The Energy and Sustainability Performance Analysis of Bernard Weatherill House

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Report Submitted to:

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ABSTRACT:

This report, prepared for Croydon Council's Sustainable Development and Energy Team, evaluated the energy and sustainability performance of Bernard Weatherill House. The team analysed the building's design specifications, in-use energy consumption, Building Management System, and occupant satisfaction. These led to the creation of an Energy Management Software Provider Portfolio and visual tools that will increase energy use awareness and optimize energy management processes. Finally, a complete evaluation for fixing the building management system and recommendations to improve the overall performance of the building were prepared for the Council.

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EXECUTIVE SUMMARY

Introduction:

In September 2013, the Croydon Council moved their new headquarters to Bernard Weatherill House (BWH). The construction of BWH exemplified the Borough of Croydon's commitment to the sustainability goals of the Croydon Council Urban Regeneration Vehicle (CCURV), a plan to spur sustainable development in the Borough of Croydon. Like all other public buildings in the UK, BWH must be evaluated annually. In September 2014, a third party will conduct a performance review of BWH to publicly rank the building. The Council proposed a midyear analysis of the building energy consumption to have an initial evaluation of its performance. Since the building was constructed so recently, there was no data from the past against which to compare current building performance.

Data provided by the Trend system, which is the Building Management System (BMS), and utility bills were the only resources available to do the evaluation. Energy efficient buildings are designed with multiple environmental features to reduce their energy consumption and carbon emissions relative to the minimum targets set by the Building Regulations. As a part of efficient designs, a BMS is installed in buildings to monitor and control the energy systems. A BMS is very important for the energy performance evaluation of a building because it provides continuously recorded values of energy consumption in specific areas of a building. This project analysed and evaluated data obtained from BWH's BMS as well as the design Energy Strategy Statement to assess whether a performance gap existed between actual in-use energy consumption and predicted energy consumption values. Previous evaluations had not included the comfort level and liveability of the building in their analyses. Our project considered these factors in the evaluation of the building performance gap along with other qualitative aspects of this important public building. These social aspects were crucial for the Croydon Council to promote awareness of sustainable practices because they have a direct effect on the reduction of energy usage and other resource consumption.

Six major objectives guided our project to assist the Sustainable Development and Energy Team of the London Borough of Croydon to evaluate the energy and sustainability performance of BWH. First, the team analysed the design specifications of BWH and obtained the predicted energy consumption values. Second, the team collected actual in-use energy consumption data for the first six months of BWH occupancy and identified significant problems with the building's BMS. Third, the team identified and analysed the performance gap between the predicted energy consumption of BWH and its actual energy usage. Fourth, the team inquired about occupant satisfaction and awareness of the building's environmental features with an occupant survey. Fifth, the team created visual tools to communicate BWH energy consumption to the BWH occupants. Sixth, the team created an energy management software provider portfolio that will help the Council decide which company to use in the future. Finally, the team communicated this performance evaluation to the Sustainable

Development and Energy Team of the London Borough of Croydon and provided recommendations to improve the energy efficiency of BWH.

Project Findings:

Following the analysis of BWH, the major findings were grouped into six main categories that correspond to the methodology steps. The six categories of findings, presented below, are followed by a series of subsections that directly lead to the recommendations of this investigation.

1. **BWH Sustainability Specifications: Predicting Building Performance**
    a) Estimated carbon emission rates were inconsistent in the BWH Energy Strategy.
    b) Monthly energy usage estimates were difficult to obtain from the BWH Energy Strategy
    c) Improvement in BREEAM categories could achieve a higher BREEAM accreditation
    d) A post-construction BREEAM accreditation could not be located

The analysis of the BWH Energy Strategy document was difficult because the design values for carbon reduction estimates were inconsistent throughout the document. The predicted energy consumption was presented only on annual usage. Monthly energy data was not shown as explicitly. This lack of consolidated numerical data added a layer of complexity to the process of data collection. The analysis of the 2010 BREEAM report showed that the areas of health & wellbeing, energy, water, land use & ecology, and pollution could be improved. However, an analysis of the post-construction BREEAM accreditation was not possible because the document could not be located.

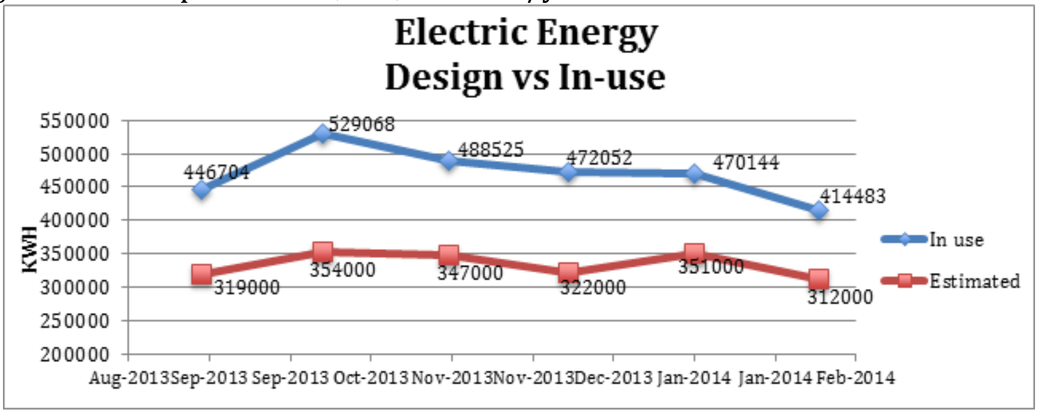
2. **Building Energy Analytics: Overcoming Data Limitations**
    a) Control points did not have clear names or cataloguing
    b) Trend data points were largely inconsistent and missing
    c) Trend was recording 9 times smaller than actual small power values

Several problems were encountered with the Trend system when recording in-use energy consumption data. It was quickly determined that multiple sensors often had cryptic names, such as "Town Hall 16A," which references either a pump or cooling device. This issue was further compounded by the fact that Combined Heating & Power (CHP), heating, water, and cooling data were completely absent. Even the electric consumption data recorded was not reliable because of the presence of considerable outliers. The largest discrepancies were in the area of small power, values recorded by the Trend system were found to be 9 times lower than estimates of in-use small power.

3. Building Performance: Design Phase vs. Actual Performance

a) Electricity use was 42.3% higher than predicted
b) Small power was about 29% higher than predicted values

A variety of sources, including the BWH Energy Strategy, utility bills, on-site half hourly meter readings, and the Trend Building Monitoring System, were used to find that the in-use electrical usage was 42.3% higher than the predicted usage (pictured below). This performance gap was evaluated by comparing the actual energy use of the building to its predicted energy use. A large part of this performance gap was attributed to small power, which was found to be 29% higher than the predicted 2,704,546 kWh/yr.



Electric energy predicted vs. in-use

4. Energy Management Software Providers

a) Eight companies are capable of providing the services necessary to the Council
b) Eight boroughs currently use or have used similar outsourcing methods for bill validation and analysis/reporting

There are several energy management software providers that were identified, through recommendations or research, which are capable of meeting the Council's needs. They include TEAM Sigma Bureau Services, STC Energy, SystemsLink, EnergyCap Enterprise, Credit360, Optima, LASER, and STARK. We identified eight other boroughs in London that utilize a coupling of LASER & SystemsLink or LASER & STARK for bill management, validation, analysis, or reporting. These eight Boroughs include Hammersmith & Fulham, Kingston, Ealing, Brent, Richmond, Surrey County, Newham, and Tower Hamlets.

5. Occupant Satisfaction Survey: Gauging BWH Occupant Opinions

a) 84% of respondents believed BWH was a good working environment
b) 32% of respondents were aware of the building's BREEAM accreditation

Public awareness and investment in sustainable development are a major ongoing goal of the council. Based on a survey conducted throughout BWH, it was found that 84% of respondents considered the overall work environment of BWH as better than the previous council building they had worked in. However, only 32% of the respondents were aware that the building even had a BREEAM accreditation. Of that fraction of respondents, only 67% knew that the building was BREEAM "EXCELLENT".

6. **Visual Tools for Occupant Awareness**
    a) Sankey diagrams can display complex and complete energy systems, making them easy to understand and ideal for raising energy use awareness.
    b) Sankey diagrams highlighted BWH energy consumption in specific areas
    c) Data for producing a complete Sankey diagram of in-use energy consumption was not available nor accurate

Throughout the creation process, Sankey diagram samples containing predicted energy consumption values, found at the end of this section, were presented to our liaison, advisors, and a sample group of occupants. We found that our tool was visually appealing and helped the viewer to comprehend the complex BWH energy system. These diagrams were helpful to determine the demand loads of each one of the areas where energy is used, in this way every specific area is highlighted and easily identified. Our team found that it was not possible to create a second diagram that reflected the actual in-use energy consumption because of inaccurate and absent data.

Recommendations:

Based on these findings, six major recommendations were devised to optimize BWH building performance, improve occupant satisfaction, and convey the performance of this building to the public. These are:

1. Locate or obtain a post-construction BREEAM accreditation

Locating or obtaining a post-construction BREEAM accreditation should be completed as soon as possible. Not only is this a very important document for the Council to possess, but it can also help the Council target areas for improvement.

2. Fix the issues with Trend Building Management System by recalibrating, renaming, and aggregating the sensor points

Since BWH is still under warranty, the Council should have the Trend system fixed with the recalibration, renaming, and aggregation of the sensor points. It is recommended that the Council use Long and Partners Ltd to assist in the BMS auditing service, which was carried out successfully in the Borough of Brent. A well-calibrated BMS will ensure that BWH's energy use can be managed and expressed to the public successfully.

3. Address the BWH energy performance gap by reducing small power consumption

Based on energy usage estimations, small power seems to be the largest contributor to the performance gap of the building. There are several methods to lower the overall small power usage. For example, reminding occupants to power down their electronics when they are not in use and informing them to avoid bringing in electronics with high-energy demands are helpful methods to lower small power energy use. Another recommendation is to ask the employees to work on one specific floor during afterhours, allowing all others to be shut down.

4. Change or upgrade energy management providers

The contractual changes to the Facilities Management Department in 2016 provide the Council with an opportunity to explore different energy management service and software providers to utilize at Bernard Weatherill House. Three scenarios were considered while forming the following recommendations. They include the continued use of TEAM Sigma Energy and Carbon Management software, switching to the TEAM provided Bureau Service, or switching to a completely different provider.

Scenario 1:
If the Council decides to continue utilizing TEAM Sigma, it is recommended that they either fully use the TEAM Sigma Energy and Carbon Management software services or switch to TEAM Sigma Bureau Services offered by the company. Fully utilizing the TEAM Sigma services would provide the Council with visual reports as well as bill and consumption analysis.

Scenario 2:
If the Council decides to continue utilizing TEAM services, it is recommended that they switch over to the Bureau Services provided by the company. This would completely outsource the billing validation, analysis, and reporting responsibilities to TEAM and lessen the burden on the Facilities Management Department.

Scenario 3:
If the Council decides to switch energy management software providers completely, we recommend that the Council couple LASER with one of the service providers mentioned in the Energy Management Portfolio, preferably SystemsLink or STARK. More information on each provider can be found in our Energy Management Portfolio.

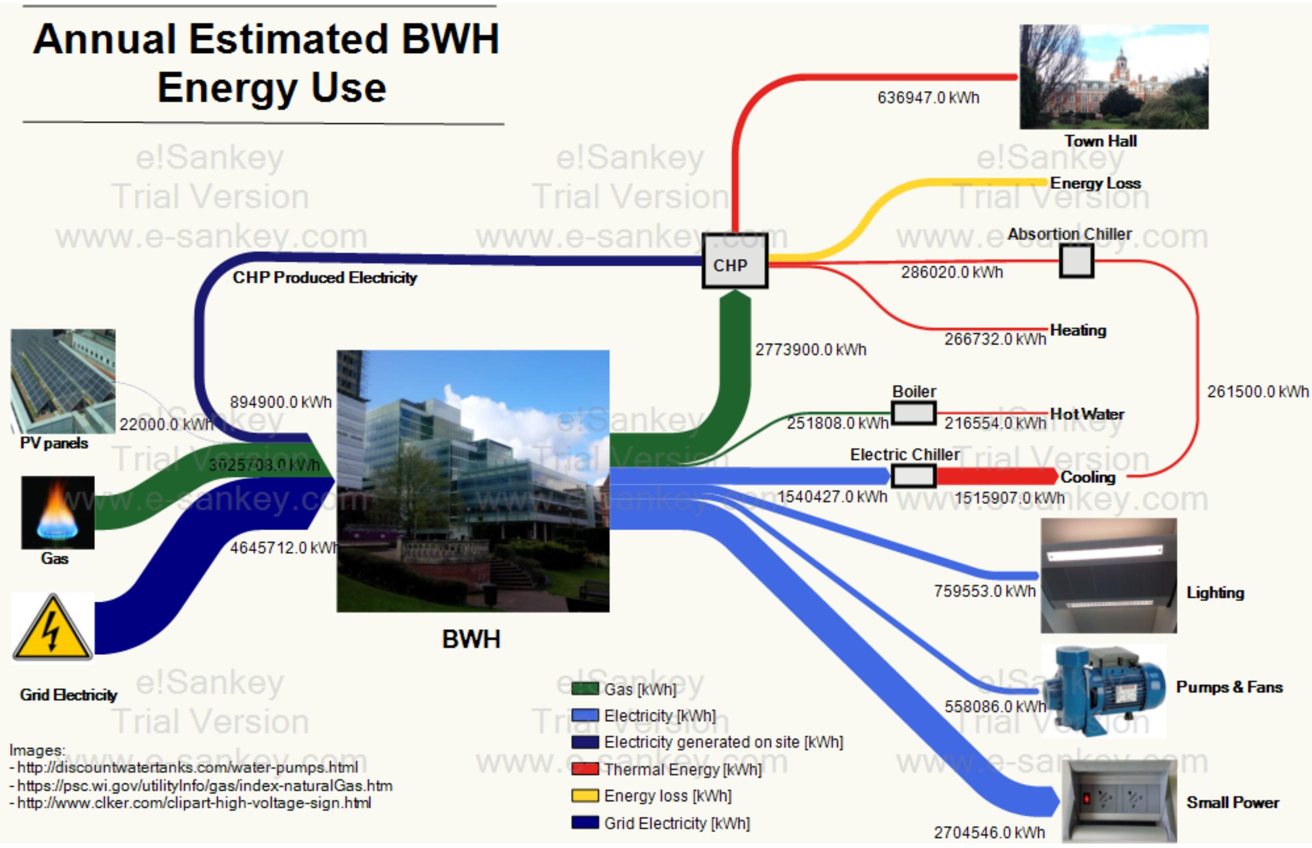
5. Positively influence occupant behaviour and increase awareness of the building's environmental features through education

Based on the results we obtained from our survey, it is clear that occupant awareness about BWH's BREEAM "EXCELLENT" rating needs to be increased. This can be addressed by adding informative messages where these features are in place so that occupants can directly associate with and understand them. Also when increasing occupant awareness, the council should focus on highlighting that the users are the key factor for reducing energy consumption. This would including clearing up the common misconception that and automated building is completely sustainable and no effort by the occupant is needed.

We also suggest that the Council promotes and enforces its recycling practices. Waste disposal areas have been implemented and labelled but the key factor is how the occupants are utilizing them. Only with behavioural changes, can the recycling program become highly successful. This could also be achieved by re-implementing the Recycling Champions Programme, which was established in Taberner House.

6. Create and display visual tools depicting energy usage and energy management

The use of visual tools is a method that can raise awareness about energy consumption. It is suggested that the Council show engaging visual representations of the BWH energy performance through displays located in the lift lobbies and the internet/intranet. A key outcome of the project is a Sankey diagram (figure below).



Annual estimated BWH energy use Sankey diagram

CHAPTER 1: Introduction

Through much debate and research, climate change has emerged as a significant worldwide challenge, largely caused by an increasing concentration of carbon dioxide in the atmosphere. It has become an on-going effort to propose feasible solutions and combat its effects. Many nations have taken steps to find cleaner fuels, develop more efficient infrastructure, and construct more sustainable buildings. To address this challenge in the United Kingdom, London has implemented a series of regulations and goals to encourage sustainable practices in the building sector. Local governments have imposed these regulations to minimize greenhouse emissions in newly constructed buildings. However, sustainable development is a learning process, aiming to find a balance between the design and implementation.

As of 2008, the Department of Energy & Climate Change National Indicator placed Croydon as the seventh highest carbon emitter out of the thirty-three Boroughs of London. It is estimated that the Borough produces 1,660 kilo tonnes of carbon dioxide a year. Mirroring The London Plan and other acts set by Parliament, the Croydon Council included in their 2013 Borough Plan a target CO_2 reduction of 60% by 2025 and 80% by 2050 (*Croydon Local Plan: Strategic Policies*, 2013). The construction and development sector is a very large contributor to CO_2 emissions and has undergone regulation and adaptation to become more efficient and utilize more sustainable practices. In the past decade, the Borough introduced several important policies to limit carbon emissions and reduce energy consumption. Regulatory mechanisms, such as the Zero Carbon Homes Policy, the Energy Performance in Buildings Directive, and the requirement to publicly present various certifications furthered the council's effort to bring the Borough in compliance with their emission goals. To assure the necessity of these standards, Croydon Council promoted sustainable development though the Croydon Council Urban Regeneration Vehicle (CCURV), which had the council's new headquarters, Bernard Weatherill House (BWH), as their first project.

Like all other public buildings in the UK, BWH has to be evaluated after each year of occupancy. In September 2014, a third party will conduct a performance review of BWH to publicly rank the building. The Council proposed a midyear analysis of the building energy consumption to have an initial evaluation of its performance. Since the building was constructed so recently, there was no data from the past against which to compare current building performance. Data provided by the Trend system, which is the Building Management System (BMS), and utility bills were the only resources available to do the evaluation. Energy efficient buildings are designed with multiple environmental features to reduce their energy consumption and carbon emissions relative to the minimum targets set by the Building Regulations. As a part of efficient designs, a BMS is installed in buildings to monitor and control the energy systems. A BMS is very important for the energy performance evaluation of a building because it provides continuously recorded values of energy consumption in specific areas of a building. This project analysed and evaluated data obtained from BWH's BMS as well as the design Energy Strategy Statement to assess whether a performance gap existed between actual in-use energy consumption and predicted energy consumption values. Previous evaluations had not included the comfort level and liveability of the building in their analyses. Our project considered these factors in the evaluation of the building performance gap along with other qualitative aspects of this important public building. These social aspects were crucial for the Croydon Council to promote awareness of sustainable practices because they have a direct effect on the reduction of energy usage and other resource consumption.

The focus of this project was to assist the Sustainable Development and Energy Team of the London Borough of Croydon to evaluate the energy and sustainability performance of BWH. First, the team analysed the design specifications of BWH and obtained the predicted energy consumption values. Second, the team collected actual in-use energy consumption data for the first six months of BWH occupancy and identified significant problems with the building's BMS. Third, the team identified and analysed the performance gap between the predicted energy consumption of BWH and its actual energy usage. Fourth, the team inquired about occupant satisfaction and awareness of the building's environmental features with an occupant survey. Fifth, the team created visual tools to communicate BWH energy consumption to the BWH occupants. Sixth, the team created an energy management software provider portfolio that will help the Council decide which company to use in the future. Finally, the team communicated this performance evaluation to the Sustainable Development and Energy Team of the London Borough of Croydon and provided recommendations to improve the energy efficiency of BWH.

CHAPTER 2: Background

This section provides a background understanding of the topics pertaining to our project. It starts with a broad outlook of the environmental problems that have shaped the nature of sustainable development. A background of the current mechanisms for regulation and efforts in promoting sustainable development are also provided, which leads to a more specific look into the regulations that shaped the Bernard Weatherill House (BWH) design. After providing a general description of a complete analysis of a building's environmental impacts, the specific environmental assessment method used in the UK is defined. Finally, a description of our sponsor, the Sustainable Development and Energy Team, and the importance of our project to them and the public conclude this section. While reading this section it is important to keep in mind that in accordance with the Borough Plan, the council moved their offices from an older, inefficient Taberner House to the BREEAM rated BWH. Located on 8 Mint Street in the centre of Croydon, this building is a standard of sustainability for developers in the Borough to follow. BWH was finished in 2013 and the council moved in during September of that year.

2.1 Global Warming

There is a general consensus that the level of carbon dioxide in the atmosphere is increasing due to the high consumption of fossil fuels in many developed countries. The addition of "Old Carbon" from fossil fuels has upset the delicate CO_2 equilibrium, which plays a pivotal role in regulating our planet's environment. This has created a "hockey stick" in the relatively constant carbon cycle, resulting in an unprecedented increase in CO_2 levels (Cook, 2010b). While the effects of an increasing amount of carbon dioxide in the atmosphere is uncertain, "97% of climate experts agree" (Cook, 2010a) that human use of fossil fuels has increased CO_2 in the atmosphere, which is the cause of climate change. Therefore, it is important that we take steps to improve energy efficiency to minimize CO_2 production.

2.2 Current Regulatory Mechanisms

The design and performance of BWH is directly affected by several regulatory mechanisms and entities that have the common goal of maximizing sustainability in buildings. Figure 1 shows the key players and regulations that influenced and affected BWH's sustainable design. These regulatory mechanisms are multi-scalar. We have organized these entities according to the scalar impact they have. The Energy Performance in Building Directive is the broader key player, having impact on the European Continent. Also we have compiled the national entities and regulations that shaped the design of BWH. Finally we have will look in the local Borough Plan.

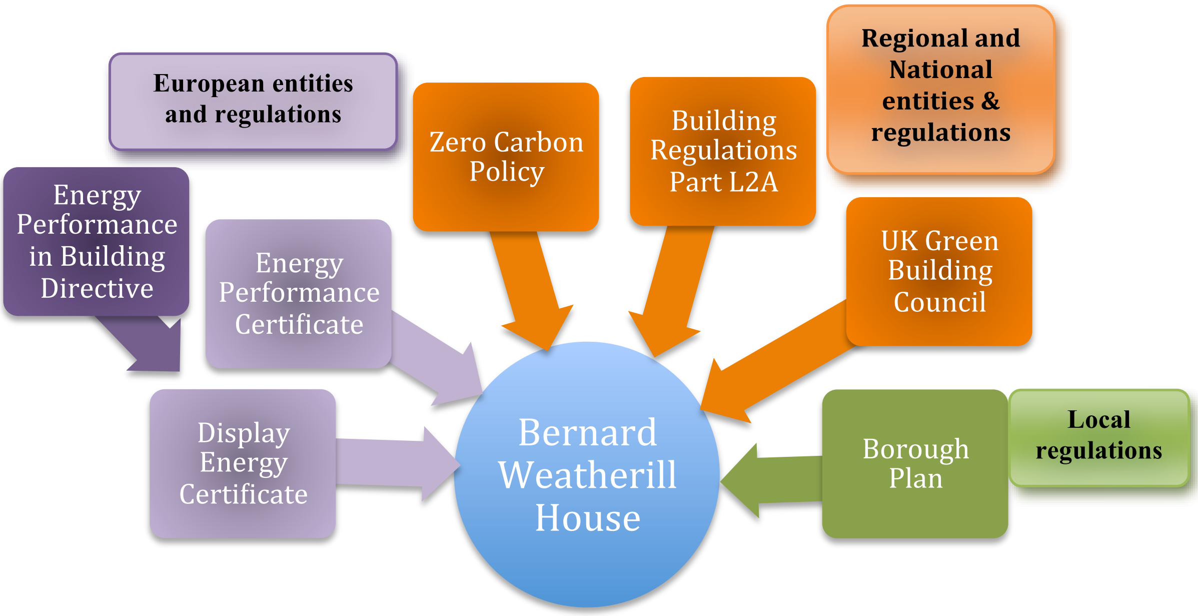


Figure 1: Mechanisms for regulation

2.2.1 Zero Carbon Homes Policy

The UK government has several regulations to limit the emission of greenhouse gasses and to ensure sustainable growth and green practices. The UK became part of the Kyoto Protocol in 1995 and ever since it has been continuously regulating the impact on climate change ("The Climate Change Act and UK regulations," 2008). As a result of these efforts, the Climate Change Act (CCA) was passed in 2008, which includes the creation of the following:

- 2050 Target. This act states that the UK will reduce emissions by at least 80% in 2050, compared to the emissions levels of 1990.
- Carbon Budgets, which are defined as a cap on the total greenhouse emissions produced in the UK in five years.
- The Committee on Climate Change, with a mission of advising the Government on future emission targets and keep the Parliament informed on the progress achieved in this process
- A National Adaptation Plan. The creation of strategies in which the UK Government has to assess the climate change risks.

- ("The Climate Change Act and UK regulations," 2008)

The Zero Carbon Buildings policy was created by the UK government in order to address sustainability issues, while at the same time contribute to the fulfilment of the CCA target. In addition, the Code for Sustainable Homes (CSH) was published in 2006. It serves as an aid to achieve zero carbon development. The code aims to reduce emissions while promoting standards of sustainability that exceed the minimum requirements of the building regulations ("Improving the energy efficiency of buildings and using planning to protect the environment," 2013). The policy's goal is to be achieved through the use of a variety of methods that will ultimately result in regulated energy use. The Zero Carbon policy regulates the energy used in buildings related to space heating and cooling, heating water, fixed lighting and ventilation systems, as established in Part L of

the Building Regulations. The policy has affinity with European regulations including the Energy Performance of Buildings Directive.
The Zero Carbon policy requires all new residential buildings from 2016 and non-residential buildings from 2019 to mitigate all carbon emissions produced on-site. A building has to comply with three basic requirements in order to be considered a zero carbon building:

1. The fabric performance must, at a minimum, comply with the defined standard known as the Fabric Energy Efficiency Standard (FEES) and
2. Any CO_2 emissions that remain after consideration of heating, cooling, fixed lighting and ventilation, must be less than or equal to the Carbon Compliance limit established for zero carbon homes, and
3. Any remaining CO_2 emissions, from regulated energy sources (after requirements 1 and 2 have been met), must be reduced to zero.

-("Zero Carbon Policy," 2014)

The Fabric Energy Efficiency Standard (FEES) is the demanded energy to be used for space heating and cooling in a zero carbon building. The FEES should be proposed as an amount of energy that will allow the maintenance of comfortable internal environment temperatures. The insulation design and performance of the building as well as the gain of external and internal heat significantly influence the demanded energy. The FEES gives space for flexible design approaches that can be achieved by combining different materials and product specifications ("Fabric Energy Efficiency Standard," 2014).

The Carbon Compliance limit, detailed in the second core requirement of the policy, sets the maximum allowed CO_2 emissions or other greenhouse gases produced by the previously mentioned building systems detailed in Part L of the Building Regulations. The amount of emissions produced can be reduced to the Carbon Compliance limit by the implementation of low or zero carbon technologies as well as by using an energy efficient approach to building design ("Carbon Compliance Target," 2013). Also the amount of carbon emissions can vary with the use of different combinations of heating and fuel types.

A building should look for “allowable solutions” once it has fulfilled the first two requirements of the Zero Carbon policy. Allowable solutions are a mechanism developed by the government in order to facilitate the achievement of zero carbon in a building. Once the Carbon Compliance is fulfilled and there are carbon emissions that cannot be offset on-site remaining, they will be addressed by different measures specified in documents published by the Zero Carbon Hub since 2011 ("Allowable Solutions," 2014).

2.2.2 Building Regulations Part L2A

The set of national building standards regulating any ‘building work’ is called the Building Regulations. Issued by the Department of Communities and Local Government (CLG), these regulations are composed of a series of approved documents that a general guidance on specific building designs and construction standards. The Building Regulations are applied to most new buildings and alteration to existing buildings, with a few exceptions ("Building Regulations," 2014). The main concerns addressed in this regulation are safety, energy consumption, and contamination, which give importance of these regulations.

As part of the Building Regulations, which set out requirements for specific aspects of building design and construction, Part L controls the insulation values of buildings elements, the allowable area of windows, doors and other openings the air permeability of the structure, the heating efficiency of boilers, hot water storage and lighting while also setting requirements for carbon emission ratings ("Building Regulations," 2014). In this project, Part L2A regulated BWH's energy design. The approved document L2A Conservation of fuel and power in new buildings other than dwellings defines the design standards, quality of construction, and operation and maintenance instructions. The design process includes the calculation of the Target CO_2 Emission Rate (TER) and the Building Emission Rate (BER), which can be obtained following the National Calculation Method (NCM). These values can be estimated by the use of approved simulation software that uses a Simplified Building Energy Model (SBEM).

The TER is the minimum allowable standard for the energy performance of a building. It is defined as the amount of CO_2 emissions produced annually by a notional building of similar type, size and shape to the designed building. The TER is expressed in annual kg of CO_2 per m^2 ("Conservation of Fuel and Power Approved Document L2A," 2006). The BER is the actual building emission rate for the designed building. It is calculated on actual energy performance specifications and is expressed in annual kg of CO_2 emissions per m^2. In order to comply with this regulation the BER should not exceed the TER. Before the construction phase of a project, a design plan and calculations must be issued to the Building Control Body (BCB), stating the TER, and BER for the proposed facility ("Building Emission Rate BER," 2014).

The values for carbon dioxide emissions were calculated as defined in the Building Regulations Approved Document L2A:

- Gas 0.194 $kgCO_2/kWh$
- Electricity from grid 0.422 $kgCO_2/kWh$
- Electricity generated on site 0.568 $kgCO_2/kWh$
- Biomass 0.025 $kgCO_2/kWh$

-(Nkonge, 2009)

The Building Research Establishment (BRE) revised the conversion factors listed above for the calculation of accurate values of net CO_2 emissions in buildings. We can observe that the factor used for electricity generated on site is greater than the electricity from the grid. The factor used for avoided electricity "… is based on a mixture of the average carbon intensity of the marginal plant and the carbon intensity of new plant built or avoided" (Pout, 2005). The average carbon intensity of a marginal plant was modelled based on actual electricity generation data from an assumed plant of combined cycle gas turbines. Also, this model takes into account any expected transmission and distribution losses to obtain a system average emission factor (Pout, 2005). In this project, the electricity generated onsite might produce a smaller amount of carbon emissions compared to the modelled combined cycle gas turbines but a common conversion factor is used for regulatory purposes.

2.2.3 UK Green Building Council

In an effort to minimize the negative environmental impacts of buildings in the UK, the UK Green Building Council (UK-GBC) was created. After it was launched in 2007, the focus of the organization has been to "radically improve the sustainability of the built environment, by transforming the way it is planned, designed, constructed, maintained and operated" ("What We Do," 2014).

Many of the UK-GBC's goals align with our objectives; thus, we can look to its goals and methods as guidance. The UK-GBC outlines its priorities as follows:

- Influence government policy
- Lead industry action
- Build industry knowledge and green skills

-("What We Do," 2014)

For the purpose of this investigation, we will align with the UK-GBC's third priority (Build industry knowledge and green skills). While this investigation may influence government policy, the primary objective of this investigation is to explore and communicate the energy gap of the newly constructed BWH in the London Borough of Croydon. This communication is intended to inspire an effort from the occupants of BWH to behave in sustainable manners.

2.2.4 Energy Performance in Buildings Directive

The European Union (EU) implemented the Energy Performance in Building Directive (EPBD) in 2002 with the intention to improve the energy efficiency of new buildings in Europe. This directive required numerous inspections on the cooling and heating systems in each building. During this implementation, the Concerted Action (CA) EPBD was put in place to "[find] common approaches to the most effective implementation of this EU legislation" ("Home," 2013). Later, EPBD was recast in 2010, which added additional expectations for new building; chiefly, this was a call to construct and retro-fit all buildings to be "nearly-zero energy" ("Home," 2013)by 2020.

Naturally, this call to action is the motivation for this investigation. It is the intention of this investigation to demonstrate that the energy usage of BWH is zero or near-zero. While this information is reflected on BWH's Energy Performance Certificate (EPC) and Display Energy Certificate (DEC), it is important to demonstrate that the building is sustainable in practice.

2.2.4.1 Energy Performance Certificate

An Energy Performance Certificate (EPC) is presented to each new building in London that evaluates the energy efficiency of that facility. The energy efficiency of these buildings can vary from rank A (highest building efficiency) to rank G (lowest building efficiency). Because these rankings are dependent on the building's energy efficiency and CO_2 based index, buildings with a higher rating typically pay lower energy bills and generate fewer CO_2 emissions ("EPC or DEC for building compliance," 2009). However, this does not necessarily mean that a building with low energy bills or CO_2 emissions will have a good EPC rating.

One important note about EPC's is that they are highly regulated and can only be "generate[ed] using approved software by accredited energy assessors" ("EPC or DEC for building compliance," 2009). Moreover, any evaluation generated for an EPC considers every part of the building so that the average rank of a building cannot be bolstered by increasing efficiency in one specific area. To achieve a higher EPC rating, a building must have a high-level all-around performance.

2.2.4.2 Display Energy Certificate

A Display Energy Certificate (DEC) is a mandatory document required for all public buildings over 1,000m^2 in size. It was implemented in October 2008 in accordance with the public display clause of Article 7.3 of the Energy performance of Buildings Directive (Davies, 2014). The certificate focuses on a building's operational energy use and its level of sustainability. The production of a DEC requires a visit from a qualified assessor to collect building parameters such as structure size, electricity usage, heating methods, lighting, and insulation methods ("EPC or DEC for building compliance," 2009). The assessor can gather additional information from building drawings and plans.

Similar to an EPC, a DEC utilizes a rating scale of A-G, with a score of an A being the most energy efficient and G being the least (See Appendix A). The reports accompanying the score certificate usually provide recommendations to help improve the energy efficiency of the building, reduce fuel bills, and encourage potential buyers and tenants to continue sustainable energy use practices. After the assessment, the score and recommendations are assigned a report reference number and then logged in the government's centralized register ("EPC or DEC for building compliance," 2009). Properties requiring a DEC must display the certificate in a visible location within the building for the public to see. Unlike EPCs, which are required only on new buildings or property transactions, a new DEC must be acquired annually but last for seven years. There is evidence already emerging on the value of DECs implemented in buildings, with many of them achieving year-on-year reductions in energy cost, resulting in the improvement to their ratings ("Display Energy Certificate," 2014).

Taberner House, the previous headquarters for the Croydon Council, received a DEC rating of F on its last assessment. The 19-storey building was constructed in 1964 and was very inefficient in its energy usage. BWH, however, has not been occupied for a full year and currently does not have a DEC rating. The Council will have to perform an assessment in September 2014.

2.2.5 Borough Plan

The Croydon Local Plan lays out the visions and goals for the future of the Borough and the methods that will be implemented to achieve those visions. The document takes account of the current and future challenges that Croydon faces and proposes the most effective solutions to address them up to 2031. The most important part of The Plan is section 6, A Place with a Sustainable Future. This section explains how the Borough can become more sustainable in its development and make preparations for a changing climate and environment (*Croydon Local Plan: Strategic Policies*, 2013).

In the 2013 plan, the Croydon Council set a target carbon emissions reduction of 34% by the year 2025. A series of clauses and policies were also included in the plan in order to reach this lofty goal. The first, Sustainability Policy 6.2, is concerned with the development of the Borough. It aims to ensure that development and construction are made accountable for minimizing carbon dioxide emissions and comply with the London Plan energy hierarchy (use less energy, supply energy efficiently and use renewable energy) to meet target reductions (*Croydon Local Plan: Strategic Policies*, 2013). The plan continues on to include policies specifically regarding sustainable design and construction.

Sustainable Policy 6.3 sets up the requirements for design and construction for new development, refurbishment and conversions. The council proposes that in order to meet carbon dioxide reduction targets, a high standard of sustainable design and construction must be implemented. This can be achieved by:

A. Requiring new-build residential development to achieve a minimum of Level 4 of the Code for Sustainable Homes or equivalent;
B. Requiring conversions and changes of use of existing buildings providing more than 10 new residential units to achieve a minimum of EcoHomes Very Good rating or equivalent;
C. Requiring new build non-residential development of 500m2 and above to achieve a minimum of BREEAM Excellent standard or equivalent;
D. Requiring conversions and changes of use to non-residential uses with an internal floor area of 500m2 and above to achieve a minimum of BREEAM Very Good standard or equivalent; and
E. Requiring development to positively contribute to improving air, land, noise, and water quality by minimizing pollution, with detailed policies to be included in the Croydon Local Plan: Detailed Policies and Proposals DPD.

-(*Croydon Local Plan: Strategic Policies*, 2013)

Points C and E of this policy are most pertinent to the construction of BWH because it is a public non-residential building over 500m^2. The Croydon Council also wanted to lead by example with their new offices at BWH and show how important sustainable development is to reducing carbon dioxide emissions.

They achieved this by designing and receiving a BREEAM “EXCELLENT” accreditation and requiring minimum accreditation levels for new buildings. The council hopes that their efforts through the Borough Plan will ensure new developments achieving high standards of environmental performance which addresses energy/water consumption, environmental impact of materials, waste, surface water runoff, and pollution. The implementations of these policies also mirrors that of London Plan 51 and are steps to achieve the objectives set out in Croydon’s Climate Change Mitigation Strategy and Climate Change Adaptation Strategy (*Croydon Local Plan: Strategic Policies*, 2013).

2.2.5.1 Croydon Council Urban Regeneration Vehicle

The Croydon Council decided to look forward into urban development and regeneration together with the private sector by creating a 50-50 partnership, which involves land investment from the Council and John Laing PLC investing equity and providing development expertise ("CCURV,"). John Laing is an international infrastructure investor and asset manager who leads on the market in the UK, Continental Europe, North America, and Eastern Asia. The company has expertise in management development risk, project asset management, operations, primary investment and secondary investment ("John Laing," 2014). This public-private partnership was established in 2008 under the name of the Croydon Council Urban Regeneration Vehicle (CCURV), which is one of the first Local Asset Backed Vehicle (LABV) between a local authority and a private developer. The CCURV consists of a 28-year partnership in which £450 million will be delivered for the regeneration of key sites in the Borough’s centre. Five development master plans were brought together and over five million ft^2 of development have been proposed, creating investment opportunities in the Borough despite the recession (Antoniu, 2012). This partnership seeks to increase emerging development opportunities and influencing the maximization of regeneration benefits. The partnership has targeted the development of areas such as employment, education and training, and supply chains to be included in these regeneration benefits ("Croydon CCURV,").

The CCURV promotes Partnership, Commitment, Quality, Innovation and Community as their core values in order to improve their business strategy, not only between partners but also with clients, colleagues, and suppliers. Also the urban regeneration vehicle seeks to use these values to achieve the objectives of the partnership which are listed below:

1. Enhance the quality and design of development in Croydon and ensuring that the Council has an influence and place shaping role in Croydon
2. Ensure the regeneration of Croydon and ultimately the wider Borough
3. Encourage employment generation and growth of a buoyant economy for Croydon
4. Ensure developments in Croydon offer the best and most appropriate use of sites, both now and in the future and ensure the sustainability of developments in Croydon

5. Revitalize town and district centres whilst retaining Croydon's character and sense of community
6. Provide affordable housing and supporting the long-term aim of increasing the number of residential accommodation units available in Croydon (including a drive towards higher quality and higher density residential accommodation within Croydon)
7. Provide a better environment for Croydon and its residents
8. Ensure environmental and sustainability objectives are achieved as set out in the Environmental Policy (the 'Green Commitment')
9. Ensure the best use of assets by adopting a whole-life approach
10. Provide place shaping accommodation to combat the Council's short-term and long-term accommodation requirements
11. Consolidate the Council's office holdings and reducing the operational costs on asset maintenance and operating multi-centres for the Council's accommodation requirements
12. Target investment in quality of place, creating healthy, safe, sustainable communities to help attract and retain businesses and skilled people within Croydon
13. Procure a return to the Members commensurate with their investment and the level of risk in respect to such investment and so far as consistent with the overall objectives to maximize the profits made by CCURV

-("Objectives," 2011)

The CCURV ground breaking projects were focused on the regeneration of public offices and housing areas. In the housing development area, the CCURV completed the Waddon Leisure and Housing project, which involved the construction of a new leisure space as well as 119 homes. Also, the old Taberner House building is planned to house around 400 residential units and 200 private rented sector units. The public regeneration movement has direct impact on BWH development and the building has became the cornerstone project for the CCURV ("Project Details," 2014). The building was designed to house the Croydon Council and other local service providers while also achieving BREEAM "EXCELLENT" office building standards. The CCURV partnership had direct influence in the creation of this new building that not only provides the community with a better facility to enclose the public affairs of the Council, but also delivers high level of socio-economic benefits to the Borough ("Bernard Weatherill House," 2014).

2.3 Building Research Establishment Environmental Assessment Method

The Building Research Establishment (BRE) was established in 1921 to provide advice to better the construction of individual buildings and communities. BRE is an impartial research group that aids various governments and the industry sector with knowledge of the environment and standards for sustainable development. Much of their research has focused on methods of energy and emissions reduction and methods for client awareness. The organization has implemented the Environmental Assessment Method (BREEAM), along with The Code for Sustainable Homes and The Code for Sustainable Built Environment, to combat climate change and environmental impacts. Through their programs, the company provides consultancy, research, testing, and sustainability recommendations to their clients. These programs provided by BRE are often used by the borough governments of London, but especially by the environmentally proactive Borough of Croydon. BREEAM and The Code for Sustainable Homes have been utilized as the main assessment methods for the Borough and continue to set standards for sustainability throughout the United Kingdom ("BRE," 2014).

The BREEAM is an environmental assessment method and rating system that is applied to many types of structures. The rating system aims to analyze and communicate the building's sustainable design, environmental impact, and operational performance levels. Since being launched in 1990, over 250,000 buildings have been assessed using BREEAM ("BREEAM: What is BREEAM?," 2013). BREEAM is fairly versatile and can be applied to new-construction, whole communities, in-use buildings, and refurbishments. Depending on an overall percentage of the points a facility receives from the assessment system, a building can be accredited with a rating of "PASS", "GOOD", "VERY GOOD", "EXCELLENT", or "OUTSTANDING" (Table 1).

Table 1: BREEAM Classification Ratings & Scores ("BREEAM New Construction: The Code for a Sustainable Built Environment," 2012)

BREEAM Rating	% Score
OUTSTANDING	≥85
EXCELLENT	≥70
VERY GOOD	≥55
GOOD	≥45
PASS	≥30
UNCLASSIFIED	<30

An assessment includes popular performance criteria such as energy and water usage, internal environment factors, pollution, transport, materials, waste, ecology, and management process (Table 2). Each of these sections has a maximum number of credits available and carries a specific weighting in the overall assessment score (See Table 3 for an example score). By obtaining a BREEAM assessment, building owners can compare the sustainability of their facilities against a benchmark as well as buildings with similar specifications. For the purpose of these comparisons, the assessment uses a transparent and easily understood scoring system. Since BREEAM addresses such a comprehensive range of environmental and sustainability topics, it is often used to make clients and building developers aware of the impacts their facilities have on the environment. It can be used to encourage designers to consider low impact development, minimal energy demands, and low carbon technologies ("BREEAM: What is BREEAM?," 2013).

Table 2: Weighting of environmental section in final scores ("BREEAM New Construction: The Code for a Sustainable Built Environment," 2012)

Environmental Section	Weighting
Management	12%
Health & Wellbeing	15%
Energy	19%
Transport	8%
Water	6%
Materials	12.5%
Waste	7.5%
Land Use & Ecology	10%
Pollution	10%
Total	100%
Innovation (additional)	10%

Table 3: Example BREEAM Assessment Score Report ("BREEAM New Construction: The Code for a Sustainable Built Environment," 2012)

BREEAM Section	Credits Achieved	Credits Available	% of Credits Achieved	Section Weighting	Section Score
Management	10	22	45%	0.12	5.45%
Health & Wellbeing	8	10	80.00%	0.15	12.00%
Energy	16	30	53.33%	0.19	10.13%
Transport	5	9	55.56%	0.08	4.44%
Water	5	9	55.56%	0.06	3.33%
Materials	6	12	50.00%	0.125	6.25%
Waste	3	7	42.86%	0.075	3.21%
Land Use & Ecology	5	10	50.00%	0.10	5.00%
Pollution	5	13	38.50%	0.10	3.85%
Innovation	2	10	20%	0.10	2%
Final BREEAM Score				**55.66%**	
BREEAM Rating				**VERY GOOD**	

All government funded buildings are required to reach a BREEAM "VERY GOOD" accreditation. BWH received an assessment of "EXCELLENT" on their assessment. More information will be gained on this topic when the team analyzes the actual BREEAM assessment.

2.4 Bernard Weatherill House

In accordance with the Borough Plan, the council moved their office building from an older inefficient Taberner House to the BREEAM rated BWH. Located on 8 Mint Walk in the centre of Croydon, this building is a standard of sustainability for developers in the Borough to follow. BWH was finished in 2013 and the council moved in during September of that year. BWH is 13 stories tall and has over 21,770m^2 of floor space, giving it enough room for several of the previously scattered local governmental buildings to consolidate under one roof. Its design allowed for terraced roofing, providing accessible amenity space for the occupants.

In order to achieve the high environmental standards set out by the council during the commission of the building, several sustainable design aspects were integrated into the design. Some of these design aspects are photovoltaic panels, combined heat and power (CHP) system, chilled beam air-conditioning, rainwater collection and a climate wall. Photovoltaic cells and the CHP system are used to offset the energy usage of the building by producing power onsite. Chilled beam air-conditioning is a high efficiency cooling system that uses convection to ventilate the air. Finally, the rainwater collected is used to flush toilets in the building. This system of design elements is run by a building energy management system to ensure maximum efficiency.

2.4.1 Energy Management Software Provider

The billing records for BWH are an important tool to measure the gas, water, and electric consumption of the building from the grid. These data points are collected by the energy auditing agency Targeting, Energy Auditing, and Monitoring (TEAM), which has three members working within the council to monitor and track the billing of utilities. The council specifically utilizes the company's web-based Energy and Carbon Management Software, TEAM Sigma. This modular system allows for the management of energy and fuel data from a number of suppliers across multiple sites ("TEAM," 2014). Some of the features that the TEAM Sigma package provides include accrual management, analysis and browsing, bulk bill checker, budget management, performance map, performance overview, reporting, and an overview dashboard ("TEAM," 2014).

The information collected on this system can be accessed and shared through a browser interface and can be shown on customizable dashboards. Different levels of access can be set for different users, depending on their requirements. This would be useful for sharing information with the public on the usage of different utilities, while preserving full access to the members of the council who need it. The system also provides several methods to generate reports. A dashboard could be customized to display an interactive map, real time data, graphs, and any other information concerned with utility usage the council would want to present to the public (Figure 2).

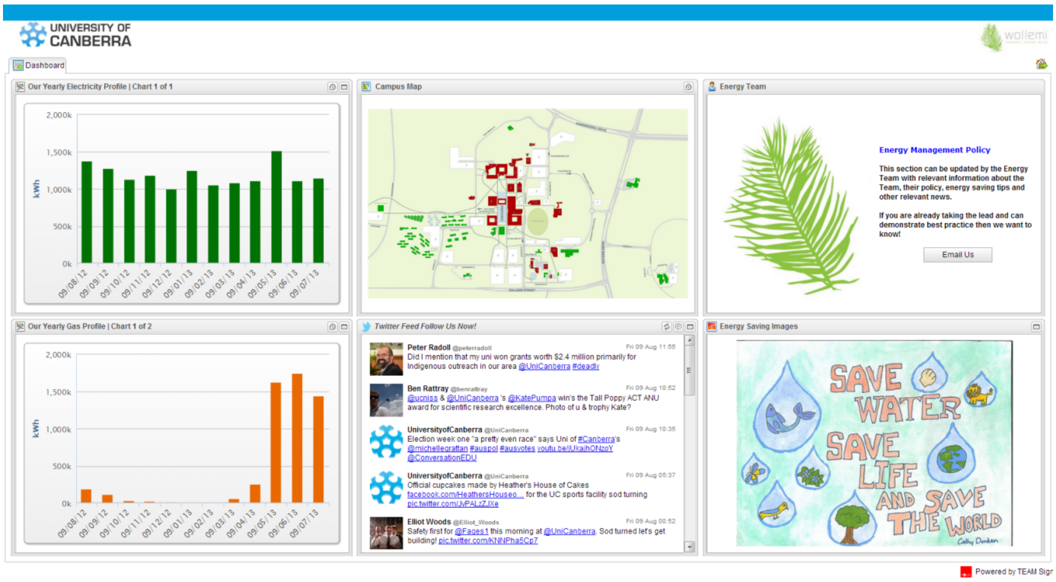


Figure 2: TEAM Sigma dashboard for University of Canberra ("TEAM," 2014)

An online dashboard similar to that used by the University of Canberra (above) might work well as a display to the public of the energy usage of BWH and the other council buildings. The dashboard shows an interactive map of the University with the user having the ability to select a certain building and view its usage data. This could be useful to the Council because they could include the energy usage of the other Council buildings around the Borough Centre. The dashboard also shows annual gas and electricity usage plots, which would give the public an idea of the efforts put forth by the council to operate in a sustainable manner. The council might be interested in showing the usage from different time frames (year to year or season to season). Finally, there are two message boards on the dashboard, which the Council could relay content on BWH and other sustainable development projects they are working on.

2.4.2 Building Energy Management Systems

A Building Energy Management System (BEMS) is an automated piece of equipment that operates and monitors buildings electrical systems such as air-conditioning/heating, lighting, energy generation, and even security (Trend, 2014). These systems use a series of sensors along with the known occupant usage patterns to optimize the use of the facilities and eliminating waste. In a case study done on residential buildings in Italy, researchers found that a properly installed BEMS would, on average, reduce the building's electrical usage by about 25% depending on the original efficiency of the house (Ippolito, Riva Sanseverino, & Zizzo, 2014). A 25% reduction in energy usage makes the BEMS an essential component of any high-efficiency building.

2.4.2.1 Trend

To monitor and operate the energy systems in BWH, the building design team implemented Trend as the BEMS. Founded in 1980, Trend is based out of the UK and has quickly become one of the leaders in the BEMS manufacturing industry. Their systems comply with many of the accepted industry standards for energy usage (Trend, 2014). Trend prides itself on the ability to take its global expertise on building to optimize a buildings energy usage. It uses a method similar to the engineering design process. The four steps of the Trend optimization process are as follows: Review, the BEMS design criteria are compared to the buildings needs to ensure performance; Monitor, the energy use is watched to spot irregularities that may lead to inefficiencies; Demonstrate, these energy findings are shown to stakeholders and designers; and Optimize, based on the findings parameters of the design are altered to deliver a better performance (Trend, 2012). This is a cyclic process of constant review and optimization to ensure the building is operating in a sustainable fashion.

2.4.3 Building Performance Gap

While the certification systems and design models for the performance of a building are helpful to create a standard to judge buildings on their sustainable measures, the accuracy of these scales have shown to be lacking. The widely recorded discrepancy between the predicted and the real energy performance of many green buildings has been labelled as the “Performance Gap.” This performance gap is an issue facing those who work with sustainable building, as it undermines the accreditation. It can also make potential clients hesitant on commissioning a building when the performance of the facility cannot be guaranteed. There is no single cause to this problem, as described in World's Greenest Buildings: Promise Versus Performance in Sustainable Design by Jerry Yudelson and Ulf Meyer. They break down the cause of this gap into three categories; poor occupant practices, faulty or improperly installed equipment, and inaccurate model.

While a building might be efficient and well insulated, poor occupant practices such as an open door from a careless employee can eliminate any efficiency the building may have. While most poor sustainable practices are not as blatant as leaving a door open, they do include less noticeable practices such as leaving a computer on overnight or forgetting to close a cracked window. A study by the New Buildings Institute that looked at the effects of occupant behaviour on a building’s energy performance showed that occupant behaviour can alter a building’s performance by as much as fifty percent (Heller, 2011). The study pointed to lax occupant sustainable practices as a primary driver to this large variance in building performance. In a study by LEED, evidence showed that in automated buildings, like those with BEMS, occupants showed poorer sustainable practices than in buildings without high levels of automation. The study concludes that by simply making occupants more aware of their actions in the context of energy conservation has shown to lower the energy usage of a building (Menezes, Cripps, Bouchlaghem, & Buswell, 2012).

The BEMS and connected equipment do often fail or run outside of their intended parameters, leading to a higher energy usage. A study in California showed that over half of the air sensors in the surveyed buildings were not working as intended. Defects in the manufacturing process and improper control logic were the causes of these faulty sensors (Yudelson & Meyer, 2013). In another study by The Lawrence Berkeley National Laboratory found that ninety percent of HVAC, or heating, venting, and air-conditioning, systems didn't work properly in the first year (Yudelson & Meyer, 2013).

As described in the Trend handbook, a common scenario in these buildings is a sensor falsely reading too high of a temperature, which causes the BEMS to keep the room at an uncomfortably cold temperature. The occupants cannot easily change the automated system so they bring in space heaters. The space heater warms the space, but the BEMS tries to cool it back down. This battle between space heater and air-conditioning consumes a great deal of energy (Trend, 2012). As the building ages the usage patterns can change and the layout of rooms can be altered from the original design. These changes need to be reflected in the BEMS in order for the building to run properly (Trend, 2012). A storage room that is converted to a server room needs to be fitted with a different set of sensors and control logic. These changes are needed, as a server room has different operating temperatures and a higher cooling load than a storage room. Close monitoring of the building's performance and communication between the occupants and the BEMS technician can lead to these scenarios becoming a rare occurrence.

In many cases neither the occupant nor the building are performing poorly but still there is a large performance gap remaining. This is due to inaccurate modelling of energy usage. Predicating a building's energy use can be a challenging feat, as there are many small variables to take into account. Energy usage is categorized into five groups; heating, cooling, fans/pumps, lighting, and small power. Small power is the energy used by devices plugged into a socket. Most of these categories are relatively easy to model, but small power is by and far the most difficult to predict. In the case of heating, the heater efficiency times of use known and easy to model. Using building's insulating properties and the regional climate, the typical heating requirements throughout the year can be estimated. The parameters around the use of heating are either known or controlled which makes modelling its usage easy.

However, small power is much more difficult to measure because it is uncertain as to what appliances are being used. In a study by the Chartered Institution of Building Service Engineers, the current standards for estimating small power did not reflect the power usage in the field. In the case of computers, the study found that the actual usage was much higher than the model predicted. It also showed that the energy usage between a low powered laptop and a high end desktop could easily differ as much as four hundred percent (Menezes, 2013). With so much variance just between computers it makes it hard to predict their energy usage within a building. Large variances between appliances of the same type were also found in fridges, televisions, microwaves, printers, photocopiers, and vending machines. This large degree of uncertainty in the power requirements of appliances makes small power hard to predict. As described in the Trend handbook, when an appliance has a higher energy usage it generates more heat, which puts higher cooling demands on the building further increasing the energy usage.

2.5 The London Borough of Croydon

The Borough of Croydon has had many industrial developments in the last century, which has resulted in a very diverse region and culture. This history in large-scale buildings began in 1915 when the Croydon Airport, the first international terminal in London, was built. This encouraged an influx of ideas, which were funded in part by the Croydon Corporation Act of 1957, which granted of 500,000m^2 of office space in 7 years. After this development was the growth of shopping centres in the 1980's and 1990's, followed by the construction of a train station in East Croydon in 1992.

These developments are important because this variable culture in Croydon resulted in its nickname: "the Borough of contrasts" (*Croydon Local Plan: Strategic Policies*, 2013). It was also during this time that the local government began to realize that many buildings in Croydon were not designed sustainably. In an effort to strike a balance between the sustainable buildings and Croydon culture, the Croydon Local Plan was initiated in 2011. The goal of the Croydon Local Plan was to create "strategic policies…to maintain the feel of Croydon while allowing it to expand"(*Croydon Local Plan: Strategic Policies*, 2013).

This project is sponsored by the London Borough of Croydon, specifically the Croydon Council's Sustainable Development and Energy Team. The Croydon Council is a public entity that is funded with governmental resources.

2.5.1 The Sustainable Development and Energy Team

The Sustainable Development and Energy Team mainly deal with management services and reducing the council's overall energy consumption. Their mission is to align the council's own actions and usage with the Carbon Management and Energy Efficiency Plan that was put in place for the Borough. The team also branches out to support energy efficiency projects throughout Croydon and to offer initiatives to lower domestic energy use. Finally, the team reviews environmental impacts of planning applications and promotes/supports planning policies that foster sustainable development.

This project addresses the possibility of a significant gap in the building's sustainable performance, which would represent a discrepancy between the council's existing regulations on sustainable development and their actual proceedings. As the governing body enforcing the regulations, the Council is expected to lead by example on sustainability. Having a new office building that was planned to perform as an environmentally friendly facility shows their dedication to sustainable practices and compliance with the new regulations. The Croydon Council has made efforts to not only design a green building but also use systems that will help them monitor and achieve the planned level of sustainability. Figure 3 displays the different divisions of the Croydon Council; the team will work with all the areas under the Chief Executive Office.

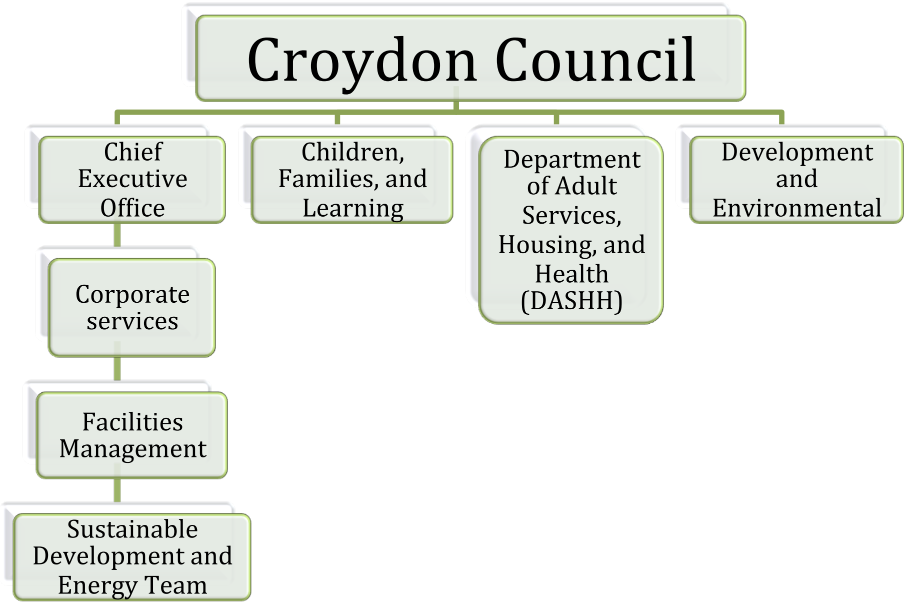


Figure 3: Divisions of the Croydon Council

2.6 Background Conclusion

The project will be looking at the current energy practices and comparing them to those in the design of the building. For this we will need to look at the energy demands of the building by source. This will be provided by the Trend program, which has the real time energy demand of the building. The designed energy usage will have to be ascertained from our sponsor in a report done by the design engineer. BRE (Building Research Establishment) is an accreditation agency that has rated this building. They work to make an easy-to-use scale that accurately measures a building's environmental impact. The performance gap is an issue for them, as they have to update their model in order to prevent this gap from making their accreditation system obsolete.

CHAPTER 3: Methodology

The focus of this project was to assist the Sustainable Development and Energy Team of the London Borough of Croydon to evaluate the energy and sustainability performance standards of Bernard Weatherill House (BWH). The team calculated the operational energy performance of the building using real time data and displayed the energy flow through engaging visuals. We also analysed the usability, comfort, and occupant satisfaction in relation to the sustainability of the facility. Finally, we compiled a list of energy management service providers into a portfolio to be used by the Facilities Management Department.

The major objectives for this project were completed in the following order:

1. Reviewed the design plan for the energy sustainability of BWH
2. Assessed BWH's predicted versus in-use energy performance
3. Evaluated any performance gaps of the facility against accepted sustainability standards
4. Analysed the occupant's opinions and use of the building
5. Provided the Council with a portfolio outlining the services and benefits of Energy Management software and bureau service providers
6. Designed visual tools that communicate to the public how the building performs and raised awareness of the energy use to contribute to behaviour changes
7. Made recommendations to the Croydon Council for further sustainable practices

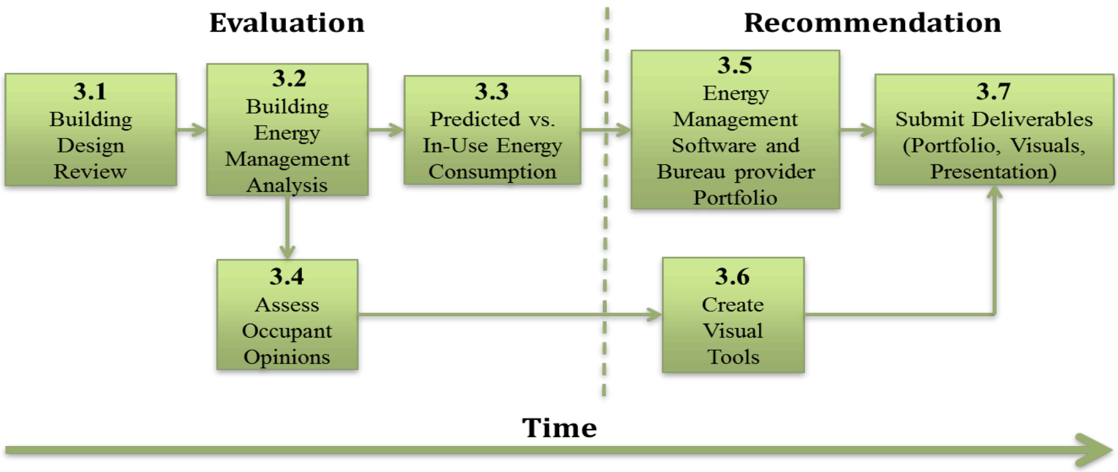


Figure 4: Linear intentions of our project

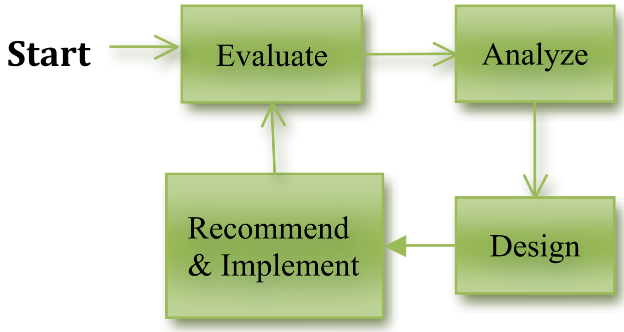


Figure 5: Cyclic design for the project in the future

This project was run similarly to the engineering design since it is a cyclical design process of continual improvement (Figure 5). First, the team evaluated the building's design and energy use to understand the current state of the building and to compare it to the designer's plans. This step included a review of the design plans, an audit of the building's performance, and outreach to the occupants to understand how they feel about the buildings performance. This process is described below in sections 3.1, 3.2, and 3.4 of the methodology. Once we understood the current state of the building and its intended performance, we began to identify and analyse these performance gaps. Then, solutions to reduce the performance gaps were designed alongside visual tools to communicate the building performance to the building occupants. Solutions were customized to address each gap once its nature is known. The design step is covered in sections 3.3 and 3.5. These solutions were then implemented or recommended to the council, depending on the scale of the solution in section 3.7. During this phase our team assessed the effectiveness of BWH on an economic and environmental basis, as covered in 3.6. This analysis was done during the recommendation phase to incorporate the most amounts of data. Once the recommendations are made, the building was evaluated for performance leading back into the first phase. The WPI team or a volunteer "green team" of BWH employees will continue this cycle.

3.1 Review the design plan for the energy sustainability of BWH

A complete review of the energy and sustainability design of the building was done with available information. The team obtained the energy strategy for the building, which was called the Public Service Delivery Hub (PSDH) at design stage but will be referred to throughout the paper as the BWH Energy Strategy, and found the considerations that influenced the facility's design. The team investigated part L2A of the Building Regulations to understand the calculations that were performed by Faber Maunsell using industry standard Integrated Environmental Solutions (IES) Virtual Environment software. The team intended to contact the design firm to gather further information about the energy design process. Unfortunately we were not able to contact Faber Maunsell because it merged into AECOM and the contact information for the person responsible of the BWH Energy Strategy was no longer current. The team also performed its own calculations to analyse an optimized wind turbine power arrangement. After the team obtained a general understanding of the design energy estimation process, we proceeded to analyse and define the predicted energy use on a monthly basis and other targets such as the quantities of CO_2 emissions.

The design phase BREEAM accreditation was also reviewed and analysed. We started by looking at the different categories that were included in the assessment, which include management, health and wellbeing, energy, transport, water, materials, land use and ecology, and pollution. Then the calculation processes were analysed to find any discrepancies. For some calculations the team was not able to verify their accuracy due to lack of information. Finally, the categories where maximum credits were not achieved were evaluated as to whether or not it would be feasible to gain more credits in those areas. We were able to use this preliminary report to make comparisons to the initial energy strategy provided for the council by Faber Maunsell and find any discrepancies.

To conclude this first objective the team proceeded to compile all the information and analysis from the Energy Strategy into a database that was used to assess and compare the predicted consumption versus in-use energy performance.

3.2 Assess BWH's predicted versus in-use energy performance

In this project, the team accounted and compared the building's in-use energy to the design energy consumption values. We worked with the Trend system to collect the energy consumption data. The utility bills were also analysed and aggregated to create a better perspective of the amount of energy and types of sources the building is using.

By aggregating the energy consumption data from half hourly measurements we created a database containing information about the energy consumed since the building started operating. The team also incorporated the use of BWH's Building Management System (Trend) and used its multiple monitoring points to obtain data. Trend monitors all the energy systems of the building, which allowed the team to collect data that was recorded continuously. Unfortunately, the measurements had vast degrees of variance and could not be considered consistent for all data points. To counteract these inconsistencies, the team statistically analysed the different control points and floors. The team located the best data from the trend monitoring point first by excluding negative values for lighting and small power, and then by excluding all values that did not fall within a 99.7% confidence interval of the remaining average. A 99.7% confidence interval was calculated by adding and subtracting three standard deviations from the average of the non-negative lighting and small power data. Then, the team normalized the data by dividing each value by the floor's respective population and square footage to better compare data between floors.

For the pumps a similar process was performed, except the distinction was the type of pump rather than the floor number. Once we had a set of data that didn't contain any obvious outliers, we averaged out the points to find the weekly average usage. We summed the weekly average of all the pumps for the first thirty weeks of the BWH's performance and multiplied by fifty-two to find the predicted yearly usage.

After the first two criteria were applied to the lighting and small power data, a third criterion was applied to the remaining data. First, a line of best fit was created from the averages of each floor's energy consumption. Second, a 99.7% confidence interval was created around each data point. Third, any intervals that did not overlap with the line of best fit were replaced with the corresponding value from the line of best fit. The team also collected data of the energy produced by the PV solar panels installed in BWH's roof. In the case of the Combined Heating and Power (CHP) system used at BWH, the energy produced was calculated using known values for hours of operation and efficiency.

Small power also required one additional step of data processing. Because the values presented by the Trend software was so low, the fifth floor was used as a model for the total energy use of the building. This was accomplished by enumerating all the electrical equipment in use on the fifth floor. Then, a factor of total power usage per day was applied according to Table 4.

Table 4: Total power usage per day factors

Device	Percentage of Use per Day
Computer	37.5%
TV	50%
Dishwasher	50% (1 cycle every 2 days)

Once the total small power use was found for the fifth floor, it was normalized per person and per square meter. This was compared to the Trend data that was also normalized per person per square meter. Dividing the estimated small power use by the Trend data's measurement of the fifth floor resulted in a multiplier that was multiplied by the remaining Trend Data. Then, the normalized data was converted back into annual small power energy use by multiplying each floor by its respective population and area.

Energy Accounting Method

There are different methods for energy accounting; the most common approaches are listed below:

- Present-to-past comparison
- Multiple year monthly average
- Temperature corrected method – heating degree days/cooling degree-days
- Correction for changing square footage

-(Knox, Lew, Mills, & Sloss, 2000)

The Present-to-past comparison was the most relevant method to this project. Because the building had not been in use for a complete year, the estimated energy values were used as reference data for the comparison. The estimated energy values were collected from a graphic in the energy plan of the building. The values were not explicitly given to us in the graphic. By measuring the graph and applying a scale the team was able to approximate each monthly consumption value. This process gave us reference points for gap identification in the next objective. To obtain reasonable comparisons between time periods, the collected data in each billing period has to be prorated by month (Knox et al., 2000). The energy consumed in any time period was allocated to a monthly input. This allowed the team to have a direct comparison for similar time periods.

Graphics
We used charts and graphs that displayed the distribution of energy sources, energy uses and amount of energy used per month (Figure 6 and Table 5) in order to find the data needed for our research.

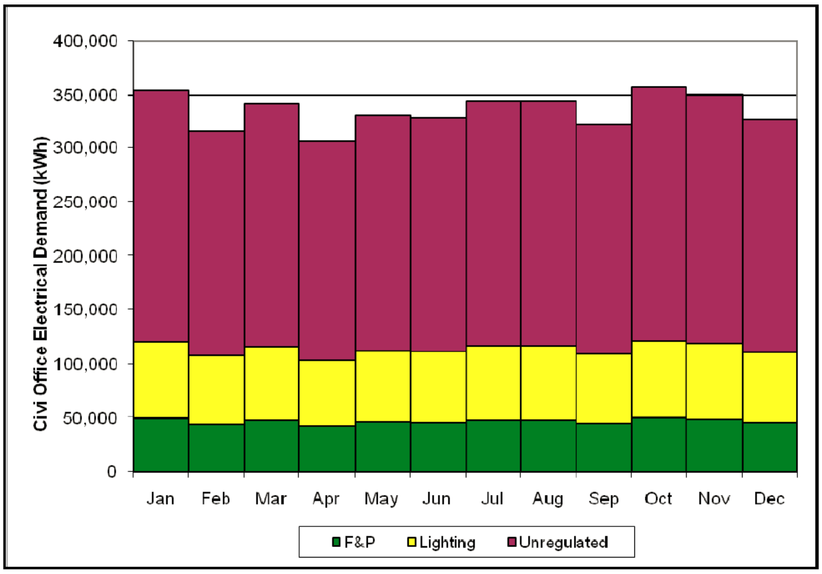


Figure 6: Predicted BWH monthly electricity use

Table 5: Yearly predicted energy usage from the BWH Energy Plan

	Building energy demand (kWh/year)	Type of fuel	Fuel use (kWh/year)	CO_2 emissions (tonnes/year)	% of CO_2
Heating	266,732	gas	310,153	60	3%
Hot Water	216,554	gas	251,808	49	3%
Cooling	1,801,927	electricity	286,020	121	6%
Lighting	759,553	electricity	759,553	321	17%
Pumps & fans	558,086	electricity	558,086	236	12%
Small power	2,704,546	electricity	2,704,546	1,141	59%
Total	**6,307,399**	-	-	**1,927**	100%

3.3 Evaluate any performance gaps of the facility against accepted sustainability standards

Once the actual and predicted consumption of energy were compiled into one database, the performance gaps became evident. After identifying the performance gaps, it was important to identify the causes of the gaps. By understanding the causes of the gaps, we were able to make recommendations to further the building's sustainable performance.

There are several causes of performance gaps discussed in CHAPTER 2: Background that includes improper use by the occupants, unrealistic performance modelling, and equipment issues. To get a general sense of the possible locations of the performance gaps, we studied the compiled data and looked for trends that could signal why a performance gap has occurred. For example, if building zone consistently has a high energy use at a specific time of day, we were able to identify the cause using the compiled data.

With a general sense of the causes of performance gaps, we were able to pinpoint the exact nature of these causes. Occasionally, it was necessary to manually check the electricity use of the building by floor and compare it to the measured electricity use in the BEMS. This was done to ensure that the BEMS has been programmed to the design engineer's specifications. The arrangement of the office in relation to the temperature sensors was also evaluated. The team checked with the design engineer's modelling that the BEMS is up-to-date and re-evaluated it according to the newest model. We spoke with the building occupants about what they have observed in the workplace that could lead to inefficiencies. A survey was made to accomplish this task.

While we uncovered the causes of the possible gaps, the current energy performance was compared to the required performance needed to maintain "EXCELLENT" status by BREEAM. The "EXCELLENT" energy performance standard was compared to the actual energy use data of BWH. Since the building has been in operation for less than a year, the data were adjusted to include expected energy usage for an entire year. This was done by looking at the energy usage trends of other buildings in the area (e.g. the old council building) and using that trend to complete a full year of energy usage. After we discovered the full year energy usage of BWH and the needed energy usage to maintain the "EXCELLENT" rating, the required performance improvements were determined. Figure 7 shows a graphic illustration of this process. While we may not be able to close all of the performance gaps many were minimized or eliminated. By having required performance improvements, we were able to gauge how much needs to be done.

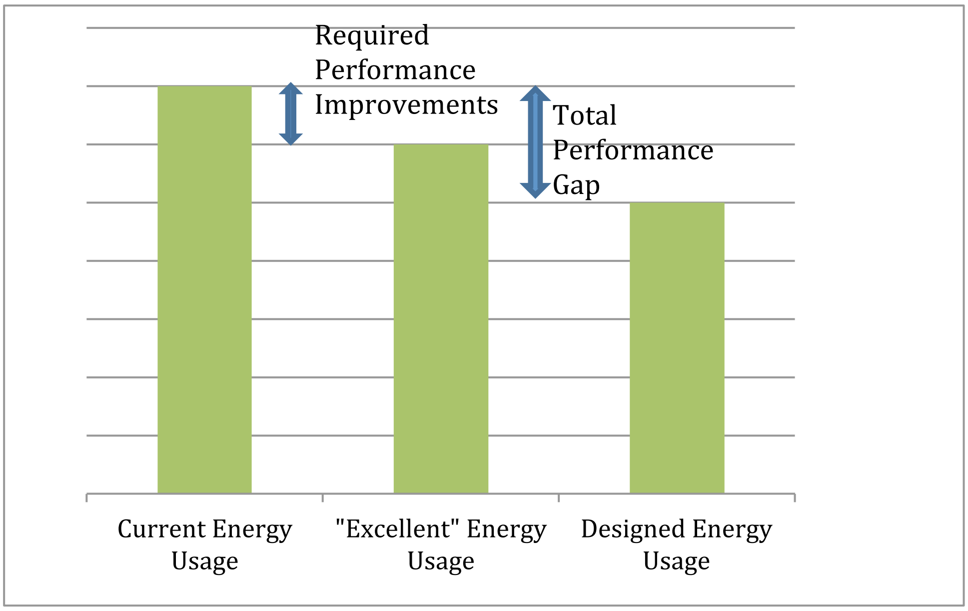


Figure 7: Example illustration of performance gap

3.4 Analyse the occupant's and public's opinions and use of the building

The start of this objective was important because it marked the point where our project broke into qualitative and quantitative data collection. All of the previous objectives had dealt with hard numbers collected from the Trend system, pre-construction design documents, billing records, and calculations. This objective explored the liveability portion of a building's performance and provided a novel set of data for the council. Liveability considerations are typically left out of life cycle analysis methods but are excellent indicators behind a building's performance. As mentioned in previous sections, the battle between faulty automated systems versus actual liveability is the root of many energy overuse problems. It also provided a starting point for behavioural changes and implementation of more sustainable practices. We aimed to understand the occupant's feelings towards the building, if it is a comfortable workspace, if it is "considerate" of their needs, and if they would like to see it improved.

Survey

The team conducted a modified Occupant Indoor Environmental Quality (IEQ) survey to obtain information about the working conditions and comfort level of BWH. The Occupant IEQ survey was developed by the Center for the Built Environment, in conjunction with the University of California, Berkeley, to standardize the collection of information on building performance and occupant satisfaction. They work to "develop new ways to 'take the pulse' of buildings in operation: measuring the occupants' responses to their indoor environments, and linking them to improved physical measurements of indoor environmental quality," ("Occupant Indoor Environmental Quality (IEQ) Survey,"). Occupant surveys are a crucial method to gain information for improving building performances. They allow for the gauging of building design features and whether or not they are working properly ("Occupant Indoor Environmental

Quality (IEQ) Survey,"). The Center has developed a web-based, confidential survey to collect occupant satisfaction and building system performance data. The survey we used was adapted from a version of the Center's generic demo survey, which was found and viewed for free on their company website.

A standard IEQ survey includes questions on key aspects of the indoor work environment of the building. This would include acoustic quality, air quality, cleanliness and maintenance, lighting, office layout, thermal comfort, and general comments ("Occupant Indoor Environmental Quality (IEQ) Survey,"). The questions for our adapted survey inquired on the performance of the building systems specific to BWH. Our survey differed from a standard IEQ because we also included an "awareness" set of questions. This section allowed us to gauge how aware the occupants were of the many environmentally conscious features their workplace offers. This set of questions targeted the "awareness" of topics such as rainwater collection, absorption chillers, photovoltaic panels, and lighting sensors and dimmers. The questions used on the survey can be found in APPENDIX B.

The team performed the survey independent from the Council's Employee Engagement and Internal Communications Department, which is normally responsible for the distribution and analysis of Council surveys. Instead, it was conducted through the Chief Executives Department, which includes the Sustainable Development and Energy Team and the Facilities Management Team. It was decided to perform the survey through the Chief Executives Department because responses to the "awareness" portion are most valuable to their work. This survey was conducted through the WPI Qualtrics Research Suite, which is online survey software that allows for the collection, analysis, and display of survey data.

3.5 Provide the Council with a portfolio outlining the services and benefits of Energy Management software and bureau service providers

In 2016 the contract between the Croydon Council and Interserve, the facilities management company for BWH, will expire. Interserve currently provides the buildings energy management for BWH as a part of their broad range of services; however, it is not their primary focus. Our liaison was interested in exploring several other energy management providers in order to make recommendations to the Council for the outsourcing of energy management.

Several providers of interest were presented by our liaison and several others were found through personal research. Two different methods were used to research the providers. Company websites and brochures were accessed and general information was compiled into a portfolio for the Council. Each company's benefits and services were reported in this portfolio as well as contact information and visual examples of their online dashboards. However, it was difficult to judge the usability and customer satisfaction for each provider solely by their company webpage so a second method was used.

The second method to research the companies included interviews with some of the other boroughs of London. A list of contacts in other boroughs, which was partly provided by our liaison, was utilized to set up six interviews. These interviews typically lasted about thirty minutes and focused on each borough's current energy management provider. Many of the questions asked them how they liked their provider, if they had issues with them, what services they wish were offered, or how many buildings were being monitored. These questions gave us a better sense of how well these service providers worked and allowed us to get a better picture of the service. The general template used for the interviews with borough representatives can be found in APPENDIX C.

3.6 Design visual tools that communicate how the building performs and raise awareness of energy use to contribute to behaviour changes

Communicating BWH's energy performance to its occupants and to the public is a major goal of the Croydon Council. The Council has a continuous interest in raising public awareness about energy consumption and to enact a change in the public's disposition towards energy sustainability. The focus of this section is to describe visual tools that were used to communicate BWH's energy usage.

BWH's energy consumption information was combined into a Sankey diagram because the energy generation is broken into specific parts and the gross energy consumption is also drawn from several energy sources. A Sankey diagram is a directional flow chart, where the magnitude of the arrows is proportional to the quantity of the flow. Our Sankey diagram outlined the energy consumption of the building, and specified to what part of the building the energy is supplied. A Sankey diagram can include cycles to incorporate any energy production supplied by BWH. Our team decided to produce a Sankey diagram that illustrated how energy is generated, transformed, and allocated throughout the building and its systems.

These infographics can be displayed weekly, monthly, quarterly, or annually, according to the discretion of the Croydon Council. An example of a Sankey diagram that may be used by the Croydon Council can be seen in Figure 8.

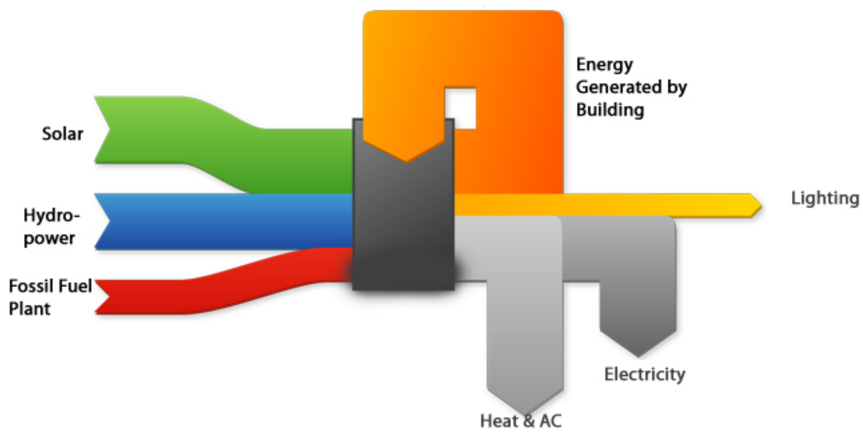


Figure 8: Example Sankey diagram for electricity usage

To create the appropriate Sankey diagram that expressed the energy flow in BWH, the team experimented with different software such as Sankey Helper 2.4, SDraw Demo, and e!Sankey. It was necessary to find an option that allowed a cyclic loop flow and detailed processes. We used the e!Sankey 3 free trial version which allowed the use of tutorial files to understand how to create the diagram.

The software refers to a “Process” as the nodes where the energy flows converge or diverge. These flows are simply named “Arrows”, which vary in width, depending on the given input values. To create an “Arrow” first we needed to define “Entries”, which are categories of flow and can be defined as mass or energy. Their colour and unit can be modified. They colour coded each type of energy used and delivered such as Gas, Grid Electricity, Electricity generated onsite, Electricity, Thermal Energy, and Energy Loss. This can be noted in Table 6 and in Figure 18 of Section 4.6 Visual Tools Findings. The team decided to use images to represent each one of the “Processes” so that that the Sankey diagram is visually appealing and easier to understand.

Table 6 shows the different input and output values for each “Arrow” in the diagram. For determining the values that were not specified in the BWH Energy Strategy we used Table 6. We performed calculations based on defined efficiencies of equipment and then balanced the remaining unknown quantities to obtain the best representation of how the energy is distributed throughout the building.

Table 6: Energy flow spread sheet for Sankey diagram

Electricity Use				
Inputs	**kWh per year**		**Output**	**kWh per year**
From PV	22,000		Electric Chiller	1,540,427
From Grid	4,645,712		Lighting	759,553
From CHP	894,900		Pumps and Fans	558,086
			Smalll Power	2,704,546
Total	5,562,612		Total	5,562,612

Electric Chiller				
Input	**kWh per year**		**Output**	**kWh per year**
Electricity	1,540,427		Cooling	1,515,907
Unknown Efficiency				
			Estimated Energy Loss	24,520

Gas Use				
Inputs	**kWh per year**		**Output**	**kWh per year**
Gas	3,025,708		CHP	2,773,900
			Boiler	251,808
Total	3,025,708		Total	3,025,708

Boiler				
Input	**kWh per year**		**Output**	**kWh per year**
Gas	251,808		Hot Water	216,554
86% Efficiency				
			Energy Loss	35,254

CHP				
Inputs	**kWh per year**		**Output**	**kWh per year**
Gas	2,773,900		Electricity generated by CHP	894,900
			Town hall heating	636,947
			Absoprtion Chiller	261,500
			Heating	266,732
Total	2,773,900		Total	2,060,079
			Estimated Energy Loss	713,821

Absorption Chiller				
Input	**kWh per year**		**Output**	**kWh per year**
Thermal Energy	286020		Cooling	261,500
Unknown Efficiency				
			Estimated Energy Loss	24,520

Total energy (electricity & gas)	8,588,320

Finally, the team produced two simplified versions of the Sankey diagram that only included the electricity consumption flow. These diagrams represented the annual design electricity consumption and the in-use energy use distribution. These diagrams can be found in APPENDIX D.

3.7 Make recommendations for further sustainable practices

Based on the findings in the other sections, our group made a series of recommendations to the council to further their environmental performance. We focused on the findings pertaining to the buildings energy performance, the BMS report, and the occupants' knowledge of the buildings features to shape the recommendations for sustainable practices. A final presentation was also used to communicate the results of our findings to the council.

CHAPTER 4: Findings and Analysis

The following section provides a detailed presentation of the major findings from our project. These findings are grouped into six main categories to roughly correlate with our objectives from the methodology section. They are further broken down into more specific subsections and can be seen below:

1. BWH Sustainability Specifications: Predicted Building Performance
    a. Design phase goals for BWH energy usage were difficult to identify
        i. Carbon reduction estimates were inconsistent in the BWH Energy Strategy
        ii. Monthly energy usage estimates were difficult to obtain from the BWH Energy Strategy
    b. The design phase BREEAM accreditation could be improved in the categories of health and wellbeing, energy, transport, water, land use and ecology, and pollution to obtain a higher BREEAM accreditation.
    c. A post-construction BREEAM accreditation could not be located
2. Building Energy Analytics: Overcoming Data Limitations
    a. The Council was billed for the correct amount of electricity
    b. The mains gas meters were improperly calibrated and could not produce a reliable breakdown of gas usage
    c. Trend data points were largely inconsistent and missing
    d. Trend was recording 9 times smaller than actual small power values
    e. Control points did not have clear names or cataloguing
3. Building Performance: Design Phase vs. Actual Performance
    a. Electricity use was 42.3% higher than predicted
    b. Small power was about 29% higher than predicted values
    c. Lighting energy usage was approximately 4.3% less than predicted values
    d. Combined Pump and Cooling energy usage was at least 12% higher than predicted
    e. PV solar panels were performing within 15% of predicted values
4. Energy Management Software Providers
    a. Seven companies are capable of providing the services necessary to the council
    b. Eight boroughs currently use or have used similar outsourcing methods for bill validation, analysis, and reporting
5. Occupant Satisfaction Survey: Gauging Occupant Opinions
    a. Work Environment Satisfaction
        i. 76% of respondents thought that the overall working environment of BWH was better than the working environment of their previous council building
        ii. There was a positive response to all specific work environment categories (airflow, visual comfort, etc.) except for temperature
    b. Occupant Awareness of BREEAM Accreditation and Environmental Features
        i. 32% of respondents were aware of the building's BREEAM accreditation

ii. Many of the occupants were aware that the building utilizes photovoltaic panels, automated lighting, and rainwater collection as environmentally friendly features

c. Respondent Recommendations

i. The majority of respondents thought that it would be valuable for occupants and staff to see a visual display of BWH's energy usage

ii. The lift lobby on each floor was the most preferred by respondents as a location for a visual display

iii. An education plan for recycling and the reduction of paper use were two major concerns for many of the respondents

6. Visual Tools for Occupant Awareness

a. Sankey diagrams can display complex and complete energy systems, making them easy to understand and ideal for raising energy use awareness.

b. Sankey diagrams highlighted BWH energy consumption in specific areas

c. Data for producing a complete Sankey diagram of in-use energy consumption was not available or accurate

A large portion of this chapter is concerned with the inaccurate data encountered in both the design phase BWH Energy Strategy and the actual in-use Trend data points. This is discussed in the BWH sustainability specifications, Building Energy Analytics, and Building Performance sections of the chapter. Encountering poorly calibrated and inconsistent data points was a large hindrance to the completion of the project. Recommendations for each category of findings can be found in CHAPTER 5: Conclusions and Recommendations.

***Note:** Throughout this report the word "predicted" is used in connection with values obtained from the BWH Energy Strategy and the word "estimated" is used in connection with values calculated by our team.

4.1 BWH Sustainability Specifications: Predicted Building Performance

This section provides detail on the analysis of the design specifications of BWH. The team analysed the BWH Energy Strategy document, prepared by Faber Maunsell, and evaluated the design phase BREEAM assessment. The numerical findings from this section provided an important baseline for future comparisons with the actual in-use values.

<u>Major findings of this section:</u>

1. Design phase goals for BWH energy usage were difficult to identify
    a. Carbon reduction estimates were inconsistent in the BWH Energy Strategy
    b. Monthly energy usage estimates were difficult to obtain from the BWH Energy Strategy
2. The design phase BREEAM accreditation could be improved in the categories of health and wellbeing, energy, transport, water, land use and ecology, and pollution to obtain a higher BREEAM accreditation
3. A post-construction BREEAM accreditation could not be located

4.1.1 Design phase goals for BWH energy usage were difficult to identify

The review of the BWH Energy Strategy presented numerous challenges, which are described in the following two subsections. Due to incomplete explanations, it was difficult to understand the design values for energy usage. These included the carbon reduction estimates and the predicted energy consumption. A complete analysis of the BWH Energy Strategy can be found in APPENDIX E.

4.1.1.1 Carbon reduction estimates are inconsistent in the BWH Energy Strategy

When analyzing the carbon emission regulations values, the BWH Energy Strategy document was inconsistent. The Target Emissions Rate (TER), which is the maximum value for emissions produced onsite, was consistent throughout the document. However, the predicted in-use carbon emission values, Building Emissions Rate (BER), changed throughout the document. As a result, the percentage difference between the TER and BER changed multiple times from 27% to 23% throughout the Energy Strategy. It was not possible to determine which number was correct since computer-based tools produced them and the methods of calculation were not shown.[1]

4.1.1.2 Monthly energy usage estimates were difficult to obtain from the BWH Energy Strategy

The BWH Energy Strategy presented tabulated energy data for the predicted yearly usage, but monthly energy data was not shown as explicitly. Instead, monthly data values had to be estimated from graphs in the document. The different graphs were spread throughout the document, which made the process of compiling the data more difficult and less accurate. This lack of consolidated numerical data added a layer of complexity to the process of data collection.

The monthly energy use of BWH from the Energy Strategy was consolidated by the team and can be seen in Table 7. Despite the uncertainty of the estimation process and the previously stated inconsistency within the document, the total yearly energy use from Table 7 aligned closely to the yearly energy values posted in the Energy Strategy. This adds confidence to the collected monthly energy data.

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[1] The building was modelled using the IES Virtual Environment software, from Integrated Environmental Solutions Ltd., which is approved for Building Regulations calculations. Weather data from the CIBSE test reference year for London was utilized for the energy analysis of the model as required by Part L2A of the Building Regulations (2006). For calculating the operational energy values NCM (National Calculations Methodology) templates were used and also modified in areas that contained an analysis of Low and Zero Carbon technologies. Finally the values for carbon dioxide emissions were calculated using the following factors, taken from the Building Regulations Approved Document L2A:

- Gas 0.194 kgCO_2/kWh
- Electricity from grid 0.422 kgCO_2/kWh
- Electricity generated on site 0.568 kgCO_2/kWh
- Biomass 0.025 kgCO_2/kWh

-(Nkonge, 2009)

Table 7: Predicted monthly energy usage from the BWH Energy Strategy

	Total Hot Water (MWh)	Civic Off Heat (MWh)	Town Hall Heat (MWh)	Civic Off Cooling (MWh)	Electricity (MWh)
Jan	45	66	99	81	351
Feb	39	46	93	75	312
Mar	44	38	75	90	339
Apr	39	14	56	111	363
May	44	2	0	176	327
Jun	41	0	0	239	324
Jul	43	0	0	282	341
Aug	44	0	0	261	341
Sep	39	3	20	184	319
Oct	45	13	42	131	354
Nov	43	32	67	92	347
Dec	41	51	91	83	322
Total Yearly	508	265	543	1805	**4,040**

4.1.2 The design phase BREEAM accreditation could be improved in the categories of health and wellbeing, energy, transport, water, land use and ecology, and pollution to obtain a higher BREEAM accreditation

The 2010 BREEAM report was generated for the initial design of the building and showed that the plan would receive a score of 76.28% and obtain an "EXCELLENT" accreditation. The report showed how many credits were received in each of the different categories and then provided a summary report of their overall weighting within the final score. Several calculated values, performed by the BREEAM assessor, were also included in the energy, transport, water, ecology, and pollution sections to provide more detail on aspects like emission rates, consumption, and percent improvement. Each assessed category and the corresponding percentage of credits received is shown in Table 8. These areas of improvement were important if the council wanted to enhance the accreditation of the building.

Table 8: Design phase BREEAM accreditation

Category	Percentage of Credits Received
Management	100%
Health & Wellbeing	61.54%
Energy (With 25.5% improvement over 2006 regulations)	72.22%
Transport (CO_2 Emission due to transport 388.93 kg/person/year)	100%
Water (Consumption 3.38 m^3/person/year)	84.85%
Materials	41.67%
Land Use & Ecology	70.00%
Pollution	80.00%

4.1.3 A post-construction BREEAM accreditation could not be located

After an extensive search the post-construction BREEAM accreditation could not be located. The post-construction BREEAM accreditation may not be available because it was misplaced or simply because it was never actually performed.

4.2 Building Energy Analytics: Overcoming Data Limitations

This section provides detail on the problems found with the building monitoring systems as well as the problems with the data points they produce. The majority of findings in this section deal with the Trend Monitoring System and the problems encountered with its use. All building energy analytics findings discussed below contributed to key methodological challenges throughout the project and the methods taken to overcome them are presented in detail in CHAPTER 3, section 2.

Major Findings of this section:

1. The Council was billed for the correct amount of electricity
2. The mains gas meters were improperly calibrated and could not produce a reliable breakdown of gas usage
3. Trend data points were largely inconsistent and missing
4. Trend was recording 9 times smaller than actual small power values
5. Control points did not have clear names or cataloguing

4.2.1 The Council was billed for the correct amount of electricity

Based on the comparison of half hourly data used by BWH and their utility bills, it was found that electricity use values were virtually identical (Table 9). This is a meaningful finding because it can assure the council that the monthly billing for BWH is accurate.

Table 9: Recorded BWH energy consumption

Month	Half Hourly Measurements (kWh)	Utility Bills (kWh)	Percent Difference
Sep	375,904	375,899	0.001%
Oct	455,908	455,903	0.001%
Nov	417,725	417,717	0.002%
Dec	398,892	398,887	0.001%
Jan	396,984	396,977	0.002%

4.2.2 The mains gas meters were improperly calibrated and could not produce a reliable breakdown of gas usage

BWH utilized two forms of energy, mains gas and electricity. The mains gas meters were reading incorrectly and were not recalibrated until the first week our team was working onsite. This meant that there was very little data for which we could analyse gas so the team's analysis focused on electricity.

4.2.3 Trend data points were largely inconsistent and missing

A major finding of this investigation is concerned with the reliability of energy data provided by the Trend system. Only data in the areas of lighting, small power, pumps & cooling, and photovoltaic generation could be gathered using the Trend software. Data in the areas of Combined Heating & Power (CHP), heating, water, and cooling could not be acquired because the data were either absent or vastly inaccurate. For the areas where data were collected there were apparent outliers. Based on an analysis of the data excluded from this investigation, two theories were formed to explain the missing or inaccurate data: the sensors were not connected to the Trend system or were improperly calibrated. The theory of improper calibration also explains the presence of outliers in the accepted data.

Analysis of the Trend data required estimations and extensive fact checking to ensure that the data was accurate. The data was broken down into weekly energy consumption or generation for higher precision. Within the gathered data, only 76.1% of lighting, 67.5% of small power, and 81.4% of pump data was actually accepted for analysis.

4.2.4 Trend was recording 9 times smaller than actual small power values

The values recorded by the Trend system were found to be about 9 times lower than the values the team estimated for small power. Such a remarkable energy savings is unlikely considering the existence of a performance gap in BWH's energy consumption. Each other area of in-use energy consumption in BWH is only slightly greater than their respective estimated values. There are two reasons for inaccurate Trend recorded data, improper sensor calibration and/or lack of sensor point aggregation.

Part of the analysis of the Trend small power data consisted of comparing the recorded values to our independent estimations. Through this process, the annual small power energy consumption of 3,477,481 kWh/yr was adapted from the Trend data. Accounting for error, this value is 8.7 to 9.2 times larger than the Trend software indicates.

The Trend data pointed to a yearly small power energy consumption of 375,076 kWh/yr. Figure 9 shows the breakdown of the weekly energy consumption.

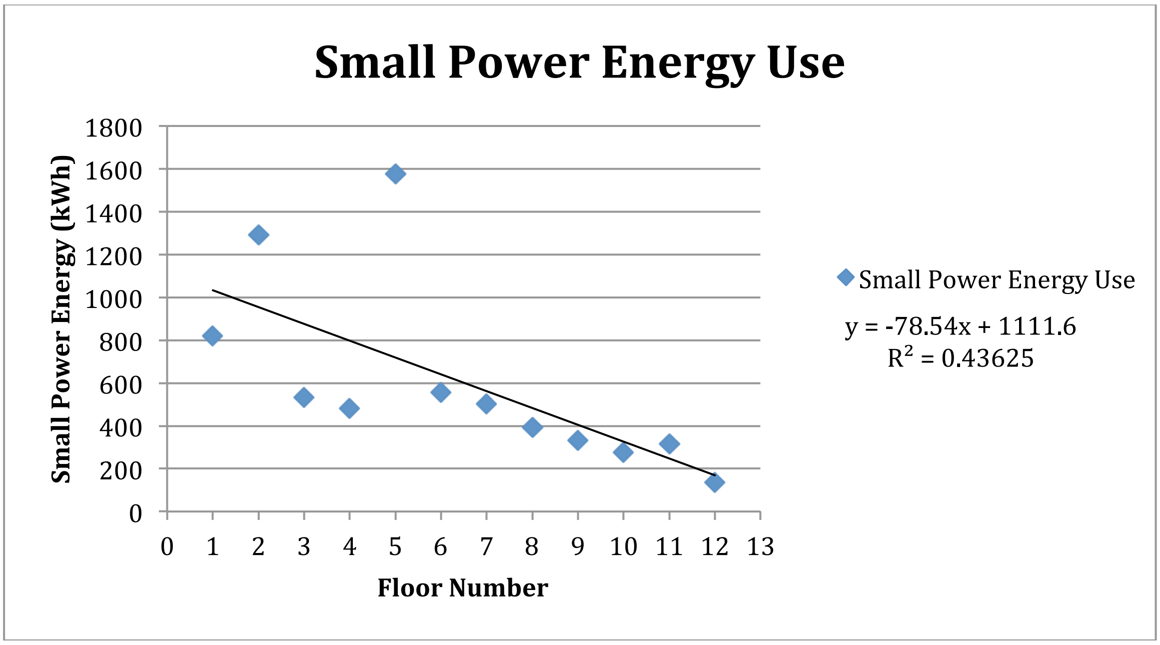

Figure 9: Trend small power weekly usage by floor

The downward trend presented in Figure 9 is reasonable since the total population and size of the building decreases at higher building levels. However, the values presented are considerably lower than they should be. When the data was corrected with a multiplier corresponding to the ratio of the predicted small power use from the design plan to the Trend data was obtained (Figure 10).

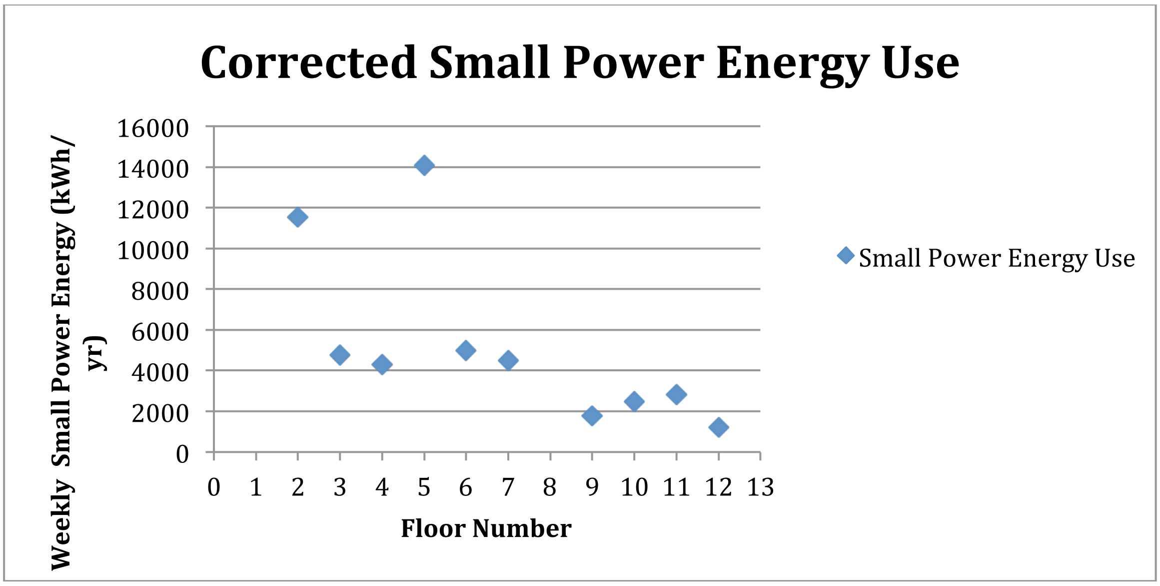

Figure 10: Corrected Trend small power weekly usage by floor

The total of this small power use by year is within 3% of the small power energy consumption estimated from utility bills (3,578,559 kWh/yr).

4.2.5 Control points did not have clear names or cataloguing

In addition to the improperly calibrated data, Trend data was unreliable due to the difficulty in identifying sensors. Because the names for sensors were often unintuitive, it was impossible to definitively identify the specific Trend data points to be gathered and analysed. This led to the exclusion of heating and water data for analysis. Specific sensors often had cryptic names such as "Town Hall 16A," which referenced either a pump or cooling device. This could be a considerable problem when a sensor improperly performs and must be identified for re-calibration.

These unintuitive names were further compounded by the confusing cataloguing of the sensors. After considerable calculations, it was found that the Trend sensors automatically combined cooling data and pump data into one group. Because of the unclear names, individual pumps and cooling apparatuses could not be identified. This made it impossible to properly analyse and report on pump performance distinct from the cooling system performance.

4.3 Building Performance: Design Phase vs. Actual Performance

This section is focused on the discovery of the building performance gap and the specific causes of this gap. A variety of sources were used in this section including the BWH Energy Strategy, utility bills, half hourly meters, and the Trend Building Monitoring System.

Major findings of this section:

1. Electricity use was 42.3% higher than predicted
2. Small power was about 29% higher than predicted values
3. Lighting energy usage was approximately 4.3% less than predicted values
4. Combined Pump and Cooling energy usage was at least 12% higher than predicted
5. PV solar panels were performing within 15% of predicted values

4.3.1 Electricity use was 42.3% higher than predicted

As seen in Figure 11, the in-use electrical usage was considerably higher than the predicted usage. This gap brought the in-use electrical usage 42.3% higher than the predicted usage. This overconsumption represented an additional £95,000 of electrical bills and 344 tonnes of emitted CO_2 in a six-month period.

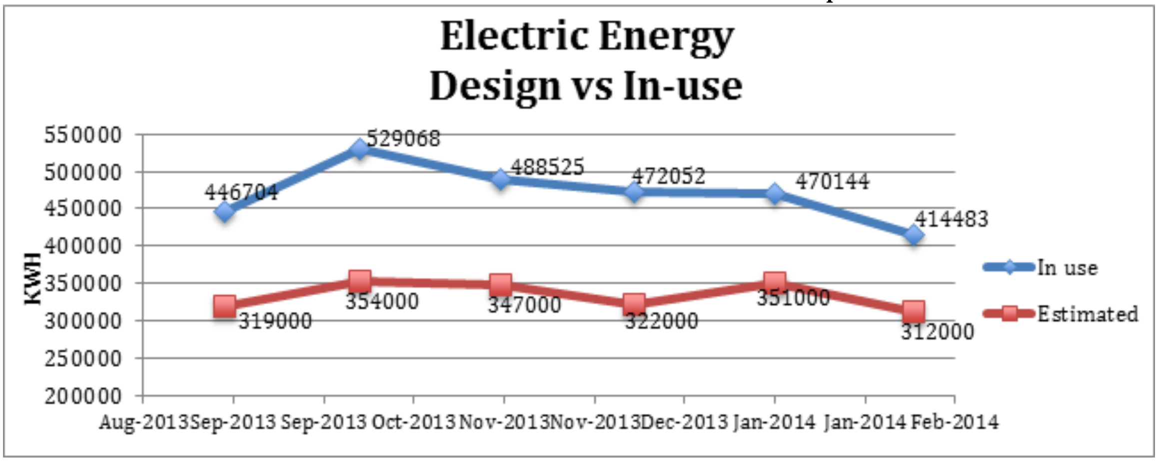

Figure 11: Designed vs. in-use electricity

The total monthly electricity usage was found by including CHP and photovoltaic values as seen in Figure 12.

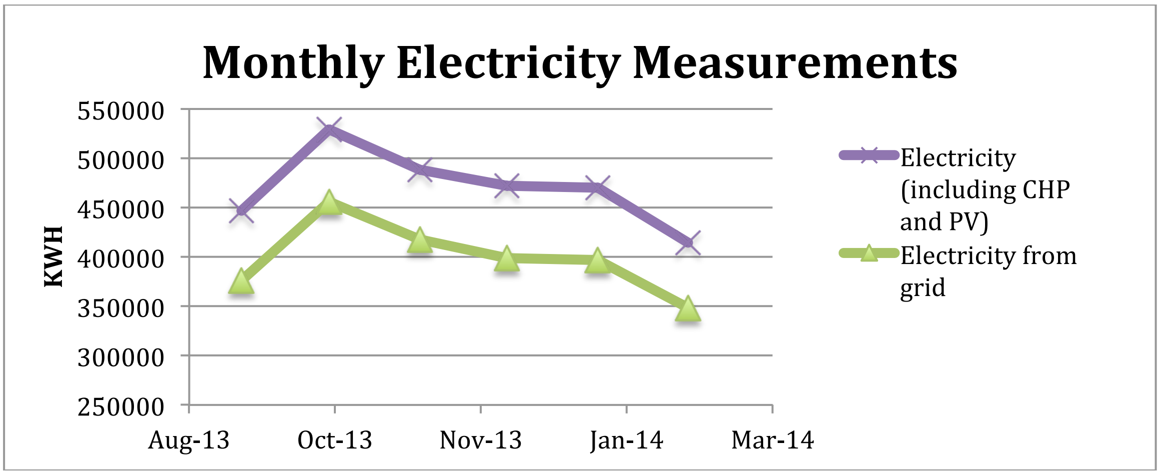

Figure 12: Total BWH in-use electricity

4.3.2 Small power was about 29% higher than predicted values

Small power data gathered from the Trend software had to undergo many refinements before it could be compared with the predicted small power data. A detailed account for refining the data can be found in CHAPTER 3: Section 2. The result of this analysis was that the in-use small power energy consumption was 3,477,481 kWh/yr, which was about 29% higher than the predicted 2,704,546 kWh/yr.

4.3.3 Lighting energy usage was approximately 4.3% less than predicted values.

A similar, but less complicated, process to small power energy analysis was also applied to the Trend data to estimate lighting performance. A more detailed account of the process can be found in CHAPTER 3: Section 2. For floor lighting, the total energy use for the building was 13,976 kWh/week. This lead to an annual lighting energy use of 726,752 kWh/yr, which was approximately 4.3% less than the predicted 759,553 kWh/yr. The breakdown of the floor lighting energy use by floor can be seen in Figure 13.

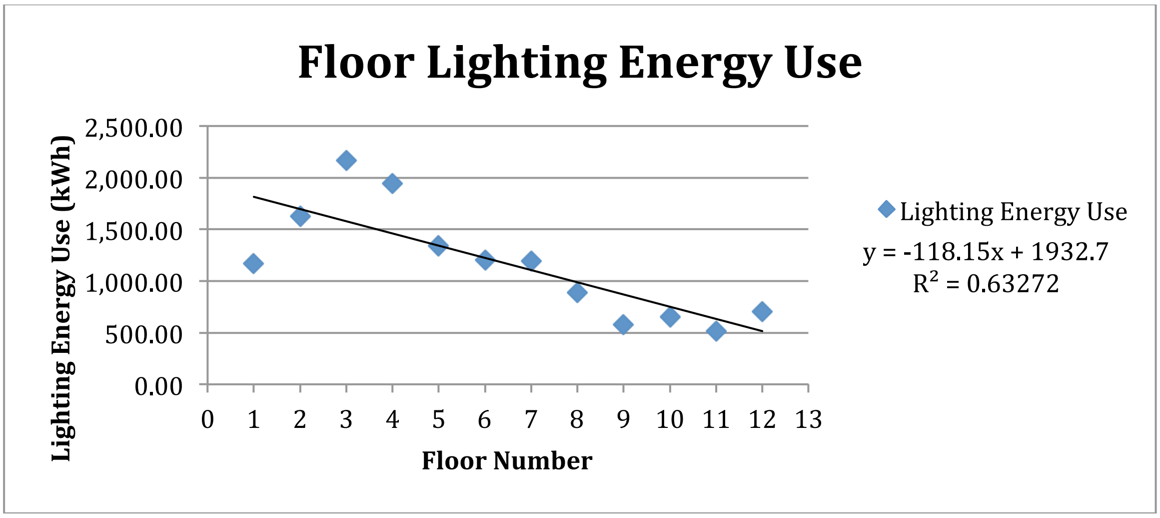

Figure 13: The average weekly energy use by floor

4.3.4 Pump and cooling energy usage was at least 12% higher than predicted

It was expected from the BWH Energy Strategy that the building would use 990,000 kWh/yr in pumps and cooling energy. This was at least 12% higher than the predicted value of 884,000 kWh/yr from the energy strategy. Considering that these averages are based on the use of pumps and cooling in the winter, 990,000 kWh/yr was a modest estimation because pump and cooling use typically increase during the summer.

4.3.5 PV Solar Panels were performing within 15% of predicted values

As seen in Figure 14, PV electricity generation has increased since the beginning of March 2014, which we assume will continue to increase throughout the summer months and perform within 15% of the predicted benchmark of 22,000 kWh/yr.

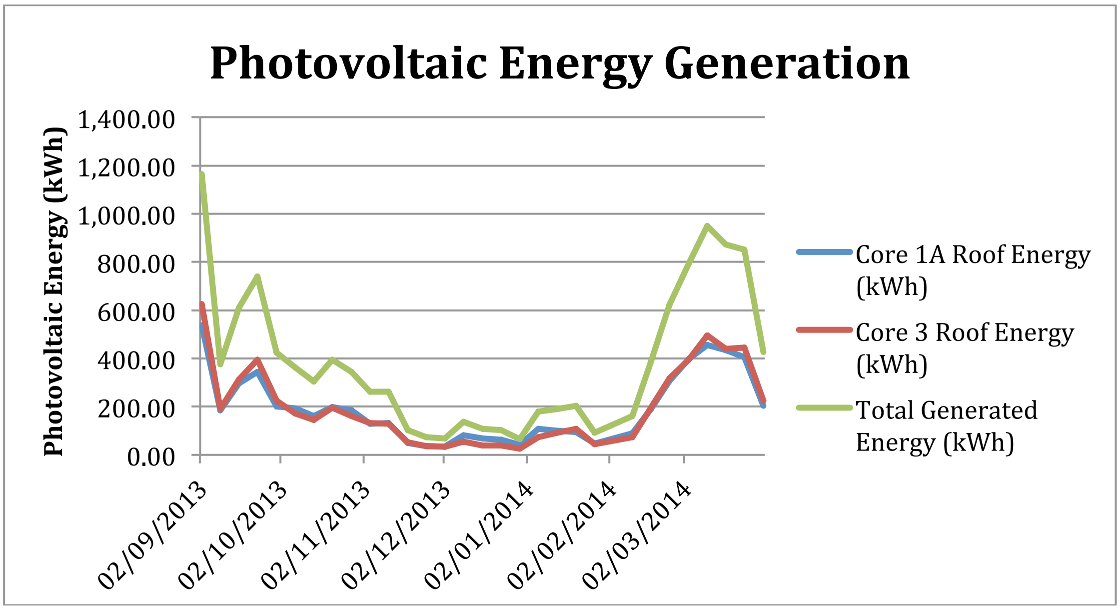

Figure 14: Photovoltaic energy generation by month

The photovoltaic system demonstrated a particularly effective performance throughout the winter. Based on the fact that London received on average 110 J/m^2 of solar energy each second (MacKay, 2009), BWH photovoltaic cells absorbed 10.3 J/m^2 of the energy each second, which translated to an efficiency of 9.36%. While this value was lower than 22.5%, the current maximum mono-crystalline PV cell performance ("Top 10 World's Most Efficient Solar PV Mono-Crystalline Cells," 2012), it had to be considered that this performance occurred during the winter. During the summer months, it is completely possible that BWH PV panel performance could increase. To support this point, Figure 14 contains a distinctive u-shape to the data, hitting a minimum amount of energy generation in January. This performance drop was expected during the winter months due to a decrease in accessible sunlight.

Despite these worsened conditions, the amount of energy generated by the photovoltaic cells for the recorded 30 weeks totalled to 11,637 kWh, which represented 52.9% of the predicted total annual generation of 22,000 kWh (Nkonge, 2009). If the panels continue to perform at the same rate they did during the first 6-month period, the total energy generated after a complete year of usage would be 86.0% of the annual predicted photovoltaic cell performance as outlined in the BWH Energy Strategy.

4.4 Energy Management Software Providers

This section provides detail on the energy management software and service providers that were researched to form the Energy Management Portfolio for the Council. It also provides detail on the energy management methods utilized by some of the other boroughs.

Major findings of this section:

1. Seven companies are capable of providing the services necessary to the Council
2. Eight boroughs currently use or have used similar outsourcing methods for bill validation and analysis/reporting

4.4.1 Seven companies are capable of providing the services necessary for the Council

There were several energy management software providers that were identified, through recommendations or research, which were capable of meeting the Council's needs. They included Team Sigma, STC Energy, SystemsLink, EnergyCap Enterprise, Credit360, Optima, and STARK. Although these organizations provide similar services, some do offer unique benefits and services. There were also several combinations of providers that could be used together in order to meet the Council's energy and bill management needs. The services, benefits, visuals, and contact information for all of the companies researched can be found in depth in our Energy Management Portfolio.

A major criterion for all of these companies was their ability to produce online dashboards that could be viewed by administrators within the Council. It was also very important that their dashboards be visually appealing and intuitive for their possible use as a visual tool for the general public. It was found that STARK's dashboard was the most user friendly and appealing to our team.

4.4.2 Eight boroughs currently use or have used similar outsourcing methods for bill validation, analysis, and reporting

From an internal survey conducted in 2013 by the London Boroughs Energy Group, we identified eight other boroughs in London that utilize a bureau service for bill management, validation, analysis, or reporting. These eight Boroughs included Hammersmith & Fulham, Kingston, Ealing, Brent, Richmond, Surrey County, Newham, and Tower Hamlets. The survey illustrated that other councils were replacing TEAM as their energy management software or bureau service provider.

Interviews with a representative from all of the previously mentioned boroughs but Surrey County, as well as the Borough of Kensington, provided information concerning the services each borough was receiving and their opinions of the provider. The majority of boroughs used a combination of services to outsource bill management and reporting. Typically, this combination was a coupling of services provided by a procurement organization and a bill validation organization.

The Borough of Hammersmith & Fulham and The Borough of Ealing both utilized LASER as their energy procurement agency coupled with SystemsLink for their bill validation, analysis, and reporting organization. The Borough of Kingston utilized a similar system, utilizing LASER for energy procurement and STARK for bill validation, analysis, and reporting.

The Borough of Tower Hamlets switched from using the TEAM bureau service because it was less expensive for them to utilize Crown Commercial services for utility procurement and an in-house team for bill validation, analysis, and reporting.

At the time of our interview, the Borough of Brent was not using any software or bureau service for procurement or energy management. The Brent Council had occupied the newly constructed Brent Civic Centre for ten months and was still in a period of adjustment. However, they were expecting to utilize a bureau service in the near future and were in the process of selecting a service provider. Like many of the other boroughs, the coupling of LASER and SystemsLink to provide a bureau like service was their top choice for provider. They were also looking into Energy Direct as a possible candidate to perform their procurement, validation, analysis, and reporting requirements.

The Borough of Kensington was currently using the TEAM Bureau Service; however, their council was actively seeking a switch to a combined service. They were considering the use of Government Procurement Services (GPS) for procurement purposes and SystemsLink software for bill validation, analysis, and reporting. It was also mentioned that the Council preferred to create their own dashboard display rather than use the one provided by TEAM.

4.5 Occupant Satisfaction Survey: Gauging Occupant Opinion

Public awareness and investment in BWH sustainability was a major goal of the Council's. The occupant satisfaction survey that was performed provided insight on the occupants thoughts on their workplace and awareness of the environmentally friendly aspects designed into the building. It also served as an indicator to any blatant problems with the operation of the building. The "use" portion of our survey gave us information about sustainable behaviour and a basic view of where recommendations for behavioural changes could be implemented. The full results report can be found in APPENDIX F. The major findings from this survey were grouped thematically and discussed in three categories; Work Environment Satisfaction, Occupant Awareness, and Respondent Recommendations. These thematic groups and their respective findings are listed below:

Major findings of this section:

1. Work Environment Satisfaction
    a. 84% of respondents thought that the overall working environment of BWH was better than the working environment of their previous council building
    b. There was a positive response to all specific work environment categories except for temperature
        i. 44% of respondents thought the temperature is too cold
        ii. 80% of respondents thought that airflow is good
        iii. 66% believed that natural lighting is adequate
        iv. 76% reported good visual comfort with no problems with glare or reflections
        v. 82% reported that the acoustic quality of the workspace was satisfactory
2. Occupant Awareness of BREEAM Accreditation and Environmental Features
    a. 32% of respondents were aware of the building's BREEAM accreditation
    b. Many of the occupants were aware that the building utilizes photovoltaic panels, automated lighting, and rainwater collection as environmentally friendly features
3. Respondent Recommendations
    a. The majority of respondents thought that it would be valuable for occupants and staff to see a visual display of BWH's energy usage
    b. The lift lobby on each floor was the most preferred by respondents as a location for a visual display
    c. An education plan for recycling and the reduction of paper use were two major concerns for many of the respondents

****Note**: The findings gathered for this section were based on the responses to the Occupant Satisfaction Survey gathered in two sessions held in the building's Café. A more complete analysis on responses collected after the completion of this report was prepared and delivered to our sponsor.

4.5.1 Work Environment Satisfaction

The survey showed that 84% of respondents considered the overall work environment of BWH better than the previous council building they had worked in. Taking into account the respondents who hadn't previously worked in a council building, this is good news for the Council. The exact response breakdown can be seen below in Figure 15. A majority of people were satisfied with the new workplace that was created for them.

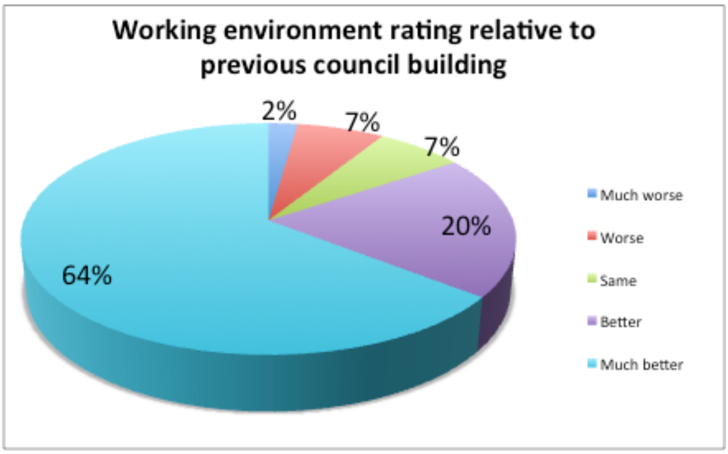

Figure 15: Responses on work environment relative to previous council buildings

When asked about the temperature of their work area, 44% of respondents thought that, on average, it was too cold. Another 44% thought that it was just right while the final 12% thought it was too hot. The exact breakdown of responses can be seen below in Figure 16. 96% thought that the airflow in the building was either satisfactory or better and only 4% thought it was poor and none thought it was very poor.

Many of the respondents were happy with the lighting and visual comfort of their workspaces. 66% responded that the lighting was adequate; which directly correlates with the use of natural light and the amount of respondents who worked in proximity to exterior windows. 76% reported good visual comfort with no problems of glare and light reflection in their workspace.

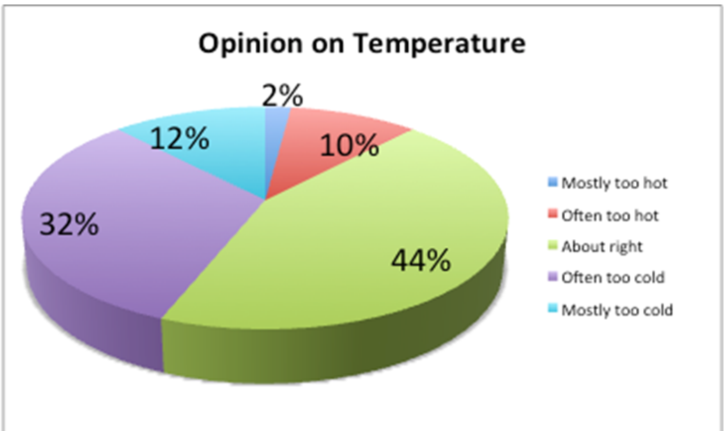

Figure 16: Responses on workspace temperature

Although BWH is an open floor, hot desking style office building, 82% of respondents reported that the acoustic quality of their workspace was satisfactory for a work environment. From the open ended "comments" question, 29% of respondents made not of the cold temperature.

4.5.2 Occupant Awareness of BREEAM Accreditation and Environmental Features

When asked about BWH BREEAM accreditation only 32% of the respondents were aware that the building even had an accreditation. Of that fraction of respondents, only 67% knew that the building was BREEAM "EXCELLENT". Three respondents thought that it had a "VERY GOOD" accreditation and one thought it had received a "PASS". The detailed breakdown can be seen below in Figure 17.

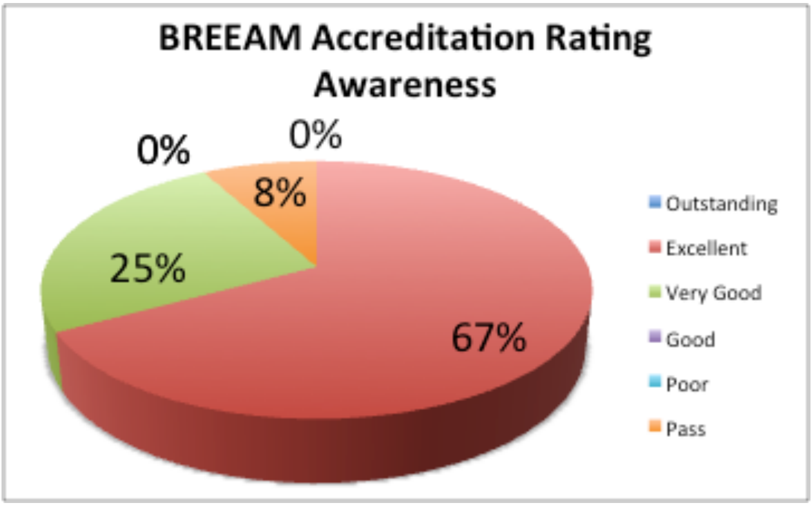

Figure 17: Responses on occupant BREEAM accreditation awareness

When asked about the environmental features of the building, 72% of the respondents could name at least one of the design features of the building. Photovoltaic panels, dimmed and automated lighting, and rainwater collection were the most commonly noted features. This was expected since these are the three most visible environmental features.

82% of respondents thought it would be valuable for occupants and staff of the building to see a visual display showing how energy is used in BWH. Respondents believed that displaying a visual in each floors' lift lobby would be the most effective method, followed by a visual on the intranet homepage and in the Council's Magazine.

4.5.3 Respondent Recommendations

From open ended questions, prompting any other comments or recommendations, it was found that recycling and paper reduction are two major concerns for many of the occupants. Although they were satisfied with the accessibility to recycling and waste disposal stations, many voiced concern about the education and proper use of the recycling facilities. Several respondents proposed the implementation of a better recycling education system for the occupants. Others believed that the overall reduction of paper in the workplace would be beneficial.

4.6 Visual Tools for Occupant Awareness

This section provides detail on the outcomes the team took away from the visual tools creation process. The findings discussed below show the inconveniences that appear throughout the process as well as important data and resources that a Sankey diagram provides.

Major findings of this section:

1. Sankey diagrams can display complex and complete energy systems, making them easy to understand and ideal for raising energy use awareness.
2. Sankey diagrams highlighted BWH energy consumption in specific areas
3. Data for producing a complete Sankey diagram of in-use energy consumption was not available or accurate

4.6.1 Sankey diagrams can display complex and complete energy systems, making them easy to understand and ideal raising energy use awareness.

Throughout the creation process, Sankey diagram samples were presented to our liaison, advisors, and a sample group of occupants. We found that our tool was visually appealing and helped the viewer to comprehend the complex system. We also found that it had a direct impact in energy consumption awareness when the viewer identifies the biggest areas of consumption.

Even though Sankey diagrams are an effective way of representing the energy flow, it could be challenging to create them because of the few software products available to create them. Most of these products were not fully functional and some of them were still in prototype/trial versions. There were very few products that were specifically designed for the purpose of Sankey diagram creation. The software products that our team identified as the most functional ones were e!Sankey 3.2 and Straw 5.x.

The BWH energy system involved a complicated system that included a cyclic loop caused by the CHP. This was a major factor that affected the diagram's development. We used e!Sankey 3.2 to create all of our diagrams. Even though we only had access to the trial version due to software expense, we found that the use of all the software's features could create an accurate and appealing visual tools but also a great resource to optimize the system.

4.6.2 Sankey diagrams BWH highlighted energy consumption in specific areas

The calculation process described in Section 3.6 allowed the team to identify specific energy allocations throughout the building. We were able to determine the demand loads of each specific energy use area. The Sankey diagram allowed for the visualization of each area's percentage of the total energy use. The energy loads are presented by amount of kWh and percentage in Table 10. These values were calculated according to design values from the Energy Strategy.

Table 10: Energy allocation of BWH

Energy Provided		
	Use (kWh /year)	**% of total energy**
Town Hall Heating	638,947	9.2%
Heating	266,732	3.8%
Hot Water	216,554	3.1%
Cooling	1,801,927	25.9%
Lighting	759,553	10.9%
Pumps & Fans	558,086	8.0%
Small Power	2,704,546	38.9%
Total	6,944,345	100%

The Sankey diagram showed that the greatest energy allocation went towards small power, which strengthened our previous finding that the Trend System is experiencing aggregation or calibration problems. Also we were able to see that the energy provided for cooling is highly significant and it will be a key area to monitor during summer months.

Finally our team was able to produce a Sankey diagram that fully represented the predicted energy system of BWH as seen in Figure 18. We found that colour-coding the different type of energy and using images to represent the sources and uses makes it easier to understand the diagram.

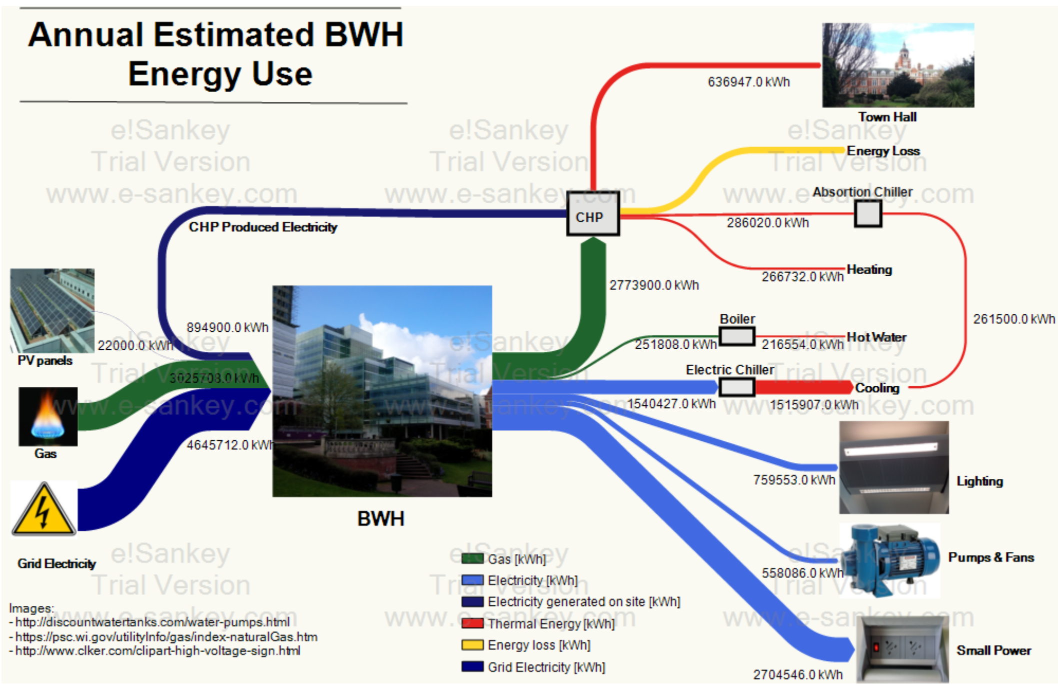

Figure 18: Sankey diagram of BWH predicted energy usage

4.6.3 Data for producing a complete Sankey diagram of in-use energy consumption was not available or accurate

Our team's original intention was to create two similar diagrams representing the complete energy system of BWH. The first one (Figure 19) expressed the annual energy consumption defined by the design Energy Strategy and the second one would have expressed the real in-use consumption. Our team found that it was not possible to create a second diagram unless there was accurate in-use data. The team found it useful for our liaison to have access to a simplified diagram that expressed a portion of the energy consumption.

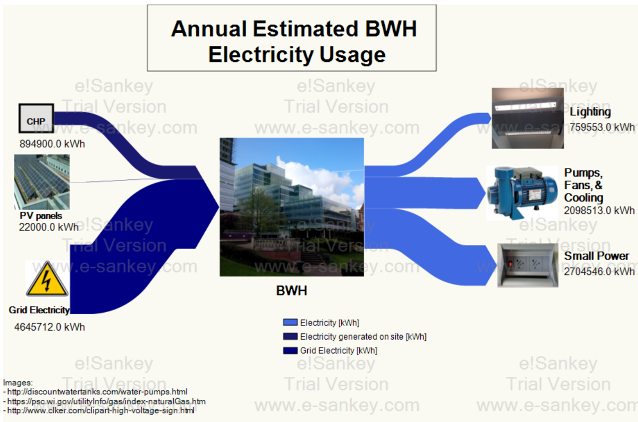

Figure 19: Sankey diagram for predicted BWH electricity usage

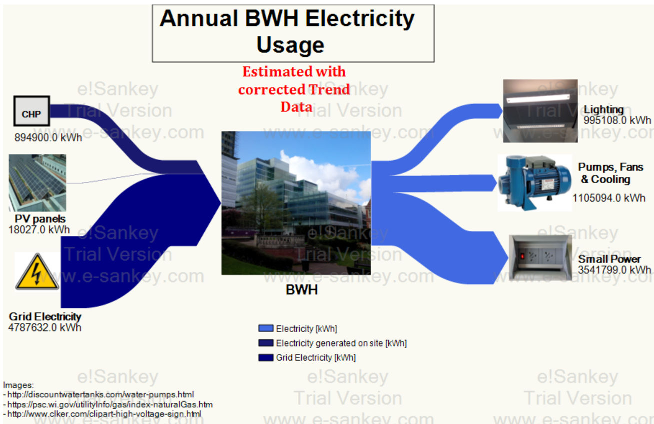

Figure 20: Sankey diagram for estimated BWH electricity usage

Figure 19 and Figure 20 (Seen larger in APPENDIX D) were produced expressing only electricity consumption, first according to the design values and second according to billing data and corrected Trend data. These diagrams could be a valuable resource for tracking and optimizing electric energy consumption. Having accurate data is vital for this tool to be successful. We could see how the second diagram expressed a more realistic model and correlated with the first diagram after Trend data was corrected and estimated.

CHAPTER 5: Conclusions and Recommendations

The following section details our main recommendations for the Council. They were developed after careful research and are shaped by our observations and findings. The main recommendations can be grouped thematically and are presented in a list below. Several of these main recommendations have multiple parts to them, depending on different scenarios the Council could encounter or if more than one recommendation was thought necessary for the topic.

<u>Main recommendations to the Council:</u>

1. Locate or obtain a post-construction BREEAM accreditation
2. Fix the issues with Trend building management system with recalibrating, renaming, and aggregating the sensor points
3. Address the energy performance gap of BWH by reducing small power consumption
4. Change or upgrade energy management providers
5. Positively influence occupant behaviour and increase awareness of the building's environmental features by education
6. Create and display visual tools depicting energy usage and energy management

5.1 Locate or obtain a post-construction BREEAM accreditation

Locating or obtaining a post-construction BREEAM accreditation is highly recommended and should be completed as soon as possible. Not only is this a very important document for the Council to possess, but it can help the Council target areas for improvement.

5.2 Fix the issues with Trend building management system by recalibrating, renaming, and aggregating the sensor points

Based on the findings discussed in CHAPTER 4 Section 2, there are several areas in the Trend monitoring system that require repair. It is recommended that the Trend sensors undergo recalibration, renaming, and aggregation. This process will address the issues with negative values for floor lighting, accurately monitoring small power, and providing ease of use to the Council. It is recommended that the sensor points for each type of energy use are aggregated together and then labelled with intuitive names.

Since BWH is still under warranty, it is recommended that the Council contacts the company that installed the Trend system for recalibration, renaming, and aggregation of the sensor points. It is also recommended that they utilize a third party organization, Long and Partners Ltd, to assist in this BMS auditing service, which was carried out successfully in the Borough of Brent.

5.3 Address the energy performance gap of BWH by reducing small power consumption

Based on the estimations we have made of energy usage, small power seems to be the largest contributor to the performance gap of the building. This will need to be verified once reliable Trend data can be collected. While small power is higher than expected this may not be a reflection of poor performance in this area of usage. Rather than the current usage being too high, the predicted usage stated in the BWH Energy Strategy may be lower than it should be. An article published by the Chartered Institution of Building Service Engineers (CISBE) finds that the current methods for benchmarking small power are inadequate and often predict lower values than are realistic (Menezes, 2013). If small power is verified, with new Trend data, to be the largest contributor to the performance gap then we would not consider the performance gap to be a real gap, rather a poor estimation.

There are still ways that you can lower the overall small power usage. Since this relies heavily on occupant behaviour, raising awareness and increasing occupant education on energy use can have a large impact. Increasing knowledge of computer energy usage and reminding occupants to power down their electronics when they are not in use are two simple ways to lower small power usage. The council could consider using a policy that has been implemented with success in Brent. During afterhours at their council building the employees are asked to work from one specific floor. This requires only one floor to be lit and air conditioned, rather than all floors. Such policy implementations could lower the energy usage of BWH.

5.4 Change or upgrade energy management providers

The changes to the Facilities Management Department in 2016 provide the Council with an opportunity to evaluate the energy management services and software they are utilizing at Bernard Weatherill House. The Council has the opportunity to update or replace their bill processing and reporting services offered by the energy management software provider TEAM. After reviewing several different energy management software providers and understanding the needs of the Council, our team would like to provide a set of recommendations concerning their energy management software. Three scenarios were considered while forming the following recommendations. They include the continued use of TEAM Sigma Energy and Carbon Management software, switching to the TEAM provided Bureau Service, or switching to a completely different provider.

Scenario 1:
If the Council decides to continue utilizing TEAM Sigma, it is recommended that they either fully use the TEAM Sigma Energy and Carbon Management software services or switch to TEAM Sigma Bureau Services offered by the company. Fully utilizing the TEAM Sigma services would provide the Council with visual reports as well as bill and consumption analysis.

Scenario 2:
If the Council decides to continue utilizing TEAM services, it is recommended that they switch over to the Bureau Services provided by the company. This would completely outsource the billing validation, analysis, and reporting responsibilities to TEAM and lessen the burden on the Facilities Management Department.

Scenario 3:
If the Council decides to switch energy management software providers completely, we recommend that the Council couple LASER with one of the service providers mentioned in the Energy Management Portfolio, preferably SystemsLink or STARK. More information on each provider can be found in our Energy Management Portfolio.

5.5 Positively influence occupant behaviour and increase awareness of the building's environmental features

Based on the results we obtained from our survey, it is clear that occupant awareness about BWH's BREEAM "EXCELLENT" rating needs to be increased. Occupants need to know that the building was designed and rated according to BREEAM specifications so that they can understand certain building features. This can be addressed by adding informative messages where these features are in place so that occupants can directly associate with and understand them. Also when increasing occupant awareness, the council should focus on highlighting that the users are the key factor for reducing energy consumption. This would including clearing up the common misconception that and automated building is completely sustainable and no effort by the occupant is needed.

We also strongly suggest that the Council promotes and enforces its recycling practices. Waste disposal areas have been implemented and labelled but the key factor is how the occupants are utilizing them. Only with behavioural changes, can the recycling program become highly successful. This could also be achieved by re-implementing the Recycling Champions Programme, which was established in Taberner House.

5.6 Create and display visual tools depicting energy consumption and energy management

The use of visual tools to raise energy consumption awareness in the building is highly recommended. By visualizing the energy flow through BWH's complex system, the viewer's comprehension of building wide energy use increases. It is suggested that the Council publish some type of engaging visual tools throughout the displays located in the lift lobbies, the internet/intranet, or issues of the Our Croydon magazine. Our team strongly recommends the use of two specific types of visual tools. If the Council decides to use any of the recommended Energy Management Software Providers in Section 5.4, their online dashboards including information about utilities consumption should be published thorough the Council. Also, a continuous production of Sankey diagrams, representing in-use energy consumption is recommended. Visual tools will also optimize energy consumption and ultimately reduce carbon emissions and costs

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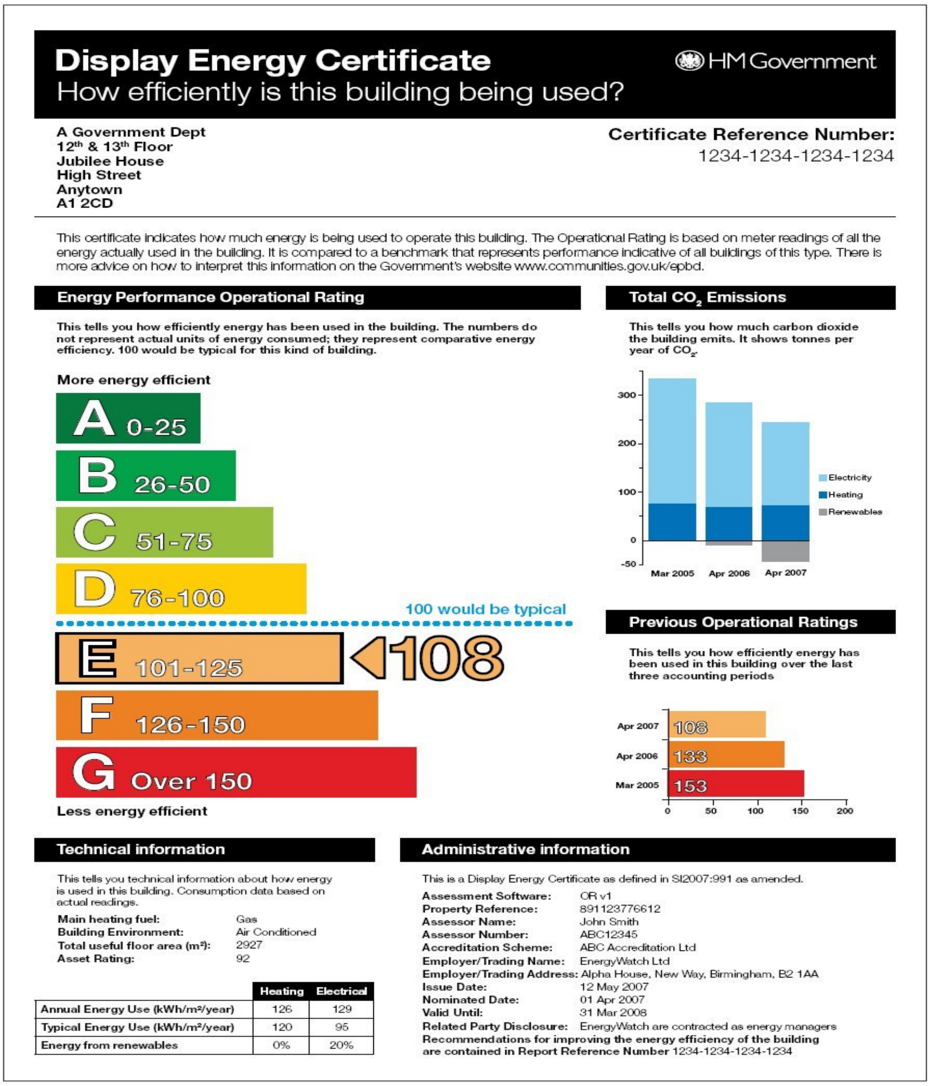
APPENDIX A: Example Energy Display Certificate (DEC)

http://www.carbonaction.co.uk/index.php/blog/view/display-energy-certificates-decs/



Display Energy Certificate
How efficiently is this building being used?

HM Government

A Government Dept
12th & 13th Floor
Jubilee House
High Street
Anytown
A1 2CD

Certificate Reference Number:
1234-1234-1234-1234

This certificate indicates how much energy is being used to operate this building. The Operational Rating is based on meter readings of all the energy actually used in the building. It is compared to a benchmark that represents performance indicative of all buildings of this type. There is more advice on how to interpret this information on the Government's website www.communities.gov.uk/epbd.

Energy Performance Operational Rating

This tells you how efficiently energy has been used in the building. The numbers do not represent actual units of energy consumed; they represent comparative energy efficiency. 100 would be typical for this kind of building.

Total CO_2 Emissions

This tells you how much carbon dioxide the building emits. It shows tonnes per year of CO_2.

Previous Operational Ratings

This tells you how efficiently energy has been used in this building over the last three accounting periods

Technical information

This tells you technical information about how energy is used in this building. Consumption data based on actual readings.

Main heating fuel: Gas
Building Environment: Air Conditioned
Total useful floor area (m^2): 2927
Asset Rating: 92

	Heating	Electrical
Annual Energy Use ($kWh/m^2/year$)	126	129
Typical Energy Use ($kWh/m^2/year$)	120	95
Energy from renewables	0%	20%

Administrative information

This is a Display Energy Certificate as defined in SI2007:991 as amended.

Assessment Software: OR v1
Property Reference: 891123776612
Assessor Name: John Smith
Assessor Number: ABC12345
Accreditation Scheme: ABC Accreditation Ltd
Employer/Trading Name: EnergyWatch Ltd
Employer/Trading Address: Alpha House, New Way, Birmingham, B2 1AA
Issue Date: 12 May 2007
Nominated Date: 01 Apr 2007
Valid Until: 31 Mar 2008
Related Party Disclosure: EnergyWatch are contracted as energy managers
Recommendations for improving the energy efficiency of the building are contained in Report Reference Number 1234-1234-1234-1234

APPENDIX B: Occupant Satisfaction Survey

Please take a few moments to respond to the following questions. This survey is being performed by a group of four students from Worcester Polytechnic Institute (Massachusetts) to assist the Sustainable Development and Energy Team assess the building performance of Bernard Weatherill House (BWH). The team is looking to gain more information on the occupant satisfaction and work environment in conjunction with the building's sustainability performance. The responses collected from this survey will be used to make recommendations on bettering the work environment; however, participants will remain anonymous.

Q2a On which floor and zone of BWH do you typically work?

Q3 Where is your workspace located?
- ❍ Near exterior windows (1)
- ❍ Near central atrium (2)
- ❍ Other (3) ____________________

Q4 Relative to the last council building you worked in, how do you rate the overall working environment of BWH
- ❍ Much worse (1)
- ❍ Worse (2)
- ❍ Same (3)
- ❍ Better (4)
- ❍ Much better (5)
- ❍ I did not work in a council building before this (6)

Q5 What are your opinions of your zone's work environment?

Temperature:

___ very poor ___ poor ___ neutral ___ good ___ very good

Comments: ____

Desk Layout:

___ very poor ___ poor ___ neutral ___ good ___ very good

Comments: ____

Lighting:

___ very poor ___ poor ___ neutral ___ good ___ very good

Comments: ____

Visual Comfort of Lighting (glare/reflections):

___ very poor ___ poor ___ neutral ___ good ___ very good

Comments: ____

Acoustic Quality:
___ very poor ___ poor ___ neutral ___ good ___ very good
Comments: ____

Air Flow:
___ very poor ___ poor ___ neutral ___ good ___ very good
Comments: ____

Q6 What are any other office environment issues you would like to mention?

Q7a Are you aware that BWH achieved a rating under the "Building Research Establishment Environmental Assessment Method" (BREEAM)?
- ❍ Yes (1)
- ❍ No (2)

Answer If Are you aware that the BWH achieved a rating under the "Building Research Establishment Environmental Assessment Method" (BREEAM); Yes Is Selected
Q7b Do you know what BREEAM rating BWH achieved?
- ❍ Outstanding (1)
- ❍ Excellent (2)
- ❍ Very Good (3)
- ❍ Good (4)
- ❍ Poor (5)
- ❍ Pass (6)
- ❍ Not sure (7)

Q7b Bernard Weatherill House was designed to be a BREEAM Excellent Building

Q8a Are you aware of any environmental features of BWH that are designed to reduce energy or water use?
- ❍ Yes (1)
- ❍ No (2)

Answer If Click to write the question text Yes Is Selected
Q8b List all the environmental features you are aware of
1 (1) ____________________
2 (2) ____________________
3 (3) ____________________
4 (4) ____________________
5 (5) ____________________

Q9a Do you think it will be valuable for staff to see a visual display showing how BWH is using energy?

❍ Yes (1)

❍ No (2)

❍ Don't know (3)

Q9b Where do you believe is the most effective location to display the energy performance of BWH? (Please click and drag the following options to rank them from 1 to 4, with 1 being the most effective location)

______ Entrance lobby display (1)
______ Lift lobby displays (2)
______ Cafe Display (3)
______ Internet (4)

Q9c Is there any other locations you would suggest?

Q10 Which sustainable practices do you exhibit while at BWH? (Please mark all that apply)

❑ Bike/Walk to BWH (1)

❑ Ride public transportation to BWH (2)

❑ Use a personal water bottle (3)

❑ Shut lights off when not in use (4)

❑ Power down electrical equipment when not in use (5)

❑ Recycle and properly dispose of waste (6)

❑ Other (7) ____________________

Q11 Are there any sustainable practices you would like to see implemented in BWH?

APPENDIX C: Borough Interview Plan Template

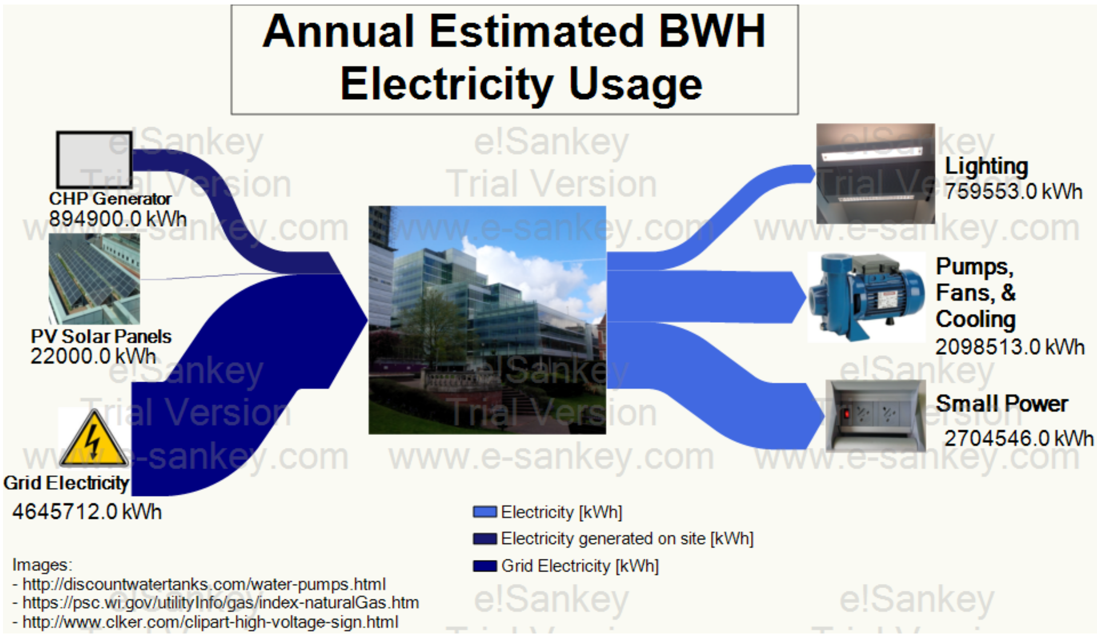
Borough of ______________________ Interview Plan:

Person of Interest:	
Date:	
Start Time:	
End Time:	
Location:	
Interviewer(s):	

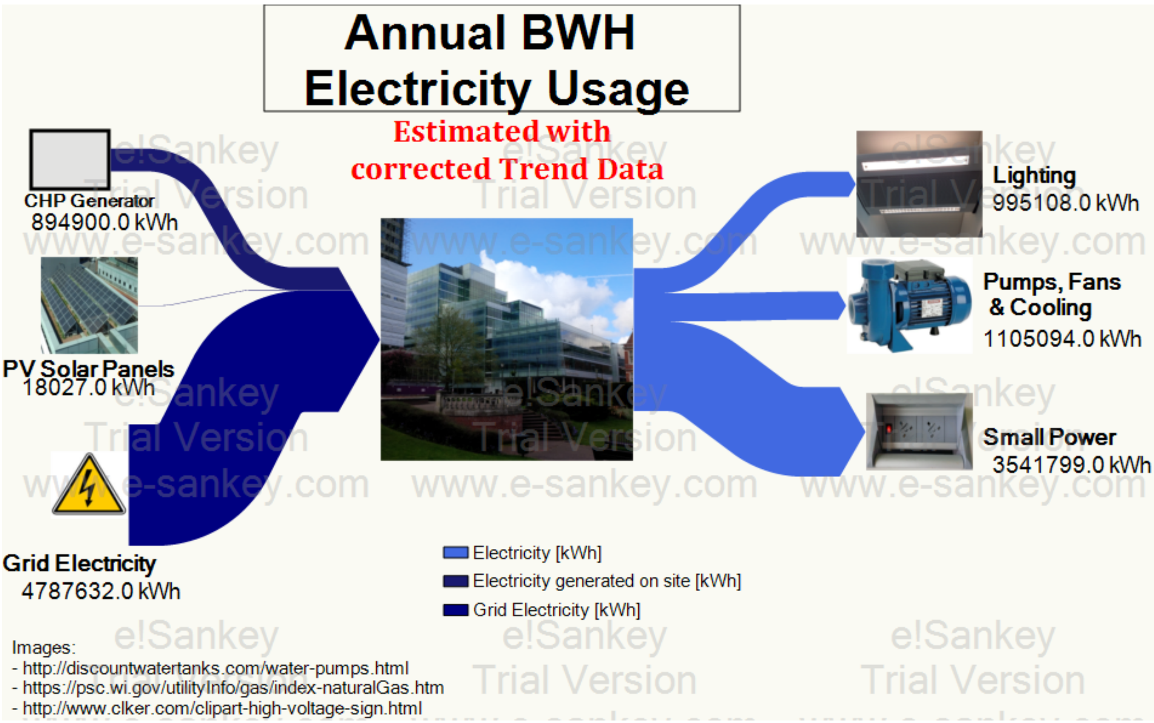
Questions:

1. **What is the hierarchy of the Facilities Management Department in (borough)?**
   - Do you use a third party company for any part of the process?
   - What are their responsibilities, in relation to bill management?
   - How is your team broken down? How large is your team?
   - How many buildings are served by your Facilities Management Department?
2. **Could you give us a little background on the energy management services or software that (borough) uses?**
   - It was indicated on the London Borough Energy Group Member Survey performed last year that the (borough) council outsources to a third party for bill processing & validation. What provider is used for this processing? Was the Council satisfied with it? Has the council considered different software or outsourcing to a different provider?
   - Do the **(borough)** Council offices have a Building Energy Monitoring System situated in its council office? If so, is it utilized by the Council?
3. **How are bills and utilities (especially electricity) usage analysed by (borough)?**
   - How is your team responsible for the billing process?
   - Is there a target that the bills are analysed and compared against?
   - Are there any safeguards to ensure that the energy monitoring points in the building are accurate?
4. **How is (borough) energy consumption reported?**
   - What form of reports do you have generated, if any? (half-hourly, weekly, monthly, year-on-year)
   - Does the Council use a company to do these reports or are they done within your team?
   - Are these reports accessible to the public through an online dashboard, display, or some other form of publication?
5. **What type of energy systems does the building have?**
   - Are your lighting systems automated?
   - What are you energy sources and how are they distributed?
   - Does the building produces energy on site? (renewable and non-renewable)
6. **Has (Borough) looked into the performance gap issue of newly occupied buildings?**

APPENDIX D: Electricity Usage Sankey Diagrams



Design Electric Usage



Estimated In-use Electrical Usage

APPENDIX E: BWH Energy Strategy Complete Analysis

This document contains the energy and carbon emissions design plan for Bernard Weatherill House. At the design stage this building was called the Public Service Delivery Hub (PSDH).

Introduction

Background and Description

The proposed project is part of the Croydon Urban Regeneration Vehicle in which John Laing, the construction developer, appointed Faber Maunsell to produce the energy strategy for the proposed PSDH office building for the Croydon Council. The energy strategy was targeted to meet local and regional energy-related planning policies. This study also analysed the possibility of having a district heating network in the town centre.

The proposed project consisted of a new office building for Croydon Borough Council, which reflected the Council's aims and aspirations for the future. The proposed facility had 21,770m^2 of net area of office space distributed in two zones; the south side of the building had 13 floors while the north side had 5 floors. The building plan offered space for the Council offices, services for the public, and other additional facilities for the council staff. The PSDH project is the first phase of the Croydon Urban Regeneration Vehicle that will redevelop several buildings in the town centre area.

Estimation Approach

The energy strategy calculations were supported by the use of computer-based tools. The building was modelled using the IES Virtual Environment software, from Integrated Environmental Solutions Ltd., which is approved for Building Regulations calculations. Weather data from the CIBSE test reference year for London was utilized for the energy analysis of the model as required by Part L2A of the Building Regulations (2006). For calculating the operational energy values NCM (National Calculations Methodology) templates were used and also modified in areas that contained an analysis of Low and Zero Carbon technologies. Finally the values for carbon dioxide emissions were calculated using the following factors, taken from the Building Regulations Approved Document L2A:

- Gas 0.194 kgCO_2/kWh
- Electricity from grid 0.422 kgCO_2/kWh
- Electricity generated on site 0.568 kgCO_2/kWh
- Biomass 0.025 kgCO_2/kWh

(Nkonge, 2009)

The Building Research Establishment (BRE) revised the conversion factors listed above for the calculation of accurate values of net CO_2 emissions in buildings. We can observe that the factor used for electricity generated on site is greater than the electricity from the grid. The factor used for avoided electricity "… is based on a mixture of the average carbon intensity of the marginal plant and the carbon intensity of new plant built or avoided" (Pout, 2005). The average carbon intensity of a marginal plant was modelled based on actual electricity generation data from an assumed plant of combined cycle gas turbines. Also this model takes into account any expected transmission and distribution losses to obtain a system average emission factor (Pout, 2005). The CHP and the PV panels generate the electricity produced on site for this project. These energy sources might produce a smaller amount of carbon emissions compared to the modeled combined cycle gas turbines but a common conversion factor is used for regulatory purposes.

Energy Efficiency

In the second chapter of the energy strategy, energy efficiency measures for the BWH are laid out. Design aspects that the consultant describes in this chapter are climate walls, use of daylight, air permeability, air conditioning, ventilation, and light detectors.

Beginning with climate walls, the consultant cites this double wall system as an excellent way to decrease heating/cooling while maximizing the amount of daylight. The buffer of air impedes the movement of heat across the wall, while allowing light to pass through unhindered (figure below). Fourteen different configurations were considered by the consultant with the current option, of triple glazed glass on three of the buildings, being the best fit. They do not go into the details of how this configuration was distinguished from the remaining thirteen. It is a bit odd that the plan does not describe how this solution was picked or mention any of the other configurations that were considered to be used.

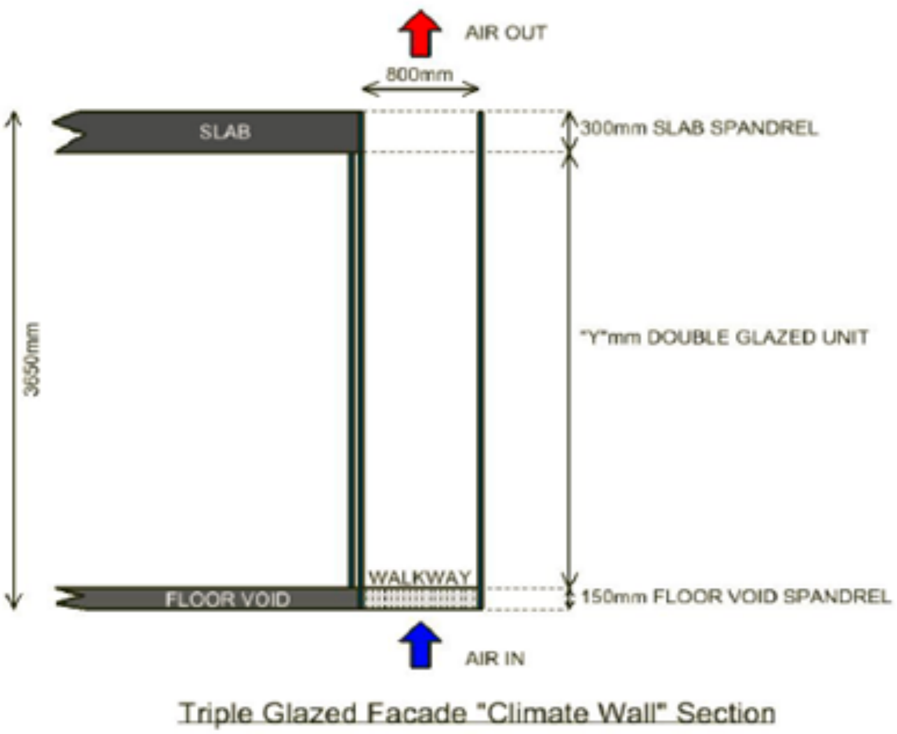


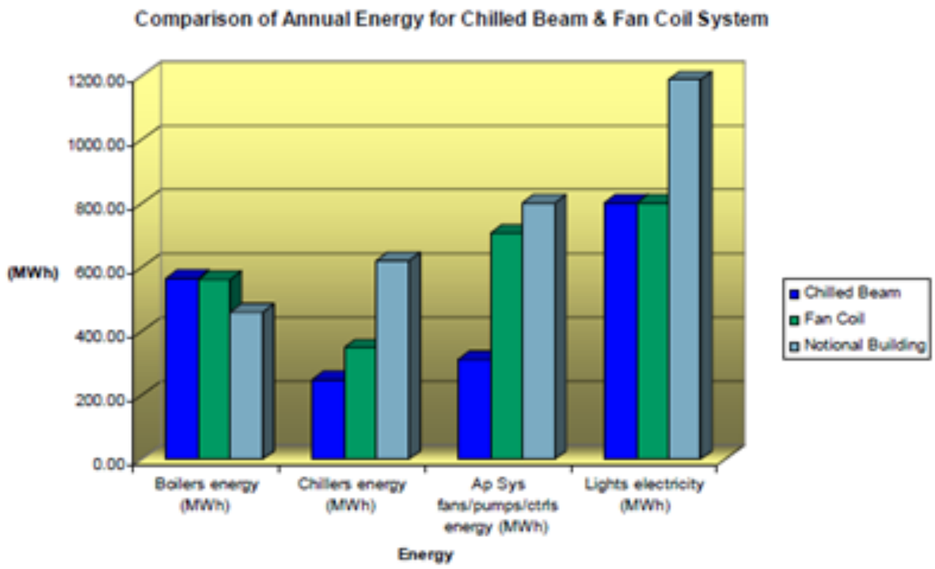
Diagram of Climate Wall

The document goes on to discuss the use of daylight in the building design. Increased natural lighting improves the working environment for the occupants while offsetting the lighting energy requirements. The implementation of the all glass walls and an inner atrium greatly increase the amount of natural lighting that comes into the building. In this document, the consultant includes computer generated models to show that the natural lighting in the building surpasses the recommended amount by about twofold.

While natural lighting does cover much of the lighting needs of the building it does not eliminate the need for artificial lighting. To reduce the energy consumption of lighting, high efficiency light bulbs controlled by a building management system and motion detectors. This setup is considered by the consultant to be the optimal design for lighting.

A topic that may not be evident to most, air permeability, is briefly covered in the energy strategy. The façade of the building is calculated to have an air permeability of half of the regulated amount. There is not much said in this chapter on how it performs so well and how much this low permeability will affect the overall energy consumption and occupant comfort.

The energy strategy does go into detail about how the final configuration for the air conditioning was determined. They start with five design criteria outlined by the council (comfort, proven technology, flexibility, maintainability, and environmental performance) and rate six different options on these criteria. The top two performing options from this table are then analyzed to see which one has the lower operating energy requirements as seen in the figure below. The chosen design is chilled air beam, which uses natural convection to draw air over chilled pipes. This system requires minimal energy to run as there is little demand from the fans and pumps.



Chilled Beam vs Coil AC

As a final point, the energy savings of the building are calculated to show how their collective improvement of BWH's performance. The document estimates that the carbon released by the building is 26.4 kg/m^2/yr significantly lower than the required 36.0 kg/m^2/yr. This is a large improvement; however, later sums are inaccurate. The total carbon emissions, not including small power, sums to 787 tonnes per year (Table below). Dividing this number by the area of the BWH (21,770 m^2) results in a carbon emission of 36.15 kg/m^2/yr, which is much higher than the document estimates.

Calculated Energy Use of BWH

	Building energy demand kWh/year	type of fuel	Fuel use kWh/year	CO_2 emissions tonnes /year	% of CO_2
Heating	266,732	gas	310,153	**60**	3%
Hot water	216,554	gas	251,808	**49**	3%
Cooling	1,801,927	electricity	286,020	**121**	6%
Lighting	759,553	electricity	759,553	**321**	17%
Pumps and fans	558,086	electricity	558,086	**236**	12%
Small power	2,704,546	electricity	2,704,546	**1141**	59%
Total	6,307,399			**1,927**	100%

Decentralized Energy

Energy that is generated and used within the buildings of interest is known as decentralized, or district, energy. A system known as a Combined Cooling, Heat, and Power (CCHP) or a Combined Heat and Power (CHP) system is responsible for this locally produced energy ("District Energy and CHP" 2012) . This system is specifically outlined for the construction of new buildings in London in Policy 4A.6 in the London Plan:

> "Developments should evaluate combined cooling, heat, and power (CCHP) and combined heat and power (CHP) systems and where a new CCHP/CHP system is installed as part of a new development, examine opportunities to extend the scheme beyond the site boundary to adjacent areas."
>
> -(Greater London Authority 2008)

Initial BWH CCHP/CHP designs could be divided into three primary categories: gas fired accompanied by renewable energy, renewable energy, and hydrogen fuel cell accompanied by renewable energy. Of the three options, the Energy Delivery Hierarchy recommended the gas fired accompanied by renewable energy; other recommendations were renewable energy systems were ground cooling, photovoltaic (PV), and wind turbines. The renewable energy CCHP/CHP systems consisted of biomass, bio-diesel, and digester gas; however, these structures were not advisable because biofuel technology is still under significant developments. Hydrogen fuel cells accompanied by renewable energy systems were also not advisable because of the overall cost for the system. A hydrogen fuel cell system incurs approximately 4 times the cost (£1,000,000) of a typical gas fired system (£250,000) (Nkonge, 2009)

Using a gas fired system accompanied by renewable energy, the BWH design concluded that this design was the most effective system to reduce CO_2 production. The system would consist of a gas fired CHP and a 40 m^3 Chiller; the exact specifications of these systems are presented in the table below (Nkonge, 2009). Together, the CHP would reduce the BWH's overall CO_2 emissions by 10%.

Gas Fired System Specifications

System	Power Capacity	CO_2 reduced
Gas-fired CHP	238 kW	200 tonnes
40 m^3 Chiller	200 kW	205 tonnes
Total:	438 kW	405 tonnes

Renewable Energy

To accompany the proposed gas fired CHP system, three renewable systems were proposed in BWH energy design: ground cooling, photovoltaic (PV), and wind turbines. Two additional systems that were considered were solar hot water and biomass boilers. However, these systems were discounted because both of them competed with the CHP for water heating. Of the first three systems, each one generates energy to offset the energy consumption of BWH in addition to lowering BWH's projected carbon footprint.

Ground cooling was achieved in BWH energy design using Ground Source Heat Pumps (GSHP), which can be separated into two different systems. The first system is Open Source GSHP, a system that pumps water from an outside source for water cooling; however, this system is not advisable because it affects local water supply. Close Loop GSHP is the other system, which is not as efficient as Open Source GSHP but is more viable for BWH design. Using a vertical Closed Loop GSHP would result in a reduction of 10 tonnes of CO_2 per year at an initial investment ranging from £837,000 to £1,396,000 (Nkonge, 2009).

Photovoltaic systems were also considered for BWH energy design. Even though PV systems are still a developing technology, they are still applicable to offset energy usage of newly designed buildings. BWH energy design planned for 200 m^2 of PV panels on rooftop areas of BWH. In total, this PV system would reduce 12 tonnes of CO_2 per year at an initial investment of £160,000 (Nkonge, 2009).

Building Mounter Wind Turbines were the final system to be considered for the BWH energy design. The calculation for this energy system was performed for two wind turbines which, together, reduced 3 tonnes of CO_2 per year with an initial investment of £30,000 (Nkonge, 2009).

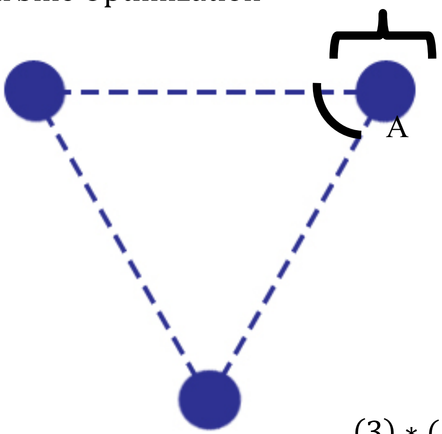
Of the three systems, the PV system was implemented in the actual design of BWH. Considering the CO_2 reduction per initial investment, it can be shown that Close Loop GSHP costs approximately £83,700 to £139,600 per tonne of CO_2 per year, PV costs £13,333 per tonne of CO_2 per year, and Wind Turbines cost £10,000 per tonne of CO_2 per year. Based on the calculated cost per tonne of CO_2, Wind Turbines appear to be the most cost effective system to reduce CO_2 generation; however, this technology takes up a great deal of space, with a minimum spacing of 5 blade diameters (3.1 m) between turbines ("qr5 – technical facts", 2012) (Nkonge, 2009). See below for a calculation of wind turbine energy density compared to solar power energy density.

Ultimately, photovoltaic systems were selected for integration into BWH based of their numbers in terms of efficiency. A summary of the qualities of each renewable energy are included in the table below.

Summary of Renewable Technology Assessment (Nkonge, 2009)

	Energy Saved					
	Heating	Cooling	Electricity	CO_2 saved		Cost
	(kWh pa)	(kWh pa)	(kWh pa)	(Ton pa)	(%)	(£ k)
GSHP Closed loop	97500	75600	0	10	0.7	837 - 1396
PV ($200m^2$)	0	0	22000	12	0.7	160
Wind Turbine (6kW)	0	0	5630	3	<0.1	30

Wind Turbine Optimization



Values:

$n = number\ of\ turbines\ (3)$

$p = 2810\ kWh$

$r = 3.1\ m$

$A = 60°$

Derivation:

$$Energy\ Density = \frac{np}{\frac{\sqrt{3}}{4}(5r)^2}$$

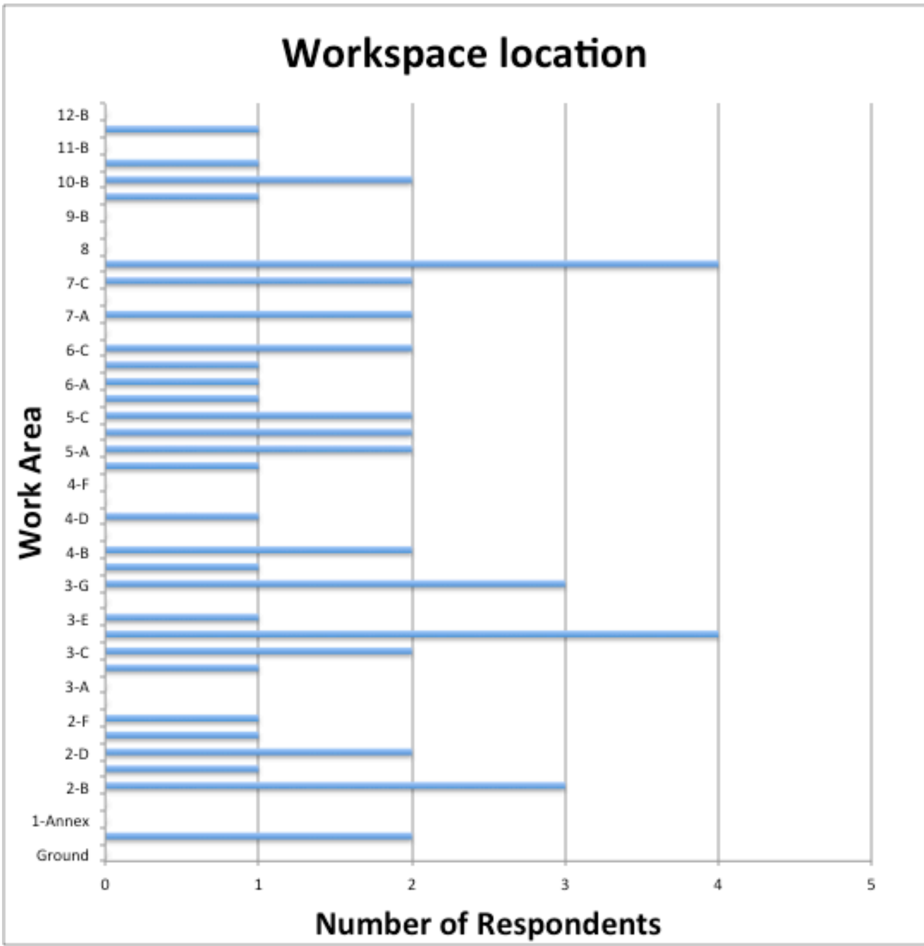
$$Energy\ Density = \frac{(3) * (2810\ kWh)}{\frac{\sqrt{3}}{4}(5(3.1\ m))^2}$$

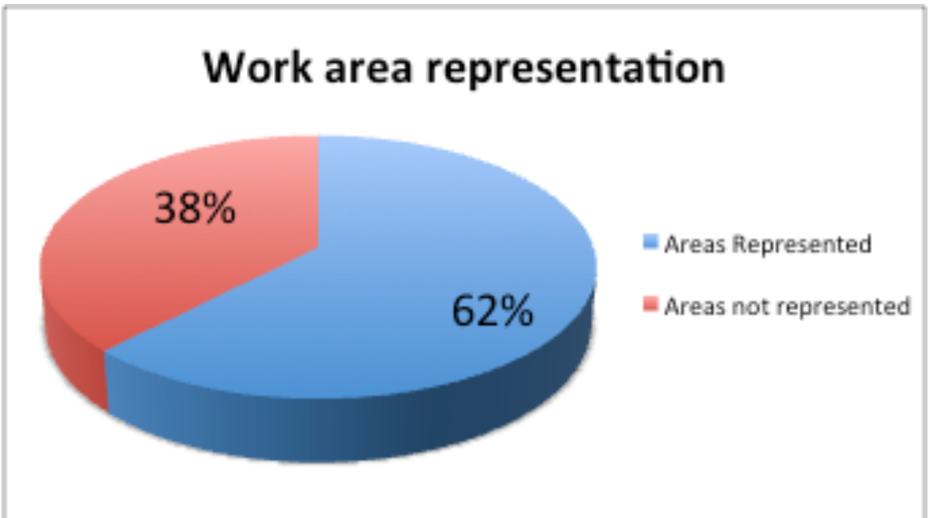
$$Wind\ Turbine\ Energy\ Density = 56.27 \frac{kWh}{m^2}$$

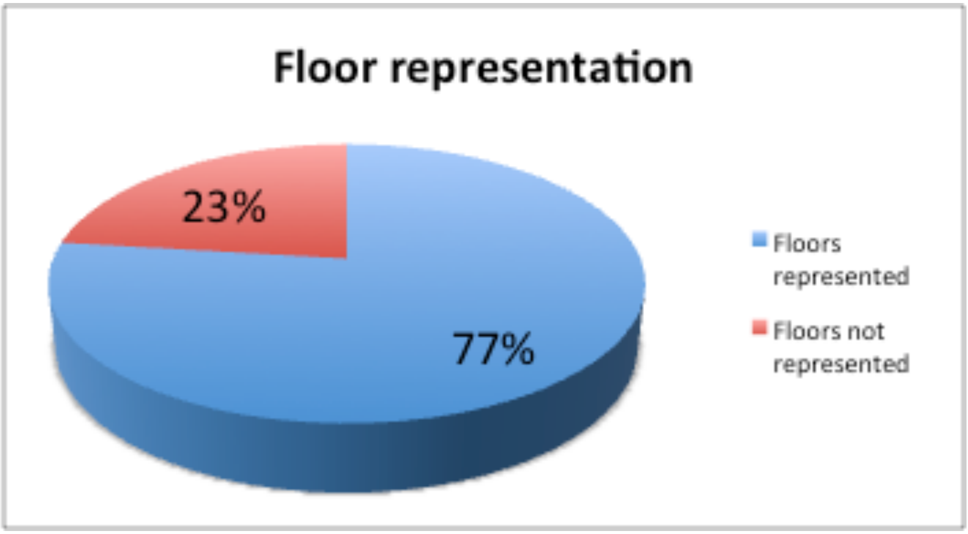
$$Solar\ Panel\ Energy\ Density = 110\ \frac{kWh}{m^2}$$

APPENDIX F: Survey Report Graphics

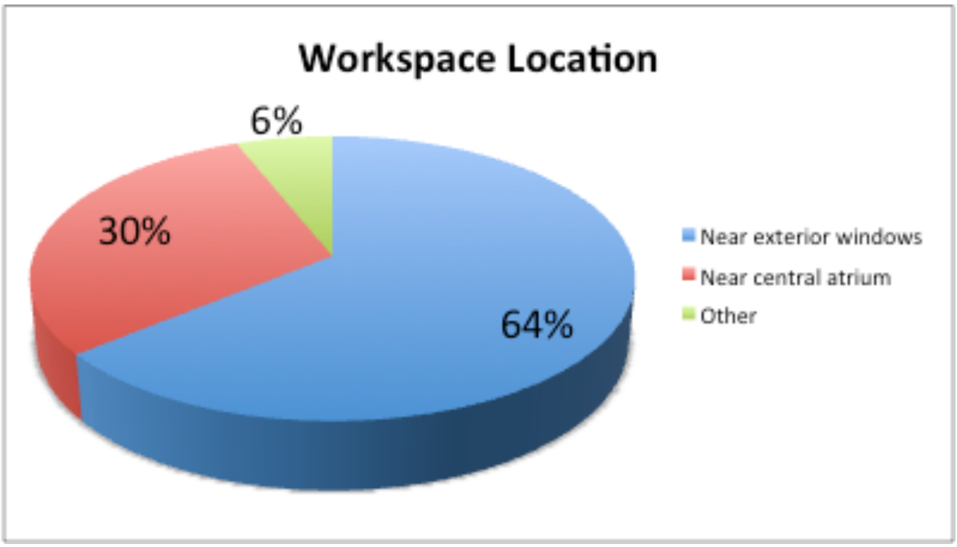
1. On which floor and zone of BWH do you typically work?



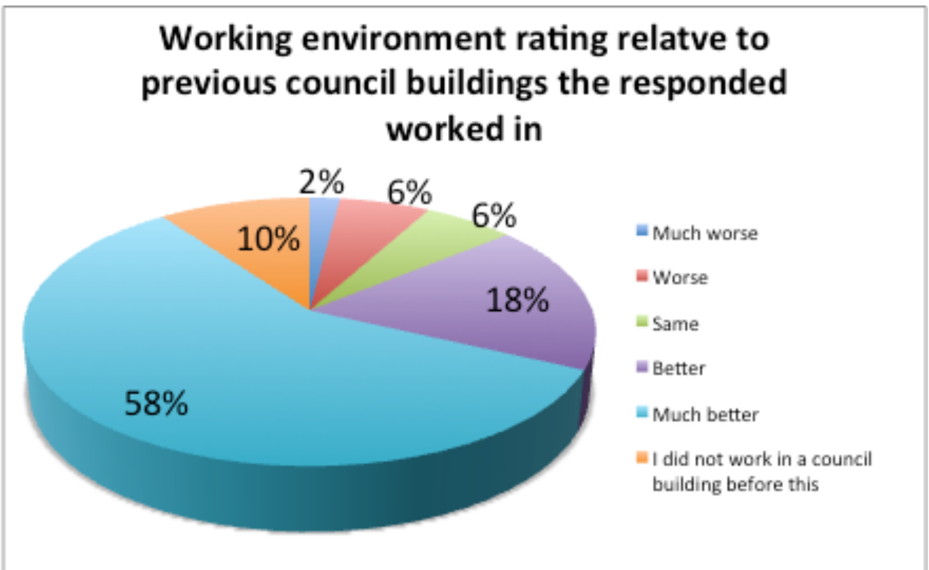




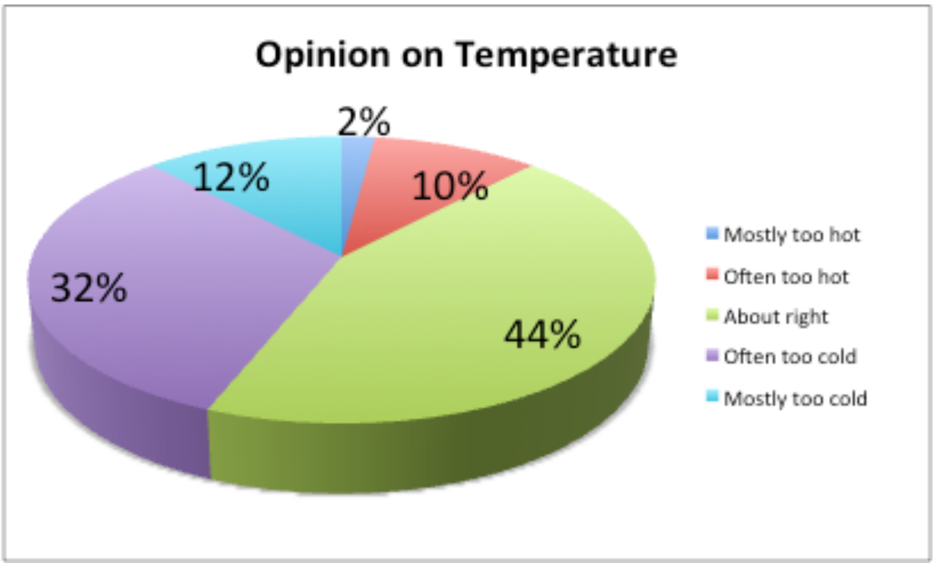
2. Where is your workspace located?

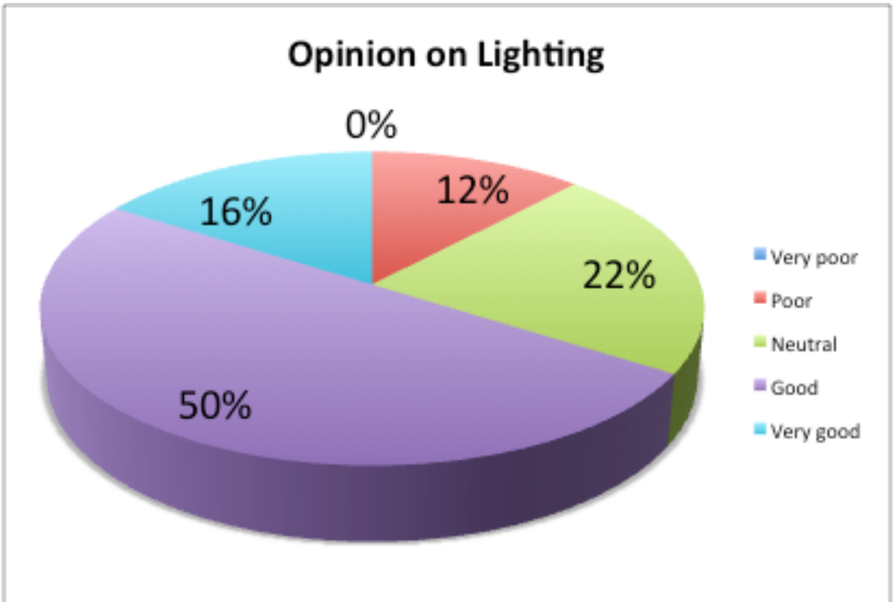


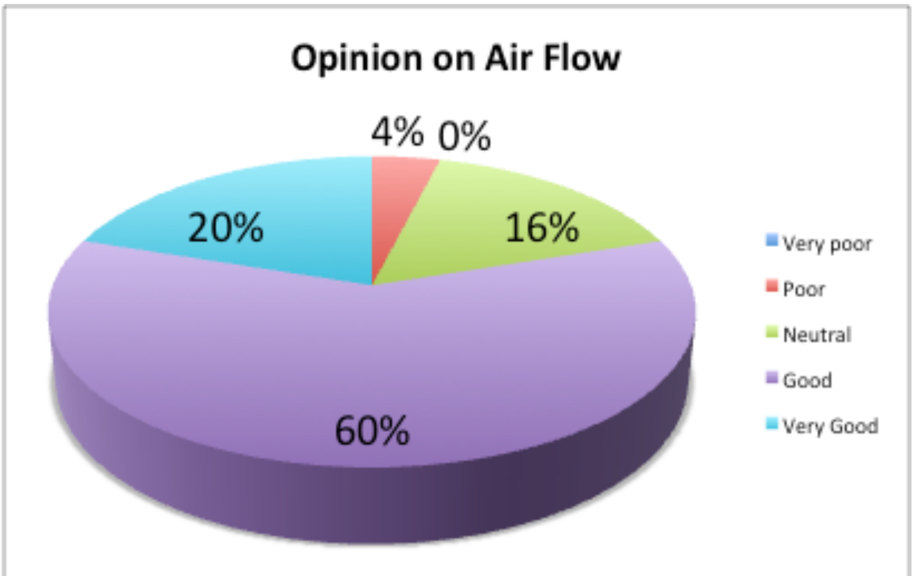
3. Relative to the last council building you worked in, how do you rate the overall working environment of BWH?

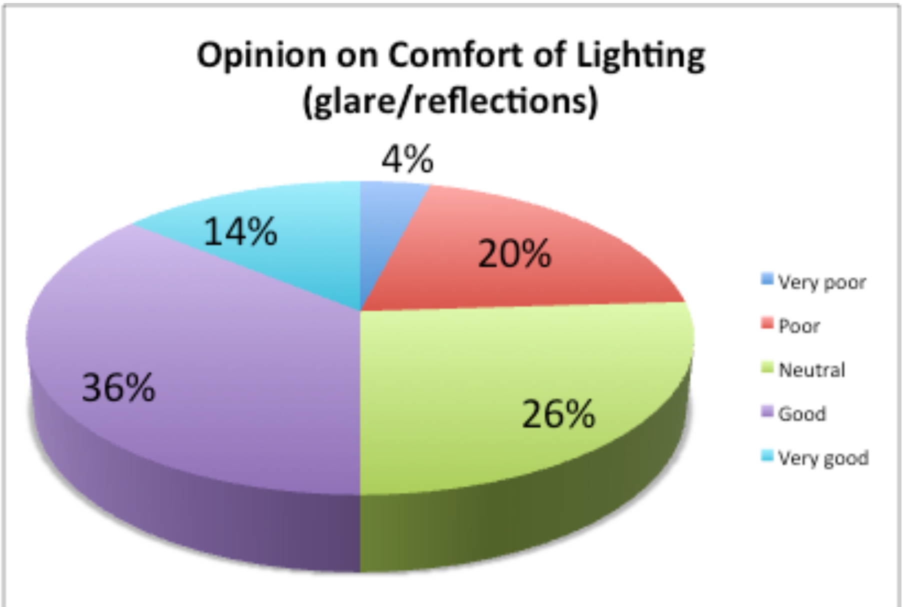


4. What are your opinions of your zone's work environment?







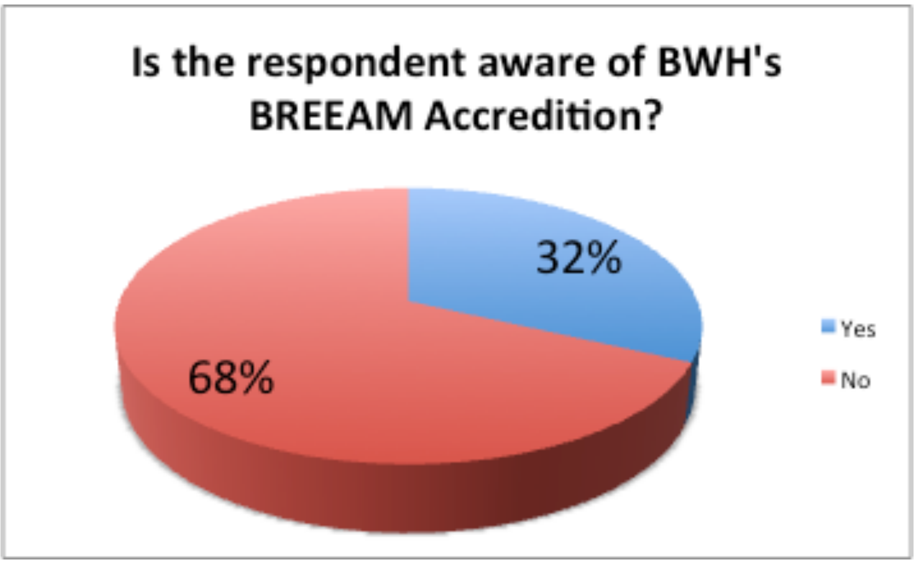


5. What are any other office environment issues you would like to mention?

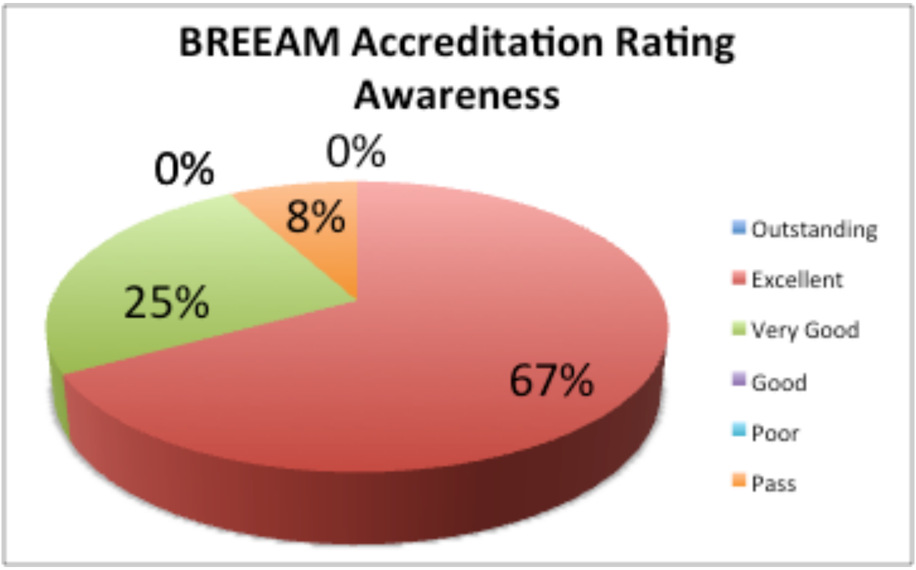
- Nowhere to hang wet coat...and..
- I have stated 'good' for visual comfort of lighting however this will drop down to a poor when it is a bright sunny day. We always have to pull the blinds down and therefore lose our natural lighting!
- The office is very cold and a lot of us are squashed together. A lot of us sit at 4 to row of desks when it should be 3
- It is cold all the time
- There is lot of office noise especially when there is an increase in the number of staff having discussions.
- Lack of seating for lunch or break out areas if you want a much needed break from the desk.
- Printers often used for big print jobs so if you haven't checked the queue beforehand you could wait a long time for your printing/emails to come through
- Lack of adequate size monitors for workstations. lack of draining boards means constant wet surfaces.
- The recycling facilities are inadequate and limited. We should be able to recycle all plastics and people need to be educated or incentivized to recycle. It is astonishing to see how much goes in landfill bins that COULD GO IN THE RECYCLING
- Noise levels - at times difficult to concentrate
- The office is very bright and the light is very strong, I am prone to migraines and the lighting sometimes triggers these
- Recycling has been made easy but most staff are not participating in earnest. more needs to be done. Let's get like North Korea "you will participate or pay the consequences" :-)
- It seems the system in place to control the temp is not sensitive to the actual need. It may be it needs to be reprogrammed as cold air is produced even though it is cool already
- As the building is made primarily of glass the building can get quite warm when the sun is shining even if the air con is on. This is also related to the glare problems

- Sometimes the air conditioning can be very cold when it blows directly on my desk space.
- Also, there is an inconsistent amount of space allocated to each bank of desks across the floor/floors.
- I don't know what materials have been used for office furniture. Sustainability criteria for example
- The toilets are good on the office concourse and having the wash hand basin in the cubicle with extra space is most welcome. There are cleaners during the day, which helps to keep the environment clean and fresh and maintains the clean environment in the building and the reliance on ones colleagues to clean up after themselves.
- Having a staff entrance is good with lifts. The lifts to the public area take time to arrive at lunchtime and breaks, which holds up access to the building and floor.
- Cold cold cold. I developed nasty colds twice this year already and I do not normally go sick.
- The office is often too cold and the outside is hotter.
- The cold temperatures are a major problem.
- Sometimes I am either too hot or too cold.
- Because we are sat quite close to each other and as the 'people' noise levels increase, sometimes it becomes difficult to hear when involved in a telephone call or close conversation with a colleague. This was not a particular problem in Taberner House but in BWH it seems more apparent.
- The fridge is often smelly and as I usually sit near it, it can be off putting
- Floor can get cold when working after 6.00pm. Slight foul odour on the floor at times.
- The glare from the sun on the windows in the afternoon make it too bright also when I go to pull blind now I get a static electricity shock.
- Sitting by the atrium does not give enough light and the are tends to be cooler.
- The temperature is fine during the day, but when it gets to about 4/5 pm it suddenly gets cold.
- The large windows give great natural light, but we often have to lower the blinds to stop glare on our computer screens. It would be nice if they weren't grey, as they look depressing, especially when it is bright outside.
- I am a hot desk working. When we initially came to the building, I found they area I sat in to be extremely noisy and there seemed to be a constant draft. I then moved to a different area within the same zone and it is much quieter and warmer to work in. I think the location of some of the walls and furniture may amplify the sound in some areas.

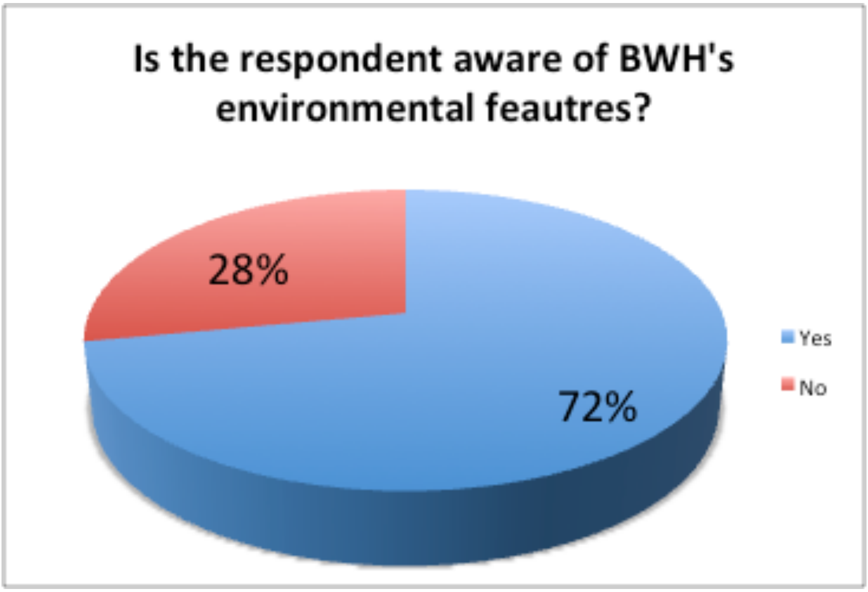
6. Are you aware that BWH achieved a rating under the "Building Research Establishment Environmental Assessment Method" (BREEAM)?



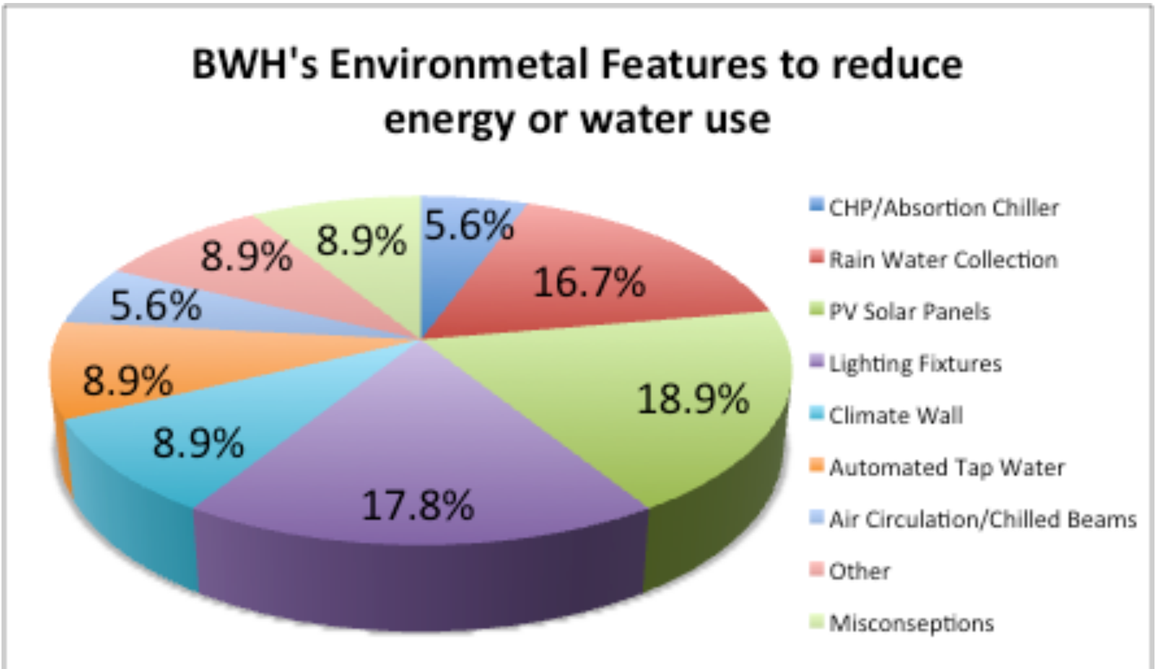
7. Do you know what BREEAM rating BWH achieved?



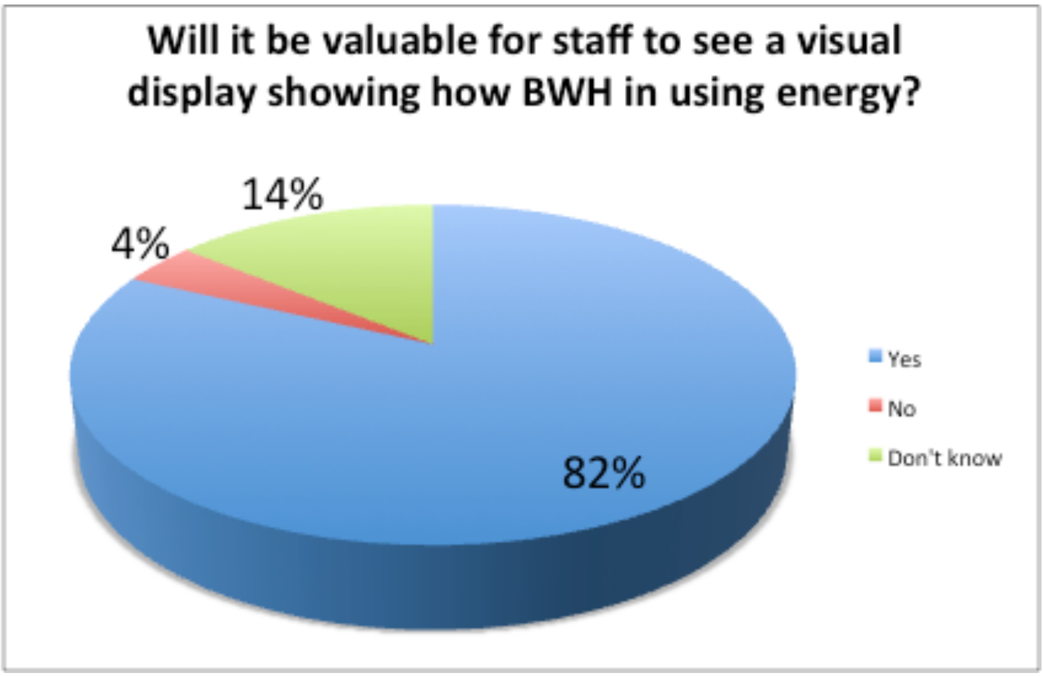
8. Are you aware of any environmental features of BWH that are designed to reduce energy or water use?



9. List all the environmental features you are aware of



10. Do you think it will be valuable for staff to see a visual display showing how BWH is using energy?

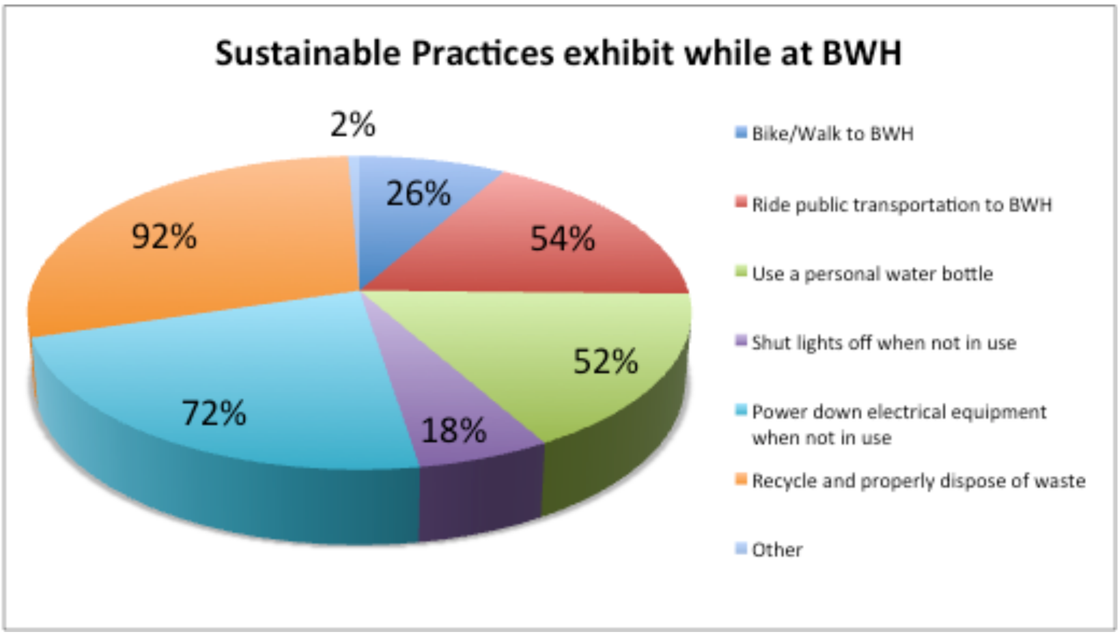


11. Where do you believe is the most effective location to display the energy performance of BWH? (Please click and drag the following options to rank them from 1 to 4, with the most effective location)

Answer	1	2	3	4	Total Responses
Entrance lobby display	6	16	11	12	45
Lift lobby displays	25	7	7	6	45
Cafe Display	6	12	16	11	45
Internet	8	10	11	16	45
Total	45	45	45	45	-

12. Are there any other locations you would suggest?
- In our magazines maybe
- Pillar each floor in a zone
- In the lift
- In the public entrance at access Croydon, so the general public is aware of this
- Kitchen Areas
- Customer entrance/area
- Posters in communal areas
-On individual pcs or laptops as pop up messages - also reminding people to turn off screens and plug sockets when they leave
-Intranet or SharePoint
- On each floor display
- Seating areas on the 8th floor away from cafe

13. Which sustainable practices do you exhibit while at BWH? (Please mark all that apply)



14. Are there any sustainable practices you would like to see implemented in BWH?

- I like to be educated in sustainable practices and am learning to the things that have been suggested at work in my home. Its a learning curve
- More effort made to get everyone on board to separate and recycling properly
- More information on how other products are disposed of e.g. photocopier materials; what our desks and other furniture are made of....
- Adjustable lights and air conditioning as was in Taberner house...makes it easier for people hot desking to adjust as they wish wherever they are sitting.
- Should use less paper in the office and waste less paper
- Focus on printing less
- We need more desks in our area as this is impacting on our team. Hot desking would work if there where enough desks we could use that had all our systems and did not affect our profiles each time we moved
- A campaign to encourage staff to switch off their monitors when they leave their hot desks so that they are not left on all night! Likewise the photocopiers/printers, we used to switch them off at our old building, but here they just seem to be left on snooze all night.
- I have noticed that there are no ceiling light motion sensors over the cubicles in the ladies toilets. This can be hazardous if someone is unwell and then finds themselves left in the dark as the motion sensors are outside the cubicles.