extension to tackle technical issues that need improving to improve user satisfaction

8.8 Conclusions and key findings for this section

This chapter and the report as a whole provide an extremely valuable basis for action planning to achieve the target of optimum Pines Calyx operation in 2015.

A commitment to monitoring and ongoing use of BPE approaches during the period 2015-2019 offers significant opportunities to optimise Pines Calyx energy use, and then to make ongoing incremental improvements to further improve energy and carbon emissions performance, with a view to establishing and maintaining the identification of the Pines Calyx's as a best practice benchmark for conference and events venues, and other commercial buildings, in the UK and across Europe.

There is potential for significant marketing and commercial benefit to be generated through ongoing monitoring and enhanced operation of the Pines Calyx, and effective communication of that outcome when it is achieved.

The events, marketing and estates staff need to collaborate and think creatively to take significantly greater advantage of the fact that the Pines Calyx is a unique building, with excellent current performance and the potential for outstanding performance. Achieving, maintaining and improving optimum performance will require
a) right knowledge,
b) right enthusiasm/attitudes,
c) right communication.

With the right data captured, the Pines Calyx is likely to be justifiably able to be marketed as *the lowest impact conference and events venue in Europe.*

9 Wider lessons

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

9.1 Introduction to wider lessons

The intention is that this lessons from this BPE project, our monitoring programme, and the changes arising from the work of the Estates Dept will be continued and produced as a detailed case study for the wider industry, in a user friendly format, perhaps as a book e.g. 'The Pines Calyx Story'. The intention is that this will be promoted through appropriate channels including to professional and industry bodies, such as RIBA, RICS and the CIOB, as well as through industry media such as Green Building Magazine.

9.2 Design and procurement

The Pines Calyx project embodied a 'design and innovation driven approach', which set admirably ambitious outcomes.
Initially there was a lot of trust in successful outcomes, with little consideration given to operation, management and maintenance, particularly of complex and innovative energy and building services systems – because of the many innovative and experimental components of the building there was often little choice of suppliers available to put systems right.

An enlightened design and procurement strategy was used which adopt a no-blame approach for both the design and construction teams – this strategy contributed significantly to the ambitious targets being achieved – it encouraged innovation in the use of unfamiliar materials and technologies, and the effective use of a solutions-oriented approach to any challenges or uncertainties that arose. The project proves that as a result of this collaborative no-blame approach, systems of construction not seen before can be adopted successfully. This can provide positive lessons for the industry as a whole, although it implies that risks can be higher, although they can also be effectively managed.

9.3 Daylighting

When windows are only located on one side of a room/space, locate roof lights off centre, away from the windows, to achieve a greater uniformity of illumination. Size windows to achieve an average daylight factor of 5% wherever possible.

9.4 Electrical circuits

Recent changes to Building regs (Part L2) call for energy sub metering to be implemented in Non-Domestic properties, so that 90% of the estimated annual energy consumption of all fuels can be assigned to specific end uses - such as Lighting, Heating, Ventilation, Pumps and Fans. It's important for the Calyx owner to adopt a clear strategy in line with these regs and the FM Team should look to establish separate circuits for the main areas of energy use. A clear policy on circuit design will enable monitoring devices (such as CT meters) to be easily installed either at the time of construction (preferred), or at a later date.

9.5 Services systems

It is recommended that strictly separate contracts are used for design/consultancy services and supply/installation contracts. If the suppliers or installers of systems are involved in specifying them, they are not likely to offer the most impartial advice. A traditional building contract, where design and construction are kept separate is more likely to result in the consultant providing the best advice to their client.

Consultants' contracts should continue through the entire commissioning phase and should ideally extend through at least one if not two annual cycles. This will enable systems to be fine-tuned to achieve optimum configuration - a soft landings approach is highly recommended.

As-built information: delivery descriptions of how services systems and their controls are intended to operate, as-built, in additions to as-built drawings should form a compulsory element of all design contracts and construction contracts.

9.6 Controls

Very careful consideration should be given to whether controls (such as fan speeds, window opening, lighting, duct dampers etc.) are manual or automatic. One rule of thumb might be that controls that are manual should be easy to see and accessible within the main spaces of the building. Controls that are hidden in a plant room should ideally be automatic.

Very clear guidance (perhaps arranged as a matrix) must be provided to the FM and operations teams on how the building is designed to operate under different use/weather scenarios and, where manual controls are used, what settings are advisable under these use scenarios i.e.:

	No Users	**Lightly Occupied**	**Full of People**
Cold Winter Day			
Mild Weather Spring / Autumn			
Hot Summer Day			

Provide simple lighting control systems that are easy to understand for casual and occasional users of the building.

Manual controls should be self-explanatory and clearly labelled. An array of switches, each for a row of lamps, is much easier to understand and use by the occasional visitor, than a touch screen with various menu options.

9.7 Conclusions and key findings for this section

There is real benefit in setting very ambitious project objectives and performance targets, and investing in high quality design and construction teams to achieve them.

BPE adds value for high performance and experimental buildings – it should be treated as *essential.*

Such buildings need significant investment in design and construction quality, and equal investment in their aftercare, management, operation, maintenance and monitoring

10 Appendices

Technology Strategy Board guidance on section requirements:	The appendices are likely to include the following documents as a minimum: • Energy consumption data and analysis (including demand profiles) • Monitoring data e.g. temperatures, CO2 levels, humidity etc. (probably in graph form) • TM22 Design Assessment output summaries • A DEC – where available • Air conditioning inspection report – where available • TM22 In-Use Assessment output summaries • BUS Occupant survey – top line summary results • Additional photographs, drawings, and relevant schematics • Background relevant papers

10.1 Supplementary technical reports

The following supplementary technical reports have been produced by University of Kent department of architecture, and are available as part of this BPE project:

- Pines Calyx Daylight Survey report v2.pdf
- Analysis Pines Calyx earth tube performance.docx
- Pines Calyx thermography report.pdf

10.2 Design and construction team

Client	Alistair Gould, the Bay Trust
Design	Alistair Gould, Helionix Designs
Architect	Issy Benjamin
Surveyor/Designer	Paul Mallion, Conker Conservation
Energy consultant	David Olivier
Structural engineer	Bill Taylor, Cameron Taylor
	Phil Cooper
	Richard Phillips, Cameron Taylor
Structural engineer	John Ochsendorf, MIT
	Michael Ramage (?), MIT (now Cambridge University)
Engineer	Peter Walker, Bath
M+E engineers	Richard and Anne Walker
Lighting consultant	Mary Rushton Beales, Lighting Design House
Contractor	Andrew Bassant, Ecolibrium
Earth building consultant	Rowland Keable
Vaulting consultant	Sarah Pennal
Technology consultant	Edmond Rube

Detailed Design
Helionix Designs, Architects - www.helionixdesigns.co.uk
Bay Trust Office
The Pines Garden
Beach Road
St. Margaret's Bay
Kent CT15 6DZ
Scott Wilson Group (incorporating Cameron Taylor), Structural Engineers - www.scottwilson.com
6-8 Greencoat Place
London SW1P 1PL
Conker Conservation, Building Surveyors and green building consultant - www.conkerconservation.co.uk
Unit 6 The Stour Centre
22-24 Stour Street
Canterbury
Kent CT1 2NZ

Building Contractors
Ecolibrium Solutions - www.eco-libriumsolutions.co.uk
Great Cauldham Farm Office
Cauldham Lane
Capel-le-Ferne
Folkestone
Kent CT18 7HQ

Specialist Analysis, Design and Project Management (timbrel vaulted domes)
Massachusetts Institute of Technology, Department of Artchitecture - www.mit.edu
77 Massachusetts Avenue
Cambridge
Massachusetts
USA

Specialist Rammed Earth Contractor
Rammed Earth Co. - www.rammed-earth.info
86 Brougham Road
London E8 4PB

Building Services Engineering
Conservation Engineering - www.conservation-engineering.co.uk
Troston
Bury St Edmunds
Suffolk IP31 1EW

Energy Advisors
Energy Advisory Associates - www.energyadvisoryassociates.co.uk
1 Moores Cottages
Bircher
Leominster

Herefordshire HR6 OAX

Lighting Design
The Lighting Design House - **www.lightingdesignhouse.com**
The Studio
380 Great West Road
Hounslow
Middlesex TW5 OPB

Electrical Contractors
Cloakes Electrical Contractors - **www.cloakesltd.co.uk**
The Old Granary
Hanover Mill
Mersham
Kent TN25 6NU

Site Planning & Safety Consultants
PCM Safety - **www.pcmsafety.com**
The Piazza
16 Bewhouse Yard
London EC1V 4LJ

Construction of Arches & Vaults
Sarah Pennal - **www.sarahpennal.com**
The Print House
18 Ashwin Street
London E8 3DL

10.3 Commercial Energy Performance Certificate

Energy Performance Certificate
Non-Domestic Building

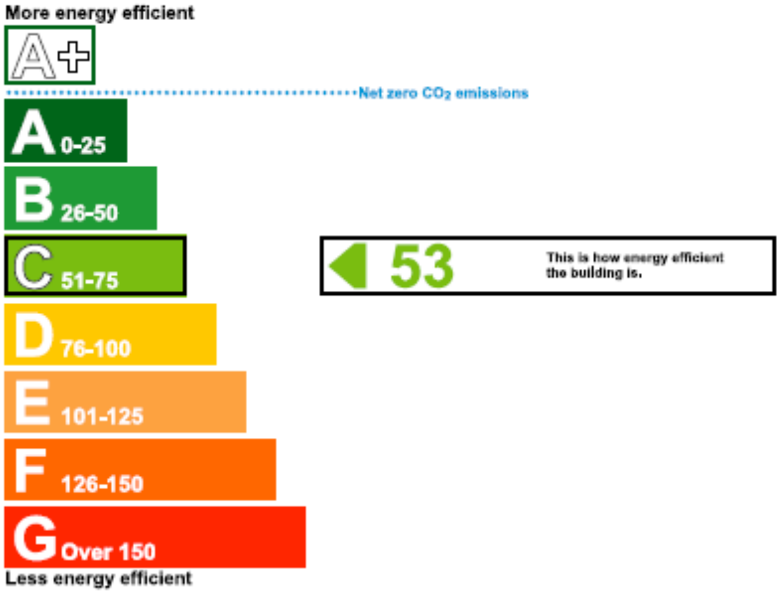
HM Government

PINES CALYX
St. Margarets Bay Trust
St. Margarets Road
St. Margarets Bay
DOVER
CT15 6EF

Certificate Reference Number:
0399-2533-9530-8200-2213

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

Energy Performance Asset Rating



Technical Information

Main heating fuel: Natural Gas
Building environment: Heating and Mechanical Ventilation
Total useful floor area (m²): 352
Building complexity (NOS level): 4
Building emission rate ($kgCO_2/m^2$): 53.99

Benchmarks

Buildings similar to this one could have rating as follows:

24 If newly built
63 If typical of the existing stock

Green Deal Information

The Green Deal will be available from later this year. To find out more about how the Green Deal can make your property cheaper to run, please call 0300 123 1234.