Energy balance in the adaptive reuse of historic urban industrial buildings

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ABSTRACT

Building adaptation is a form of development that embraces social, economic and environmental dimensions of sustainability.

Despite the environmental factor being inherent to building re-use, usually the economic and heritage conservation related concerns are the ones that lead the process. Although increasing concerns about the climate change and the subsequent reinforcement of energy efficiency requirements in codes and regulations is changing this trend, the debate on how to introduce energy efficiency in this process is still undetermined. The proposed methodology is a case study research on historic industrial buildings that have been converted in the last years following best practice architecture, in order to reveal these complexities and solutions when confronting the arisen situations.

A literature review regarding the context, current barriers and prospective opportunities as well as key considerations when developing low energy strategies in historic buildings is addressed in the first part of the work. To continue, the selected case studies are studied in depth using BUS questionnaires, interviews with practitioners and in situ analysis in order to identify the decision making process and the main problems derived from those decisions.

The main findings reveal that there is a relaxation in the energy performance of these buildings under the general assumption that measures to improve them would be detrimental to their historic value, while the underlaying reason for not developing these strategies is associated with the detachment of the capital costs from the revenue benefits. In addition, the fragmentation of the design process and the complexity of the systems in which all the decisions are interrelated resulted in extra difficulties to obtain accurate data.

The challenges identified in this work will provide useful lessons for future practitioners and policy makers by emphasizing the relevant aspects, needs, achievements and failures in these processes. The experiences and strategies found to reconcile heritage and environment also intend to be useful for future processes, while the possibilities of historic buildings to improve their energy performance exposed in this work aims to encourage the society to demand better values for heritage preservation.

“A building is not something you finish.
A buildings is something you start”

(Stewart Brand, 1994, p.188)

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CONTENT

FIGURES

chapter 1

INTRODUCTION

1.1 Background

1.1.1 Climate change and the built environment

Since the 1960s and 1970s, it is well acknowledged that the increasing concentrations of carbon dioxide in the atmosphere are correlated to the rapid increase of the climate change (United Nations, 2012) and there has been growing evidence that "unmitigated climate change would, in the long term, be likely to exceed the capacity of natural, managed and human systems to adapt" (IPCC, 2007, p.73). Hence, at the very heart of the response to climate change lays the need to reduce emissions.

"Buildings use about 40% of global energy, 25% of global water, 40% of global resources, and they emit approximately 1/3 of GHG emissions" (UNEP, 2012). For this reason, within the UK government carbon plan, "the Climate Change Act established a legally binding target to reduce the UK's greenhouse gas emissions by at least 80% below base year levels (1990 levels) by 2050" (HM Government, 2011, p.3); By 2050 all buildings will need to have an emissions footprint close to zero for which it has been established that all new build housing must be to be zero carbon by 2016 and all new buildings to be zero by 2019. Although there are several predicted strategies towards reducing the demand of energy in buildings, there are no similar targets for existing buildings, however (HM Government, 2011).

On the other hand, it is estimated that 80% of the buildings that we will be occupying in 2050 have already been built, new buildings representing only an addition of 1% to the building stock each year (Yangang Xinga, 2010, RICS, 2012b). In this context, the reuse of existing buildings to meet the needs of present and future generations represent a great opportunity for carbon emissions reduction and sustainable development.

1.1.2 Re-use of buildings

Building adaptation or adaptive reuse, is broadly defined as "any building work and intervention to change its capacity, function or performance to adjust, reuse or upgrade a building to suit new conditions or requirements" (Douglas, 2006).

This practice is a form of development that embraces the social, economic and environmental dimensions of sustainability; it usually extends the building life, encourages reuse of the embodied energy, recycles valuable buildings, promotes the smart growth and can provide the catalyst for the regeneration of whole areas. (Brooker and Stone, 2004, Douglas, 2006, English Heritage, 2011, Esther H.K. Yung and Chan, 2011).

1.1.3 Key factors and decision making

Despite the environmental factor being inherent to building re-use, usually the economic and heritage conservation related concerns are the ones that lead the process (English Heritage, 2011).

On the other hand, due to the increased concern about climate change, the Part L document in the England Building Regulations which address the energy efficiency requirements has been modified several times in the recent years; The target emissions rate (TER) in the 2006 document was improved by 20-28% over 2002 document, and 2010 document´s TER would be below 40-46% of the 2002 document (UK government planning portal, 2012a, Calford Seaden, 2012). Furthermore, propositions to extend the requirements for 'consequential improvements' (extra energy efficiency works) in 2013 to the Part L1B and Part L2B have been stated in the 2012 consultation report to changes to the building regulations in England (Department for Communities and Local Government, 2012).

As a consequence, there has been a change in this trend, however, the debate over how to introduce the environmental aspects in the re-use of historic buildings remain undetermined.

1.1.4 Industrial heritage in UK

Historic industrial buildings represent a major opportunity for adaptive reuse, not only because of their location within the urban grid and possibilities for the economic and urban regeneration, but also because they are often vacant and their unique ownership status made them more suitable for a change (Ball, 2010).

As a study for The English Heritage shows, the historical value of industrial buildings in UK is of high significance; "England's preserved industrial heritage is one of its most important cultural assets. It reflects Britain's emergence and subsequent growth as the world's first industrial nation" (Cossons, 2008, p.2).

Although the conservation bodies in UK promote "conservative repair" to oppose the destructive restorations (SPAB, 2012), listed buildings which are left empty and unprotected may be classified as being "at risk", either by English Heritage or by local planning authorities (English Heritage, 2011), for this reason, both national and international charters specializing in the care of industrial heritage promote the idea of an adaptive reuse as a good strategy for preserving them (English Heritage, 2011, ICOMOS, 1964, ICOMOS, 1999, Rogic, 2009) .

Nowadays, 4% of listed buildings and 4% of scheduled monuments in UK are industrial (English Heritage, 2012c). It is clear that industrial heritage is a limited resource, hence, it is not the solution to solve built environment´s impact, but due to its strong economic, cultural and heritage conservation potential, it can be used as an example of the

main constrains when implementing adaptive reuse interventions in historic buildings in order to achieve a methodology applicable to a wider context.

1.2 Problem definition

1.2.1 Rationale

When introducing an advanced energy standard in the construction industry, several problems related not only with construction issues but also with general system performance issues within the whole process, such as the lack of integration between different aspects of building regulation at the first stages, lack of comprehensive energy performance testing and problems with performance understanding within the design process and lack of performance measuring in the final stage, have been identified as the reasons for achieving lower performance rates than expected (Dr Jez Wingfield et al., 2007). As energy performance targets increase, these inadequacies in the construction process can result in the lost of energy efficiency. There is, therefore, the need to rethink the process and embrace new tools and methodologies.

The interest of this dissertation lies in the interface between different disciplines during the design process when facing an adaptive reuse of an historic building in relation to environmental factors.

Regarding all this facts, a research of the key factors that affect the energy performance in the adaptive reuse of historic buildings and how to address them in practice is proposed.

Related to this area, some questions will be addressed:

01. How do different disciplines interact in relation to optimizing energy performance?
02. Which are the parameters that affect the decision making in relation to energy in use?
03. How do constraints related to economic, social and historical values affect the energy in use performance?
04. When should energy efficiency take precedence over other values?
05. How can these evaluative decisions affect the project?

1.2.2 Aims and objectives

This thesis aims to evaluate the various approaches to adaptive re-use of historic buildings today with a focus on energy conscious reuse in terms of best practice.

The objectives are:

01. To understand the complexity of the adaptive reuse in historic buildings and the interface between its social, historic, economic and environmental implications.
02. Identify problem areas, convergences and divergences of the different disciplines.
03. Evaluate the decision making process and the opportunities and barriers for the environmental approach.
04. Analyse the constraints that affect the energy strategy.
05. Explore different energy strategies and processes in practice.
06. Evaluate and consider the impact and benefits of this practice.

1.3 Methodology

1.3.1 Case Study methodology

Processes within architectural practice tend to be interconnected and interrelated. To understand one thing it is necessary to understand many others and, crucially, how the various parts are linked. The case study is an adequate approach for this work because it offers the chance to explain why certain outcomes might happen rather than just find what those outcomes are (Descombe, 1998). It addresses all the objectives.

The aim of this work is to investigate an issue in depth in order to provide an explanation that can cope with the complexity and subtlety of real life situations. Focusing on the particular, the case study approach gives the opportunity to deal with a case as a whole, and thus have the chance of being able to discover how the many parts affect one another from a holistic view more than from an isolated one (Descombe, 1998).

The selection criteria for the case studies will be a combination of typical and extreme instance by selecting typical industrial buildings reused in UK within a mixture of typical and pioneers experiences in the area in order to provide reliable information about the broader class. According to an study by Flyvbjerg (Flyvbjerg, 2006), in which generalization from case study research is analysed, it can be generalized from a basis of a single case, however, generalization is overvalued whereas “the force of example” is underestimated.

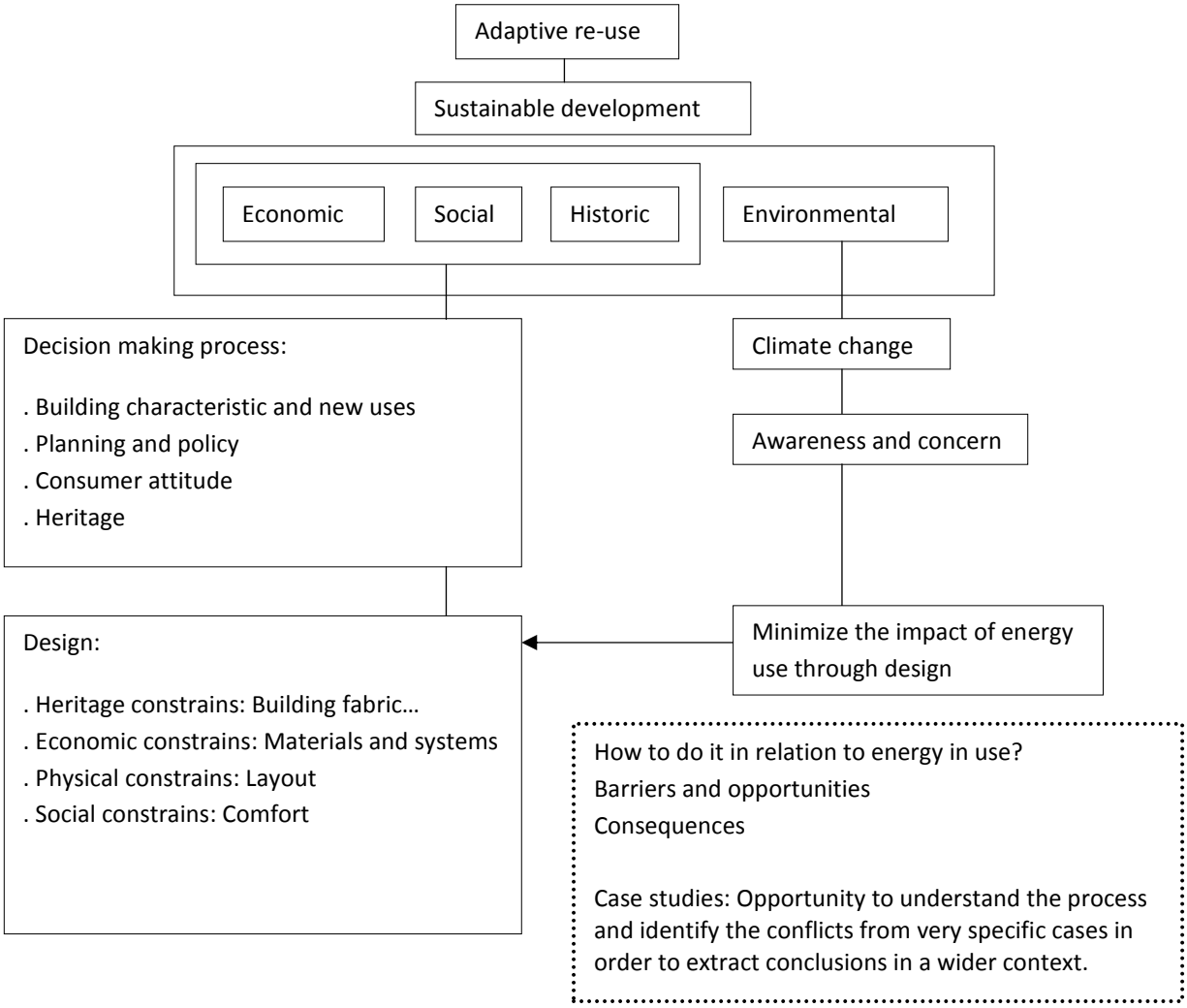


Figure No.1/ Description of the methodology to address the problems arisen in the process of adaptive re-use of historic buildings. Authors own, 2012.

1.3.2 Research Methods

The case study approach allows the use of multiple research methods, sources and data as part of the investigation to meet the objectives. Looking at the nature of the work, an intensive literature review will be developed in the first part of the project during the investigation of historical-social-physical-economical phenomena within the complex context of the energy efficient reuse of historic buildings in order to identify major factors at play in the sustainable adaptive reuse of built heritage. This will meet objective 1 and 2 of the study (see 1.2.2 aims and objectives).

The analysis of the buildings will include an exploration of the building in order to identify the main issues, a questionnaire and/or short interviews with the occupants for evaluating their comfort and usability within the building and finally a formal interview with the practitioners involved in the process to analyse the decisions taken and the reasons for them.

The option selected for gathering data about the occupants comfort and the usability of the building will be The BUS Occupant Survey Method. This approach is a proven survey method, a quick and thorough but not simplistic way of obtaining professional-level feedback data on building performance, primarily from the occupants, which can be supplemented if necessary with interviews, (Usable Buildings, 2012). This will help to evaluate the matters that cannot be directly observed by the experience of its occupants, helping to identify the problem areas and to evaluate the impact of this practice, meeting the objectives 2 and 6.

Then, the use of interviews with people involved in the design process will help to understand not only the What but also the Why of the relation between different disciplines and so to discern what is the role of the energy aspects during this process with regard to the barriers and possibilities of addressing them in practice. The objective 3, 4 and 5 of this work will be met with this method. The main factors addressed in this part will be:

01. The decision making process.
02. The approach and the strategy
03. The problems arisen
04. The consequences and conclusions of this practice

1.3.3 Structure

The main structure of the dissertation will be:

01. Explore [the interfaces and the approaches]
02. Describe [the data found]
03. Compare [case studies]
04. Evaluate [an overview of the whole process]

1.3.4 Scope

The risk of over-complication and the challenge of integrating many data sources in a coherent way from a case study approach can be avoided by establishing rules and procedures in the first part of the work.

For this reason, a specific typology and process have been addressed in order to reduce the scope of solutions and problems. The aim is to create a specific strategy related to re-use of industrial buildings pointing the main issues to bear in mind from specific cases so that the strategy can later be implemented in other cases.

chapter 2

LITERATURE REVIEW

2.1 Context

2.1.2 Sustainability and the built environment

The terms sustainable design, sustainable development and energy efficiency are often confused. Sustainable development is defined as: "Development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (Caroon, 2010, p.43), and it informs the way we approach sustainable design. Sustainability, is not limited to the environment and energy performance but it embraces the synergies among social, environmental and economic stewardship, also called "Triple Bottom Line", a term attributed to John Elkington (Caroon, 2010).

As carbon dioxide (C02) emissions in the atmosphere have been proven to be correlated to the increase in global temperatures, a fact that will exceed our capacity to adapt in a future, a key aspect of sustainable design lies in reducing CO2. Thus, as "buildings use about 40% of global energy, 25% of global water, 40% of global resources, and they emit approximately 1/3 of GHG emissions" (UNEP, 2012), they are a key aspect in the UK government carbon reduction target.

In this context, energy consumption in new and existing buildings can be reduced between 30 and 80% using available technologies, therefore, there are significant opportunities for existing buildings which performance level is frequently far below current efficiency potential (UNEP, 2012), a fact proven in Low energy building database where there are measured improvements and forecasted improvements in energy of 57,7% (Grove Cottage, Hereford) and 92% (Poplar Road, Brixton) respectively after refurbishments (LEB, 2012).

On the other hand, according to the English Heritage, although there are approximately 372000 listed building entries, only 1.5% of them are added back into the building stock each year this situation revealing the complexities related to the reuse of this kind of buildings (English Heritage, 2012b). It seems clear that energy efficiency is an increasingly important factor in the built environment but, is it necessary to improve the energy efficiency of historic buildings? Is it the energy reduction the only sustainability domain valuable when re-using them?

Understanding the interrelationship between different elements has been pointed as a sustainable way to establish a hierarchy, and so decide which elements are important to preserve and which ones are subject to change with more freedom;

"In order to achieve sustainable regeneration, it is important to identify what it is that brings character and diversity to the built environment of an area where change should be made to preserve local or regional distinctiveness, rein-

forcing what make areas or communities special. Such focus then provides greater freedom in dealing with the less important elements" (English Heritage, 1998, p7). "If regulations are applied to whole cities rather than to individual buildings, we will be able to set priorities: some buildings can compensate with aesthetics for the beauty what others sacrifice in their energy efficiency" (The Why Factory, 2010, p.22).

On the other hand, giving historic buildings a "polluting licence" can also have a negative impact as due to the significance of these buildings, they are also seen as exemplary status, and achieving a high standard of energy efficiency in them can be of particular significance. (Roberto, 2006)

2.1.3 Adaptive reuse

When approaching an existing building, there are several concepts related to the conservation of a structure that must be understood; The Preservation methods aim is to maintain the building in the found state, doing the minimum intervention to made it safe and prevent further decay; Restoration aims to return the building to its original state; Renovation aims to renew and update the building without substantially changing it; Finally, remodelling/reuse/adaptation will be the process of altering the building, by changing for example the use or internal relation, making additions and even demolitions. Sometimes, various methods can be used at the same time (Brooker and Stone, 2004).

The greenest building is clearly the one that already exists (Caroon, 2010). In the 1970s, Sir Alex Gordon (then RIBA president), coined the phrase 'long life, loose fit, low energy', as a maxim for good design (Murray, 2011). This approach states that a building should last and allow for changing uses over time while consuming low energy.

Hence, from the environmental view, adaptive re-use extends buildings life doing more worth the embodied energy expenditure of it, an important factor if taken into account that The United Nations Energy programme, estimates that "the embodied energy of a building is 20 percent if a building is operational for 100 years" (Caroon, 2010, p7). Accordingly, "it can take between 10 and 80 years for a new, energy-efficient building to overcome, through more efficient operations, the negative energy and climate change impacts caused in the construction process" (National Trust for Historic Preservation, 2012, p6). In addition, historic buildings employ design and techniques learned from centuries, embracing principles as durability, reparability and passive survivability as they were constructed to last in a time when the energy dependency was low and before mechanical systems appeared in the market allowing then to function even when modern systems and energy sources fail creating at the same time a more energy conscious way of life. (Caroon, 2010)

However, an old building cannot achieve the energy performance that a new one can and although re-use almost

always offers environmental savings over demolition and new construction if the constructions materials are not selected carefully to minimize environmental impacts; the benefits of reuse can be reduced or even negated. (National Trust for Historic Preservation, 2012).

There are also economic opportunities; In the majority of cases, reusing rather than constructing from the grounds is a great opportunity for costs savings and can have several advantages in terms of the development of local economies. In addition, the upgrade of some historic buildings can also represent a major opportunity to regenerate entire areas with the subsequent social and economic development. (Latham, 2000, Douglas, 2006) However, there are some cases in which the historic value of the building makes it to be preserved even if its state is not adequate to do so annulling the possible economic benefits, "Only 40% of listed industrial buildings at risk could be put to sustainable and economic new uses. The remaining 60% are entirely dependent on voluntary effort, private philanthropy and increasingly scarce public funding" (English Heritage, 2012c).

To sum up, it is important to assess the way in which historic buildings are reused, assuring that all the values are maintained in order this practice to be sustainable and feasible, otherwise, there is a risk of losing an important part of the UK heritage alongside with important economic and environmental opportunities.

2.1.4 Industrial Heritage in the UK

The historical value of industrial buildings in UK is of high significance given that "England's preserved industrial heritage is one of its most important cultural assets, not only nationally, but internationally, as it reflects Britain's emergence and subsequent growth as the world's first industrial nation (Cossons, 2008).

Nowadays, 4% of listed buildings and 4% of scheduled monuments in UK are industrial (English Heritage, 2012b), as a result of an institutional response and social awareness; according to a Research commissioned by English Heritage, "people really care about our industrial heritage: 85% agree that it is important to identify significant sites from our industrial past so they can be protected" (BDRC continental, 2011).

Industrial buildings are not judged any more by what they used to represent (oppressive working conditions and poor living standards) but by what they are. The gentrification process launched the idea of this buildings are desirable places to live and work and represent a big opportunity both socially and economically due to its adaptability to change, being able to accommodate a variety of uses and spatial requirements. National and international conservation charters specializing in the care of industrial heritage promote the idea of adaptive reuse as a good strategy (English Heritage, 2011, ICOMOS, 1964, ICOMOS, 1999), however, as Martin Cherry pointed out when discussing the problem of protecting industrial heritage; "in general, protection implies control of change, whereas reuse pre-

supposes change" (Rogic, 2009), and although 'adaptive reuse' is promoted as the best way to protect industrial heritage, the complicated paradox between protection and change make them be part of such of unique and contextual situations that there is no consensus as to what constitutes good practice of 'adaptive reuse'. ((Rogic, 2009) (Cossons, 2008))

In this context, the energy efficiency in historic buildings has been highly discussed. While some bodies promote a "conservative repair" to oppose destructive restorations (SPAB, 2012), others show concern about the role of the energy performance in historic buildings; "Existing historic and traditionally-built structures have a role to play in reducing carbon emissions and for that reason should not play the historic card to avoid doing so" (Historic Scotland, 2011, p3).

On the other hand, Spab´s on-the-spot recent research showed that old buildings are more energy efficient than is generally assumed and current building industry method of assessing energy performance in historic buildings is not accurate, hence, taking into account the nature of these buildings, careful and sensitive interventions rather than drastic solutions are required when approaching them. (SPAB, 2002)

2.2 Approach: Decision making process

Adapting an historic building is a complicated process that should be based on the unique context of each building. This process should address the question of how to respect and retain the building significance while adding a contemporary layer that provides value for the future (Bullen and Love, 2011, Esther H.K. Yung and Chan, 2011). The various issues concerning the decision making process are now discussed.

2.2.1 First considerations

When considering a building for reuse, it is essential to examine issues such as the building structural layout, its capacity to accommodate new uses, its potential to meet current standards, the condition of its installations structure stability and fabric in order to see if it is possible to adapt the building (Bullen and Love, 2009).

In terms of environmental performance, confronting an existing building can be restrictive due to the fixed space layout; ceiling high for the inclusion of ductwork, windows display and its impact on the daylight amount and restricted space for the implementation of new measures can lower the possibilities of achieving a good performance. Although there are not many things that can be done at this respect, the assessment of a suitable use can be positive to achieve better values.

2.2.1 Opportunities and barriers

2.2.2.1 Dealing with the past

Usually the most important consideration when dealing whit historic buildings is the historic significance. Historic buildings and their component parts are a finite resource, which once lost cannot be replaced, for this reason, there is a protection from different bodies towards these buildings historic value which can overpass through energy aspirations in a project. When a buildings is listed in UK, the local planning authority and the English Heritage will be the ones responding to development proposals (Jonas, 2007).

The position of English Heritage thought, is not opposite to energy efficiency, furthermore, alongside with other bodies in the country it is working to encourage historic buildings to improve their energy efficiency by giving guidance to achieve the best practice solutions. They promote the goal of "positive conservation" and managing rather than "preservation", therefore, the listed buildings consents regime does not aim to prohibit any change but to establish criteria for an "acceptable change" (Jonas, 2007). Nevertheless, there are still some points where the conservation and energy efficiency will crash during the process, therefore, limitations in the scope of energy efficient improvements are expected, particularly if these are changes that might affect the external appearance of the building or that may be irreversible (English Heritage, 2012e).

2.2.2.2 Economic viability

From the economic standpoint, to deliver a building with very low energy performance can be up to 10% more expensive although the resulting running cost may be lower (RICS, 2012a, Hunt, 2008). In historic buildings, where the historic significance usually leads the process, the economic effort is mostly focused on achieving this aim. There are also several grants available for historic buildings, which can fund between 20% and 95% of the total cost of these projects, but their primary aim is to retain the historic significance of them (McCleary, 2005, English Heritage, 2012d, The National Lottery Fund, 2012).

However, there are also several policies launched by the UK government to promote the energy efficiency in buildings, these include the Green Deal and the CRC Energy Efficiency Scheme (Department of Energy and Climate Change, 2012, Department of Energy & Climate Change, 2012a, Department of Energy & Climate Change, 2012b).

2.2.2.3 Market conditions

When planning an adaptive re-use project, if there is no expectation for demand, any other considerations must be

inconsequential.

There is evidence to suggest that historic buildings can command higher prices in residential use than new build while rents in offices in reused historic buildings tend to be lower than those in new built but higher than post war period´s (1960-1980) buildings (Jonas, 2007) .

In new built, it stands to reason that energy efficient properties can achieve higher market value, in fact, several studies have proven that premium are being paid to lease or buy energy-efficient properties, and that owners of efficient commercial buildings are experiencing higher occupancy rates and faster lease-up periods (N. Kok and M. Jennen, 2011, M. Hyland et al., 2012). However, in the UK no empirical evidence of capital value differentiation in the value of accredited buildings with those that are not has yet come through; although Investment Property Databank (IPD) are now beginning to track this performance in a number of buildings, no significant results are expected for some years (RICS, 2010b). In addition, the influence of the energy performance in the market value of historic buildings is even more lower as there is an apparent tendency to accept lower energy performance on most parameters under the retention of the historic character of the building (Ball, 2010). As a consequence, many developers find economical barriers when investing for high energy efficiency buildings and do prefer to just meet the required standards.

On the other hand, nowadays, policies and programs that increase transparency of building energy performance and historic buildings capacity are helping drive these trends that may be more significant in a future (Department of Energy and Climate Change, 2012, English Heritage, 2012e, RICS, 2010a, SPAB, 2002) .

2.2.2.4 Agents and positions

The role of building industry, developers, practitioners and local authorities is vital to achieve an advanced energy standard in historic building where due to the limitations in the scope of energy efficient improvements available, the importance of avoiding inadequacies in the process is vital. However, several issues such as “problems within the system of regulatory advice, a need for more integration between different aspects of building regulation, problems with levels of understanding within the design process, inadequacies in design tools and modelling protocols, failures in the training of designers and building physicists, a lack of comprehensive energy performance testing and prototyping of dwelling designs and details, a lack of feedback of performance data into the design process and the need for significant changes in planning and executing construction processes” have been identified. (Dr Jez Wingfield et al., 2007)

As buildings are complex systems, minimizing energy use requires optimizing the system as a whole, thus, the frag-

mentation of the building industry in UK is a major problem to overcome. One suggested strategy from the European Directive on the Energy Performance of Buildings in the EU to address this problem, is to bring engineers in at early stages of the design process (Levine et al., 2007).

In addition, in historic buildings, these problems are aggravated by the difficulty on understanding the performance of the building and so evaluate the possible measures. As Spab´s on-the-spot recent research showed heat loss through vernacular materials can be up to three times lower than expected (SPAB, 2002).

2.2.3 Regulations and energy efficiency

In the Building Regulations for England Part L energy efficiency requirements apply to all existing buildings if they are to be altered, extended, or subjected to a change of use. However, buildings of a historical interest are specifically excluded, being described in building Regulations Part L1B and Part L2B, where they specify that "special considerations apply if the building on which the work is carried out has special historic or architectural value and compliance would unacceptably alter the character or appearance" (HM Government, 2000).

Hence, most modifications to a building require reasonable provision to be made for the conservation of fuel and power but there is no obligation to adopt any particular solution. DTLR (Department of Transport, Local Government and The Regions) therefore decided that what constituted 'reasonable provision' was best established for each historic building on its particular merits. In addition, it recommends avoiding unnecessary intervention, for which, if the building is listed, building consent will also be required. Furthermore, the required energy performance can be obtained as a balance of the buildings function overall instead of from each specific element giving flexibility to work with different elements (English Heritage, 2004).

The Energy Performance Certificate (EPC forms also part of the Building Regulations and from 2008 is required when marketing a property (UK government planning portal, 2012b). The Energy Act 2011 states that from April 2018 it will be unlawful to let residential or commercial properties which have an EPC rating of F or G (Department of Energy and Climate Change, 2012). EPCs have been criticized for their inaccuracy, and low reliability for old and listed buildings and therefore the English Heritage warns of the possible implications of this method (English Heritage, 2012a), however, no alternative assessment method has been provided for historic buildings.

Other non compulsory design assessment methods such as BREEAM method´s "BREEAM in use" and "BREEAM refurbishment" are also starting to consider the performance of existing buildings.

2.3 Key considerations towards developing a low energy strategy

There are three main steps that must be considered in order to reduce the energy in use of a building during the design stage: (HM Government, 2000, National Refurbishment Centre, 2010, Yangang Xinga, 2010)

01. The reduction of the energy demand
02. The installation of energy efficient and effectively controllable equipments
03. The application of renewable energy systems.

Supporting this hierarchy, the 'fabric-first approach' adopted by several institution, researchers and enterprises (National Refurbishment Centre, 2010) states that the insulation and air-tightness of a building is the first step in order to the rest of the measures be worth.

In historic buildings, the approach to the fabric is one of the most delicate design challenges, not only because of the minimal intervention required in order to secure the preservation of the 'aesthetic integrity' of the building (Rogic, 2009) but also because of the delicate balance between materials, moisture-transfer, ventilation and thermal performance in an historic building can be disrupted by the application of modern systems, as shown in illustrations 2 and 3. For this reason, it is important to think of the building as an integrated environmental system where the nature of the building must be assessed in each case to determine the most advantageous approach to heating, ventilation, insulation and energy efficiency. Failure to do so can lead to inadequate internal conditions such as condensation and mould, and the inefficient use of energy due to overheating or the use of artificial cooling. (English Heritage, 2004, Historic Scotland, 2007, Stirling, 2002)

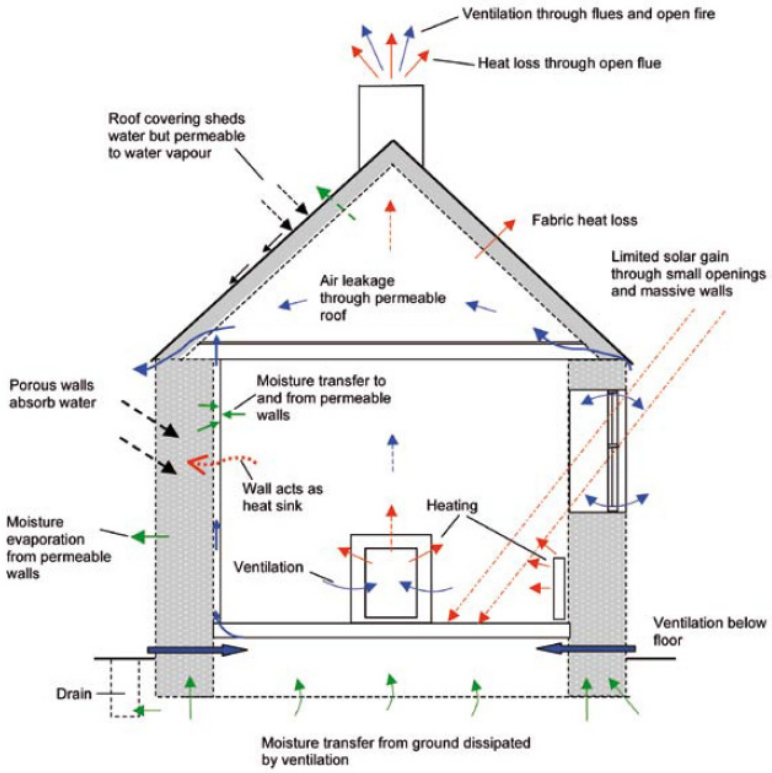


Figure No.2/ Moisture, air movement and thermal behaviour of a traditional building (Historic Scotland, 2007).

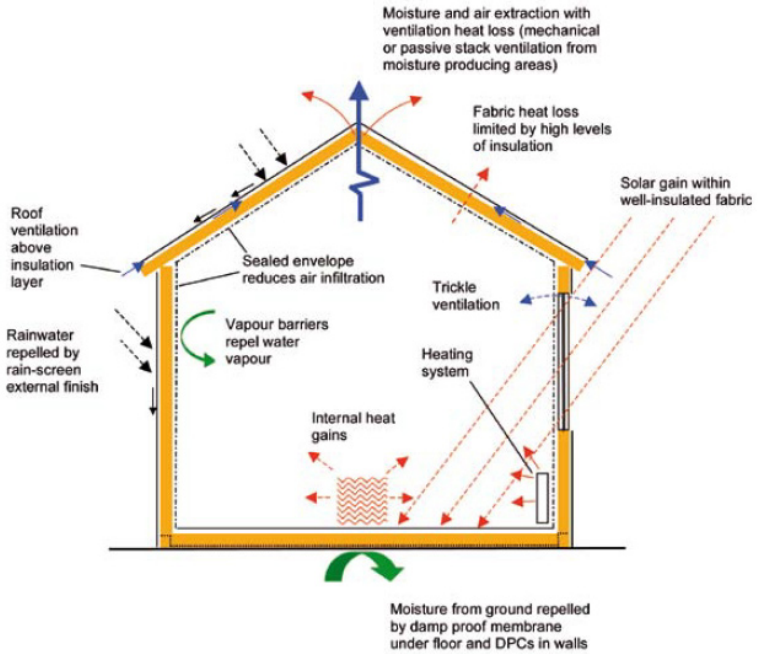


Figure No.3/ Moisture, air movement and thermal behaviour of a modern building (Historic Scotland, 2007).

2.3.1 External fabric

It is highly recognized that the buildings existing fabric is one of the most important assets when it comes to the preservation of its historic value. Despite the conservation charters promote the idea of minimal intervention, respect for the existing, compatible use and the prevalence of aesthetical terms, the extent and nature of this minimum change in practice still lacks of definition and remains on the interpretation by the conservation officer and/or other practitioners. (Rogic, 2009, Esther H.K. Yung and Chan, 2011) Therefore, the question about the extent to what the fabric should be intervened remains under contextual factors.

2.3.1.1 Insulation, vapour control and thermal mass

As space heating is the largest building energy end use (W.Rose and T. Rose, 2011), the first step in energy conscious renovation is to provide buildings with an insulation envelope. There are three main solutions for this; external insulation, cavity wall insulation and internal insulation. Various issues need to be considered, however; The external insulation method, although the most effective, it is also the most intrusive one (Stirling, 2002).

The Cavity Wall insulation system (CWI), on the other hand, leaves both sides of the wall uncovered, preserving the character of the building (Phil Ogley, 2012).

When for reasons related to preservation and character of the historic buildings conventional external insulation measures cannot be used, interior insulation comes into play with different problems arising particularly with respect to danger of condensation. (Historic Scotland, 2007, Yangang Xinga, 2010)

With the use of interior insulation the temperature of the exterior wall decreases, the dew point shifts towards the interior; to avoid the risk of condensation the use of a vapour barrier in the warmer side of the insulation will be necessary in order to avoid internal warm and moist air producing condensation on external cold walls in addition to installing means of removing water vapour close to its source (Stirling, 2002, Michael Balkowski, 2011, Hoppe, 2009).

Last but not least, the total loss of the thermal mass capacity of the fabric towards the interior space must be considered when taking this measure, limiting the use of passive environmental strategies within the building and the balancing effect of the thermal capacity in establishing internal humidity conditions. (Historic Scotland, 2007) The choice of an insulating method is therefore, very linked with the ventilation and interior air conditions of the building.

2.3.1.2 Ventilation, air-tightness and moisture control

The traditional building technology did not tightly seal buildings and it did not either generally use damp-proof courses in walls or damp-proof membranes below ground floors. The balance between moisture content, water vapour and ventilation was achieved by high ventilation rates through operable windows, doors and different kind of gaps maintaining similar vapour pressure levels inside and outside the building and avoiding this way both surface and interstitial condensation and preventing deleterious effects on construction materials, in other words, the building breathed. (English Heritage, 2004) (Historic Scotland, 2007)

By converting historic buildings, this equilibrium is disrupted, as a rule, providing a building with an insulation envelope is accompanied by an increase in air-tightness, with the aim of reducing the heat losses and making the insulation worth. Draught proofing is one of the most inexpensive and effective measures when trying to achieve a good energy performance, but disrupts natural ventilation, making a ventilation system essential to guarantee the necessary air exchange rate and to maintain the interior air quality. Maintaining a porous, breathable construction that allows moisture to evaporate internally is recommended as well in order to extract the possible moisture in the construction. (English Heritage, 2004, Yangang Xinga, 2010, Michael Balkowski, 2011)

Therefore, successful control of moisture levels in a historic building often depends on plentiful sources of ventilation, permeable building materials that are hygroscopic and hence buffer moisture and the absence of barriers to moisture flow. As a result of this, historic buildings usually need more ventilation than modern ones; great care is required in selecting an appropriate ventilation rate. (English Heritage, 2004)

2.3.1.3 Windows

The identification of windows as an important factor in determining the character of a historic building by conservation bodies make it difficult to achieve improvements to thermal insulation while retaining character.

According to English Heritage, valuable elements must be retained and alternative means of thermal improvement considered, replacements with double-glazed sealed units and low emissivity glass, for example, fail to provide an adequate visual alternative owing to the frame thickness required to accommodate the glazing cavity (English Heritage, 2004).

Alternative methods for existing windows are proposed; Draught proofing a single-glazed window has roughly the same effect as fitting an additional sheet of glass. However, when removing or draught-proofing old windows care should be taken to provide the adequate ventilation in another way (Phil Ogley, 2010a). Other unobtrusive method

can be the use of a secondary glazing, however, although the thermal performance can be excellent, it can also lead to a reduction in natural lighting and problems with condensation in the air space between the outer windows and the secondary glazing should be considered. Finally, other means of minimizing heat losses can include heavy lined or insulated curtains and internal blinds although these can be less effective (Phil Ogley, 2010b).

2.3.2 Building services

Because of the constraints explained when insulating the building, it seems unlikely that a historic building conversion will be insulated under the best practice requirements, for this reason, building service equipments have a great influence in the improvement of the energy efficiency of the building and so must be chosen carefully.

Due to the fixed conditions of the envelope and its windows layout and materials, lighting in historic buildings is a parameter that is not always easy to manage; the replacement of inefficient lamps is usually the first choice due to facts of significantly reduction of electricity usage with relatively cheaper means. (Yangang Xinga, 2010) Apart from low energy lighting, passive methods should be explored to improve day-lighting penetration and visual comfort, the analysis of adequate uses, for example, can lead to a more suitable distribution of day-lighting depending on the needs.

Traditional buildings are also not generally designed to be heated to current comfort levels, this represents a risk to historic fabric and its moisture balance which during the change can suffer great damage due to the rapid adjust to changed environment. (English Heritage, 2004) (Historic Scotland, 2007)

The installation of air conditioning systems in historic buildings should be avoided if possible, and consideration taken of not only the physical damage to the fabric due to the installation requirements, but also the effect on interior air conditions, requiring specific elements such as humidification systems in order to avoid extensive long term damage. (English Heritage, 2004)

New services should avoid unnecessary damage to the historic fabric by using long-life elements and addressing the principles of reversibility and minimum intervention, analysing at the same time the impact of the use and occupation time of the building in the system. Furthermore, the selected systems must be also related to the energy conservation systems chosen; For example, while internal insulation and timber frame construction are compatible with rapid response heating systems, external insulation or cavity fill is suited to hot water central heating systems that provide background heat, and for buildings that can exploit solar gains. (English Heritage, 2004) (Historic Scotland, 2007, Stirling, 2002)

Thus, the use of low temperature radiant heat sources that can provide comfort at lower air temperatures, when possible, can be a good solution for the control of moisture and protection of the fabric. (English Heritage, 2004)

2.3.4 Renewable energy systems

As a final step, when possible, it is important to minimize the impact of the energy consumption in use by considering renewable sources of energy.

When assessing possible systems for the building, the predicted impact of intrusive systems and the lack of energy requirements usually lead by conservation purposes, discourage designers to confront this challenge. There are instead other systems such as biomass or ground source heat pumps that although subject to availability, storage or costs, for example, can result less disruptive and so they should be considered.

chapter 3

CASE STUDIES

3.1 Selection of case studies

This study has selected cases which have been completed in the last 10 years and are best practice architecture with projects that can really illustrate solutions, complexities and trends when confronting the current situation. To be as reasonable representative as possible, these projects have a various ownership, aims and contexts.

The specific typology selected is the multi storey urban industrial buildings. These buildings, constructed in most cases during the nineteenth century´s widespread industrialization within Europe, suffered a process of abandon as a result of several technological advances and changes in economic trends. As a result, these sites became desirable places of urban regeneration and so they have usually been object of re-use processes due to their unique ownership schemes, flexible spaces, heritage value and other factors that made them a suitable for conversion creating a variety of architectural interventions (Rogic, 2009).

While protecting implies control of change, reuse presupposes change; industrial buildings are a desirable type of protected built heritage because their favourable conditions to reuse but at the same time this act of protection restricts the way reuse can be achieved. This paradox between protection and reuse make this type of buildings an appropriate example to discuss the question of energy efficiency in historic buildings (Rogic, 2009).

3.2 Parameters under analysis

The parameters analysed in the case studies are grouped under the following headings:

1. Typology and key features: Overall description of the building, brief, aims and design strategy.
2. The process: Analysis of the specific context of the building, the factors involving the decision making process, the challenges while Keeping the interface of the building fabric to the minimum, the equipment and renewable energy system used and the resulting comfort and usability.
3. Conclusions arisen from the process

3.3. The Toffee Factory – an innovative office building

This is a highly ambitious project in the NE of England, which has won numerous awards (see Appendix 1 Table 1) for more details about the project) and demonstrates that historic buildings have potential to incorporate energy efficiency within a sensitive approach towards heritage.

Figure No. 4/ The Toffee Factory Exterior View. (Bailey, 2012)

3.3.1 Typology and key features

The old Maynard Toffee Factory at the mouth of Lower Ouseburn in Newcastle is a 3 storey red-brick Victorian building that lies close to Newcastle Quayside, the Sage Gateshead and BALTIC. The brief was to refurbish and extend disused Victorian factory building to provide office accommodation for businesses in the creative industries sector. The aim was to retain and exploit the qualities of the existing brick structure while sensitively extending it to provide 2,600sqm of office space (Xsite, 2012).

The original building fabric has been restored, and an additional floor has been added. The demands of energy conservation have led to an interesting chequeboard of insulation alternating between inside and out, so one is always aware of the original structure. In addition, to achieve the BREEAM very good rating, a Biomass boiler is used and naturally lit and ventilated office spaces are maximized (Xsite, 2012).

3.3.2 The process

The whole Ouseburn area, from which the Toffee Factory is the flagship development, was subject to a grant. This incentive, though, was not only focused on the reparation of the building in order to maintain its integrity, the aim was to become the building the catalyst for private-sector development in the area, and for this reason this funding came with the condition of achieving a good energy performance in the building. In addition, the building had several conditions that made its heritage significance less relevant in terms of approach, first, although having high local significance, it was not a listed building, in the other hand, the derelict state of the building (see figure 2 below) allowed more freedom to intervene due to the fact that there were less historic elements to preserve (Brims, 2012, Skyscraper City, 2012).

Figure No. 5/ The Toffee Factory Previous State (White, 2010).

The aims of this project were very clear from the beginning; to achieve a good value for a building re-use and energy efficiency by making good practice architecture. As it was a funded project, one of the first conditions from the client was to achieve a BREEAM office "very good" rating. BREEAM is an environmental assessment method and rating system for buildings which sets the standard for best practice in sustainable building design. The evaluation criteria include elements such as energy, transport, land use and ecology and Health and Wellbeing during different phases, from design to management (BRE, 2012). The ratings go from high to lower Outstanding, Excellent, Very Good, Good, Pass and Unclassified. A "very Good" rating represent the top 25% of UK new non-domestic buildings which means an advanced good practice, "excellent" rating represent the top 10% meaning best practice and "outstanding" represents less than top 1% of UK new non-domestic buildings, meaning an innovator practice (BRE, 2011). Although a "very good" rating does not represent the best practice solution, it is relevant to point that the building is compared to new build standards. In addition, the scheme achieved an "A" rating in the Energy Performance Certificate (See appendix 1, fig.2). The EPC carry ratings that compare the current energy efficiency and estimated costs of energy use with potential figures that the building could achieve. The rating measures the energy efficiency using a grade from A to G, being A the most energy efficient band and G the less one (UK government planning portal, 2012b, Government, 2012b). However, this rating must be understood carefully as it shows the predicted energy performance of the building. The position towards the fabric came later on the process, after analyzing the best thermal model for the building by working with the engineers. Finally, the fabric first approach was taken in this case by considering three main steps: reduce the energy demand, install energy efficient equipments and the application of renewable energy systems.

The approach was to decide that what was already there, was going to be treated as an existing building, not as a new one and then to make a thermal model in order to understand the old fabric and to reach the best solution. This model established the extent to which the thermal mass of the existing structure could be established and the real insulation requirements (Bailey, 2012b).

The conditions in the existing building were special (see figure 6 below): In the thermal evaluation it was identified that due to the high surface of envelope in relation to the plan surface (aprox. 1ml envelope/4.5m2 surface), the building shape was an issue, nevertheless, two of the largest sides of the building were under-ground, so the U value in this façades was much lower (0.41 W/m2.K). Thus, in order to match the building regulations target of 1.09W/m2.K, the remaining two thirds of the façade has to achieve an average U-value of 1.47W/m2.K, leading to the strategy of insulating the building only in some parts, maintaining the old and remarking it by a rhythm of interior, exterior and non-insulation (see figures 7,8,9 below) (Bailey, 2012). The U values achieved in each part are the follows:

01. Existing façade with single glazing covering 40% of the façade: 3.27 W/m2.K
02. Existing façade with double glazing covering 40% of the façade: 1.95 W/m2.K
03. Externally insulate the brickwork between each pier with 100mm of insulation and cover with a light rain screen: 1.88 W/m2.K
04. Internally line the walls with a total of 100mm insulation: 1.03 W/m2.K
05.Remove 100% of the brick infill between piers and replace with a glazing system: 1.88 W/m2.K

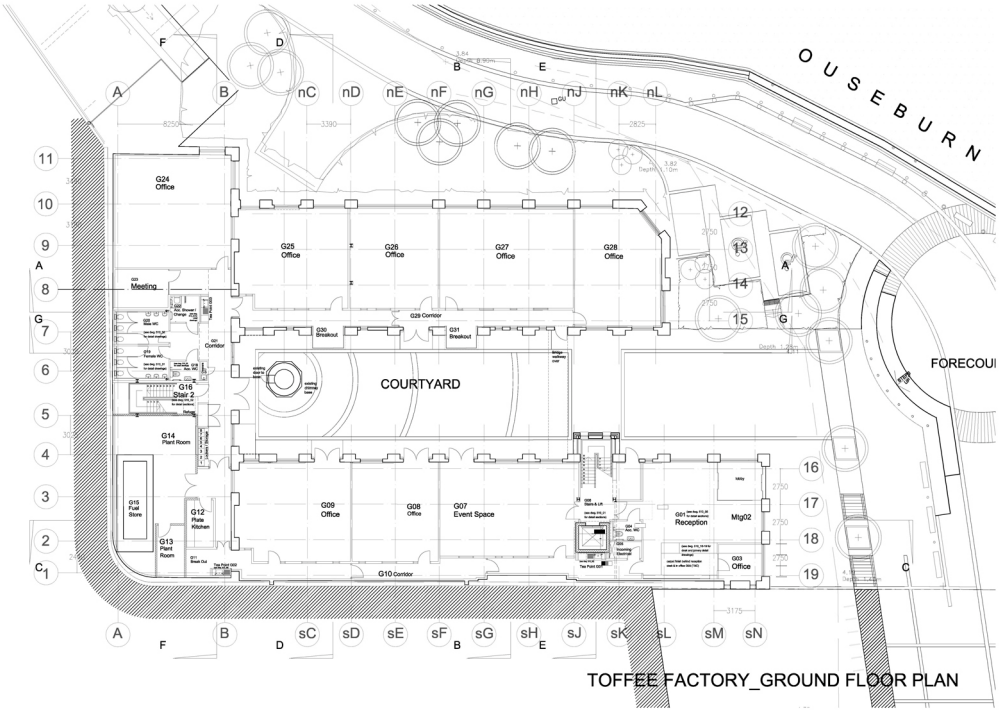
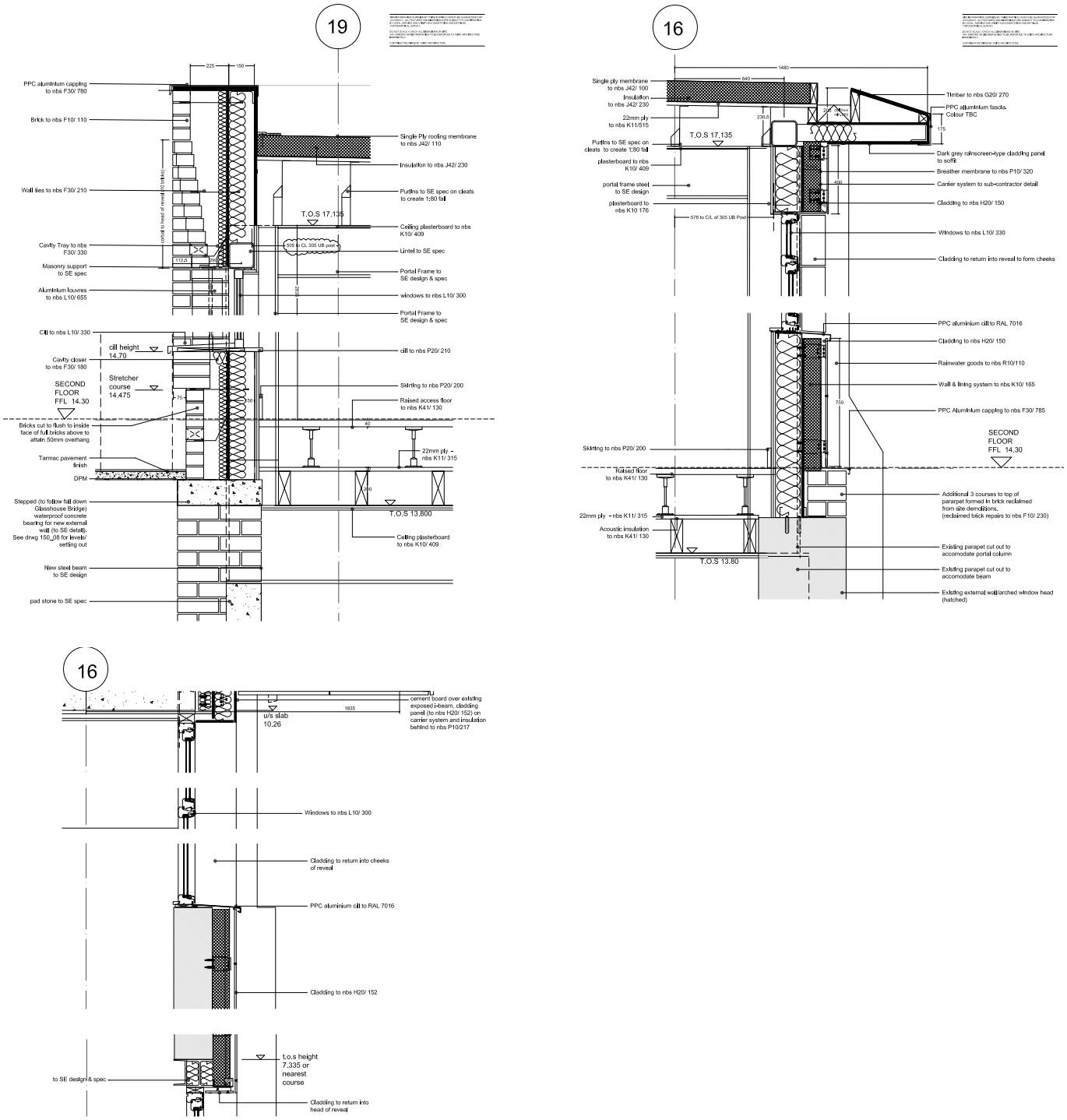


Figure No. 6/ Building special Conditions. (Bailey, 2012)



Figures No. 7,8,9/ Insulation solutions; interior insulation/no insulation, remove brick, exterior insulation. (Bailey, 2012)

In the figure 10 below it can be seen how the thermal bridges are avoided by extending the insulation and therefore extending the length of the thermal line, being then able the wall to cope with the thermal conditions at this specific point. As a result, the thermal mass is also maintained, a decision correlated with the choice of the cooling system.

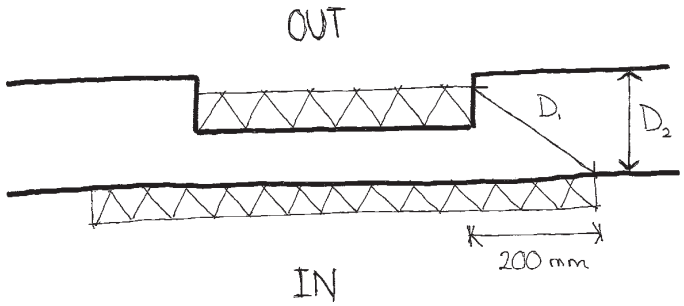


Figure No. 10/ Thermal Bridges avoidance sketch. Authors own, 2012, based upon Tim Bailey´s drawing (Bailey, 2012b).

The air exchange in the building is reached by the use of natural ventilation through a correct layout that allows the cross ventilation through the windows. In the ground floor, the ceiling high allows the use of high and low level opening windows only from the courtyard side, while the spaces in the upper floors require ventilation openings on both sides. There are some exceptions though, in the first floor against the bridge roof cowls and chimney effect were used to exhaust air and the enclosed rooms, WC and other rooms in the building with no exterior access use displacement or mechanical methods. As a result, the moisture balance of the building is maintained allowing, after an analysis of the internal air quality, the possible effect on the fabric and the climate of the area (from which it was concluded that this decision was causing less than 15 days a year of discomfort, see explanation in figure 11 below), the avoidance of a mechanical air conditioning system (Bailey, 2012). This system would had required extensive ductwork and would have duplicate the cost of heating/cooling in the building (Bailey, 2012b, Carbon Trust, 2012), while by the use of passive systems the breathability of the building was preserved and the energy consumption reduced.

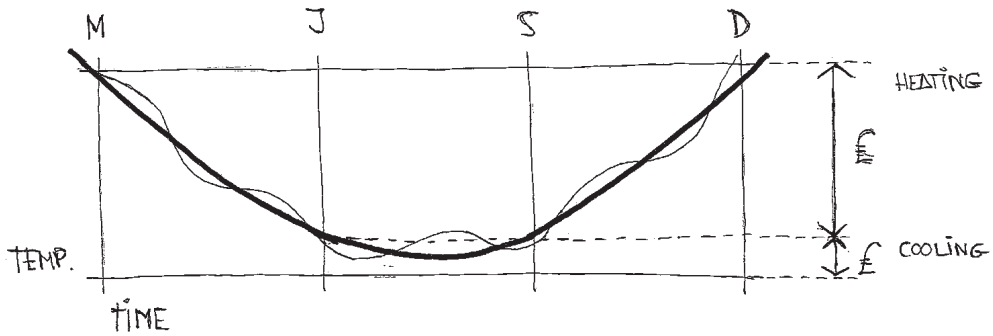


Figure No. 11/ Air conditioning; Discomfort time and costs relation sketch. Autors own, 2012, based upon Tim Bailey´s drawing.

The heating is provided by a radiators system; piped systems are generally easier to install in historic buildings as they are smaller than ductworks, thus representing less disturbance in the fabric. Radiators system is the cheapest and more straight forward option, nevertheless, though of a higher capital cost and slightly more complex to install, under floor heating provides better quality heating without draughts or dry air, a fact that can result more sensitive with the building fabric, but also because of its low operating temperature, it can be easily linked in with alternative heating sources that output at the same low temperatures such as solar/thermal or ground source heat pumps (Greenspec, 2012c). In this case, the reason for not selecting this system is that the floor surface ratio was low comparing with the room height one and therefore the under-flooring heating system would not be able to cope with the heating volume of the spaces (Bailey, 2012b).

As the heat was identified as the major energy load in the building (annual estimated space and water heating being 288502.4kWhrs VS annual electrical usage 56762.7kWhrs) (see figur2 2 in the appendix), a biomass boiler was selected to reduce the energy consumption, three main factors were taken into account; the reliability, the source of the energy required, and the costs. The air source heat pumps, were decided not to be very reliable, the gas was not a renewable energy source and the electricity was considered expensive (Bailey, 2012b). Although the reliability of heat pumps (Energy Saving Trust, 2012a, Sally Caird, 2012) being questionable, due to the nature of the building, the space available, the low running costs and reliability, the biomass was a good option for this case; This system has a good rating by BREEAM in terms of low carbon emissions, and for this particular area, the Sheffield city council provides a secure supply.

3.3.3 Resulting comfort and usability

The BUS questionnaire was performed within the occupants of this building (see Appendix 1 for full results).

The comfort is the building is very high (6.6/7 average score being 7 comfortable, 1 uncomfortable). In winter the thermal comfort being scored with 6.4/7, meaning that the temperature was really comfortable, while in summer the score is 5.5/7, being some complaints in the upper floors during some hot days the reason; the air conditioning was the factor identified as the cause in the occupants comments.

The energy consumption is lower due to the biomass boiler, nevertheless, the occupants bills are included in the rent so they are not aware of the consumption, this factor can increase the energy usage (Department of energy & Climate Change, 2012c).

Finally, the building meets the occupants needs very well (7/7 average score in facilities, 6.7/7 score in design) being also the flexibility in licence arrangements a good point. The occupants were very satisfied with the building, and

when asked why they selected an historic building to work in, many of them selected the variety of creative business, the character of the building and the good location as added bonus, being the high quality of the facilities and the meeting of current comfort standard the most valued factors.

3.3.4 Conclusions

This project shows the potential of an historic building to achieve important energy efficiency when the client is committed to do so. Nevertheless, it is also true that a better BREEAM standard could have been achieved. The fact that government is applying the BREEAM 'Excellent Standard', or equivalent, to all new builds and 'Very Good' standard to all major refurbishments shows the difficulty in these projects to achieve better ratings over new built (Government, 2012a). On the other hand, there are refurbishment projects where "Excellent" rating has been achieved (National Refurbishment Centre, 2012). Hence, this factor is more attributable to the higher costs.

The best achievement in this project is the balance between energy, design and budget, which in the opinion of the designer comes from the early understanding with the engineers, with whom they had worked before and a great client that gave them the time to research and think about the decisions.

The key element of this process is the thermal modelling of the envelope, which allowed the designers to understand the performance of the existing building and so to act in consequence.

In a more conservation-led project this approach could not have been implemented due to the level of intervention in the fabric and the windows, nevertheless, in the designer's opinion, the applicable lesson from this project into a more conservative one would be to use the thermal modelling as a tool to understand the building and apply the best solutions possible.

3.4. Butcher Works – when the history rules

Situated in Sheffield this project has won numerous awards (see Appendix 2 Table 2) demonstrating good practice in the conversion of historic buildings and showing several constraints and possibilities related to a very heritage sided position.

Figure No.13/ Butcher Works exterior View. (Race Cottam, 2009)

3.4.1 Typology and key features

The Grade II* listed building is an old factory built in 1835 and once at the centre of Sheffield's cutlery industry. From Victorian nature, the 4 storey red-brick building is set around a courtyard and standing in the shadow of the original chimney (Cottam, 2012).

The brief was to restore the building and create flats at the upper levels with shops and restaurants at ground level

around the courtyard and the old chimney. The new uses for this building were selected because of the layout, the high amount of natural lighting, and the high demand for the residential use in this area and type of building. The aim was to retain one of the few surviving intact examples of a 19th century Cutlery Works and safeguard its existence. The development has also had a massive impact on this area of Sheffield's Cultural Industries Quarter.

The project repaired the building and improved the street scene, it was not particularly ambitious in terms of energy efficiency; the building was upgraded as a fact of good practice, but the effort was not focused on meeting higher requirements (Cottam, 2012).

3.4.2 The process

Under a unique ownership scheme, the building was overall empty but for few industrial workshops situated in the ground floor. The owner did not want to sell it or make any investment, but the building was inside a regeneration design plan of the Sheffield City Council. Although the several grants available, the economic constraints were high, for this reason, the University of Hallam´s Arundel building and Butcher Works were tied in order to achieve the planning permission, this way, the first one would achieve enough profit to restore the other (e-architect, 2009, Speddings, 2012).

Due to the Grade II* listed status of the building, the decision making process was very influenced by the historic significance of it, an approach promoted by the Sheffield City Council, The English Heritage and the designers. Such focus should be reflected in the building energy performance, nevertheless, some dwellings of the building are currently rated with a "C" rating in the EPC (see apendix 2, fig.15) with 72 point scored and a possible improvement to 79 while the average property in the UK is in band D or E rating, 86% of the UK homes do not meet the C rating and only the 1% of homes achieve the B or A rating (The Guardian, 2011, Property, 2009). This shows the high energy efficiency potential of historic buildings even with upgrading measures only to fulfil the requirements, however, it must be pointed that measured data could differ from this assessment.

There were no cavities within the walls and they had never been plastered before. The 250mm brick walls were insulted internally with an 70mm insulated plasterboard in the interior face of the wall to meet the requirements therefore improving the U value of the walls approximately from 2W/m2k (typical value) to 0.35 W/m2k (UK government planning portal, 2002, South Yorkshire Energy Centre, 2010) (see figures 14 and 15 below). In some parts of the building, where the interior brickwork was significant (i.e. the ground floor coffee shop) no insulation was added, while in other parts like the roof an extra insulation was provided to balance the building as a whole (Speddings, 2012). These measures allowed a reduction of around 25% of heat losses in the ceilings and 30% in the walls (Peak District National Park Authority, 2011, National Energy Foundation, 2012, Energy Saving Trust, 2012d).

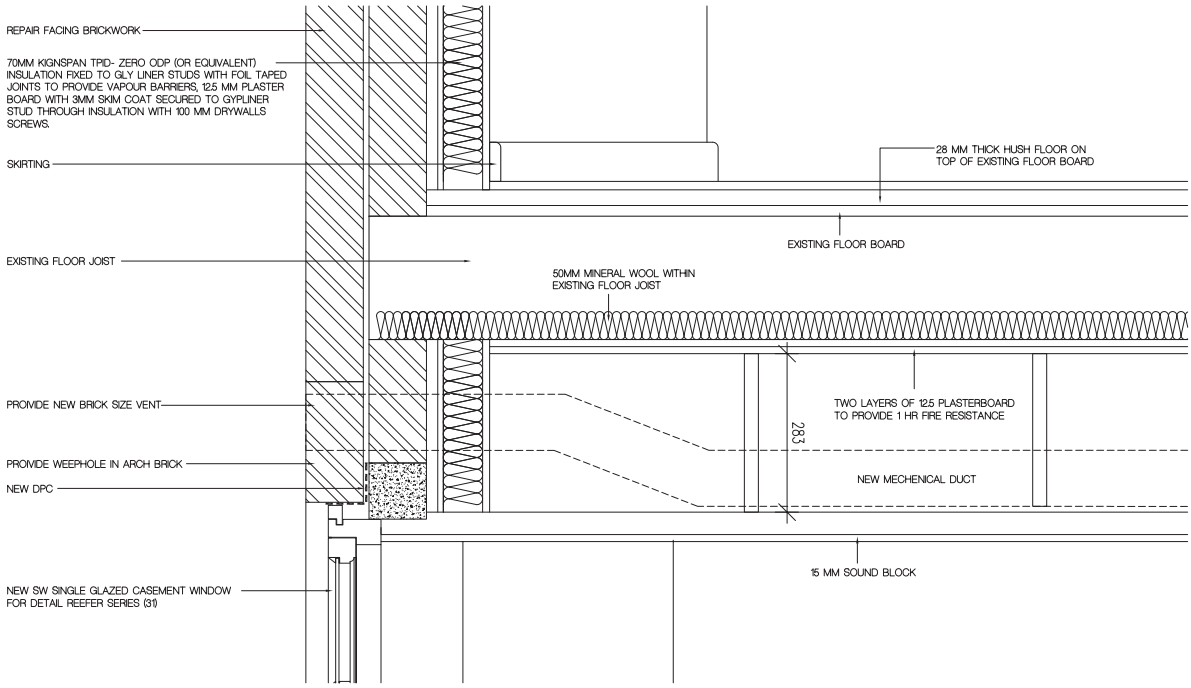


Figure No. 14/ Wall insulation detail. (Padley, 2012)

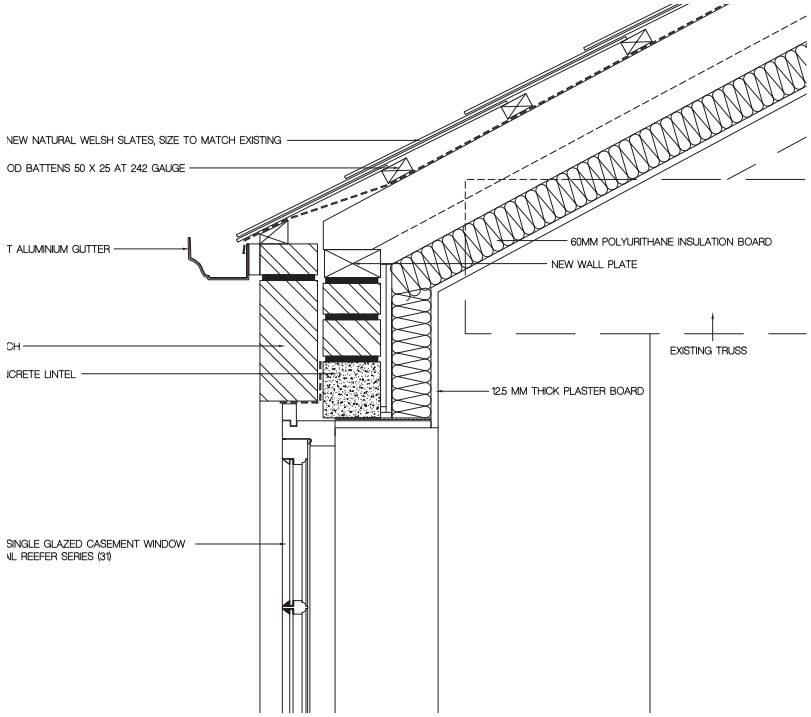


Figure No. 15/ Roof insulation detail. (Padley, 2012)

On the other hand, the windows were the major discussion within this part of the project. The 300 single glazed windows in the building were inefficient and rooted. Double glazed windows designed to mirror existing were the choice of the designers in order meet the 2002 Part L regulations (U=2.2 W/m2k), a decision that also was a condition to get the guarantee scheme of the building insurance (Speddings, 2012). Nevertheless, the planning conditions stated by the Sheffield City Council according to the English Heritage did not allow the change, so they were repaired when possible and replicated by a local manufacturer in the majority of the cases. A secondary glazing was also discussed but it did not allow the natural ventilation, causing condensations in the single glazed windows. The developers were concerned about the customer opinion regarding the single glazing windows; nevertheless, all the flats were sold during the construction works, a behaviour that shows not only the high demand for this kind of buildings and location but also the lower demand of performance on most parameters when re-using historic buildings.

The consequence of this decision is the loss of the possibility to reduce the energy losses through each window by 58% (C. Wood et al., 2009)(see the table 1 below). Although the improvement on U values from old windows 4.3 W/m2k to new windows 2 W/m2k according to typical values (UK government planning portal, 2002) should have allowed to reduce the building heat losses around 10% , it is also true that the U value method for assuring windows performance is not accurate as other aspects should be taken into account (Greenspec, 2012a).

TABLE 1: CONDUCTION HEAT LOSSES THROUGH THE GLASS AND WINDOW						
	For glass only: Directly measured			For glass & frame: Using FRAME model		
DETAILS OF THE TEST ASSEMBLY	U-value of glass (W/m²K)	Reduction in heat loss through glazing only	Temperature of innermost surface (°C)	U-value of whole window, (W/m²K)	Reduction in heat loss through whole window	COMMENTS
Window as found	5.3	—	12 (glass)	4.3	—	
Joinery repaired	5.3	—	12 (glass)	4.3	—	This also reduced air infiltration by 34%
Heavy curtains	3.3	39%	21 (curtain)	2.5	41%	
Well-fitting shutters	2.0	64%	17 (shutter)	1.7	58%	
Plain roller blind	3.4	37%	18 (blind)	2.7	38%	When the blind was tightly fitted, the U-values fell by about 0.3
Reflective roller blind	1.8	66%	19 (blind)	1.9	57%	Reflective side facing towards the outside
Honeycomb blind	2.1	60%	20 (blind)	2.1	51%	Insulating blind
Low-emissivity secondary glazing	2.0	63%	19 (glass)	1.8	58%	Aluminium frame secondary system with spring balances
Low-emissivity secondary glazing and shutters	1.4	73%	20 (shutter)	1.6	62%	With both the glazing and the shutters closed
NB: the experimental error in the tests is equivalent to an uncertainty of ± 0.3 in the U-values above[4]						

Table No. 1/ Conduction Heat Losses Through the Glass and Window. (Wood et al., 2009)

A natural ventilation system was selected because of the predicted impact of the mechanical system which would have needed ductworks for each dwelling and also to maintain the moisture balance (Speddings, 2012). To avoid any change on the ventilation balance generated by the new insulation, some specific rooms (WC, kitchens) are also aided with a passive stack system with a heat exchanger. Although by the use of natural ventilation in old buildings around 20% of the energy from space heating may be lost (Greenspec, 2012b), the cost and energy expenditure

could be double by using a mechanical ventilation and cooling system (Carbon Trust, 2012), so the passive ventilation system represents an advantage for energy efficiency.

The heating system was very conditioned by the building conservation ethos. The gas was not a possibility due to the ventilation voids required to install it and the consequent disruption in the fabric and the under floor heating was discarded because of the aim of keeping the existing floor intact (Speddings, 2012). The district heating was the preferred option as despite the difficulties in controlling and monitoring the individual consumption, it required no boiler or ventilation, but it was not available. As a result, an electric heating system was chosen, a factor that increased consistently not only the utility costs but also the carbon emissions of the building; While natural gas 1 kWh of natural gas accounts as 0.1836kg/CO2 while 1 kWh of electricity accounts as 0.5246 kg /CO2 (Carbon Trust, 2011), in addition, electricity is the most expensive and heating fuel available in the UK (Energy Saving Trust, 2012b).

No renewable energy systems were implemented in the project, options like biomass or pellet boilers were difficult to install due to the lack of space and although PV panels were considered as an option to reduce the electricity impact of the heaters (Speddings, 2012), they were later discarded due to the costs, demonstrating that when the historic value of the building is the leading factor sometimes little effort is done to implement these systems.

3.4.3 Resulting comfort and usability

The BUS questionnaire was performed within the occupants of this building (see Appendix 2 for full results).

The overall comfort was scored 5/7 (being 7 comfortable, 1 uncomfortable) and the score for temperature in winter was 4.83/7, being the single glazed windows the major reason of discomfort identified by the occupants, the boiler was also mentioned several times as difficult to control. These factors can lead to a more energy use by the occupiers by trying to achieve a better comfort or by the lack of control over the features (Siemens, 2012) .

3.4.4 Conclusions

This project demonstrates the potential of historic buildings to achieve a good energy standard even when the historic significance of the project is a big constraint in terms of implementing energy efficient measures; this fact is shown by the comparison of the EPC rating achieved by this project (C) over the UK average in same use projects (D-E), however, it must be reminded that these calculations are based on predicted rather than measured data. It also shows typical energy sacrifices by historic constraints in listed buildings and the low interest in achieving higher energy savings due to the lack of economic incentives rather than to preserve the significance of the building.

3.5. Calder and Hebble Navigation Warehouse – energy conscious historic preservation

This project in Wakefield has won numerous awards (see Appendix 3 Table 3 for more details about the project) and demonstrates how to introduce energy conscious approaches by assessing the most relevant element to preserve.

Figure No.16/ C&H Navigation Warehouse exterior view. (Davies, 2012)

3.3.1 Typology and key features

The C&H navigation warehouse is a building composed by two warehouses dated from 1790 converted to a single warehouse in 1816 and used virtually continuously until the 1980s after which it began to decay . Built for the C&H Navigation Co., it is a four storey plus attic building composed by rubble stone with ashlars dressings and stone slate roofs. The interior is particularly interesting due to is massive wooden beams and cross beams supported on square wooden piers and later circular iron columns (BDP, 2012).

The brief was to repair the building and to convert it for office use on the upper floors and commercial use on the ground floor, keeping modern interventions subservient to the historic building. The aim was to restore the grain warehouse in a well-designed contemporary idiom, clearly articulated from the historic fabric (BDP, 2012).

The project repaired the building achieving the maximum retention of original fabric; the thermal performance was optimized by the introduction of energy efficient approaches beyond the aim of meeting the regulations but still not pursuing elevated levels of performance.

3.3.2 The process

The C&H Navigation Warehouse, which was vacant together with some of the adjoining land and buildings, was owned by British Waterways when the City of Wakefield Council established a waterfront partnership, to steer the regeneration of the entire waterfront area with a strategy based on the creation of a cultural quarter from which the warehouse was the main attraction (Princes Regeneration, 2010).

Due to the Grade II* listed status of the building, from the beginning, the main focus was to retain the historic significance of it. The project was granted, furthermore, the warehouse was a special building through an important master plan and the planning permission for it was tied to the warehouse conversion as the cost of repairing the old building was greater than building it from the scratch, so the benefit for doing it was not economic.

Hence, the energy efficiency of the building was always conditioned to the significance, nevertheless, the building achieved a “B” rating in the EPC with 48 point scored, although this is not the highest rating band, it is still a high rating as new built with same characteristics are in the same band (according to the EPC assessment, see figure 27 in appendix 3) and a typical building of the existing stock would achieve a C, this means an steady improvement to new built standards despite the restricted measures, a fact that shows the improvement possibilities of this building although the current performance could differ from this rating.

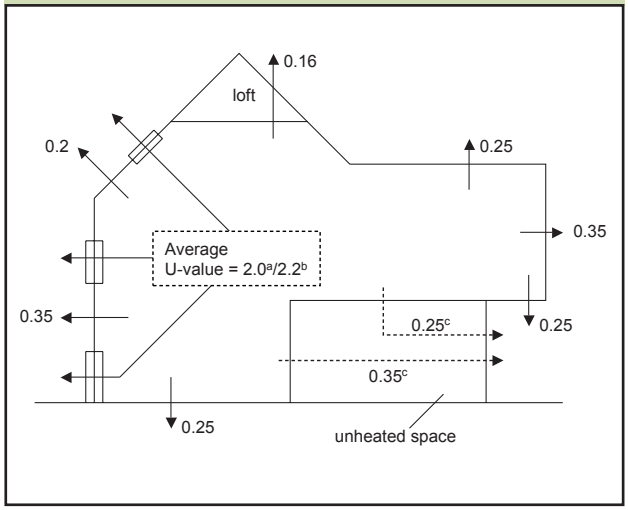
The external walls of the warehouse were retained without any enhancement to their thermal properties; they are made from solid stone with a ‘U’ Value of 2.31 W/m²K (Davies, 2012b). As a result, the breathability and moisture balance were respected and the thermal mass was conserved in the walls, as the floors were made from timber; although this can help to respect the principles of the old building, the U value is far below the minimum recommended U value of 0.35 W/m²K achieve the target reductions by the Part L2B document of 2002 (Uk government planning portal, 2006, UK government planning portal, 2002). In addition, most of the existing windows in the warehouse were refurbished during the restoration project and remained as single glazed timber framed windows with a ‘U’ Value of 5.7 W/m²k far below again from the 2 W/m²k specified in the regulations. The roof, however, was

very well insulated by way of a 200mm thickness of Mineral Wool insulation achieving a 'U' Value of 0.18 W/m²k. The result of this is that the envelope of the building does not even meet the current energy standards, losing the opportunity to avoid around the 50% of the total heat loss of it (Peak District National Park Authority, 2011, National Energy Foundation, 2012, Energy Saving Trust, 2012d), however, these measures where considered necessary to allow the use of passive cooling systems.

Table 1 **Standard U-values of construction elements**

Exposed Element	U-value (W/m²K)
Pitched roof [1, 2] with insulation between rafters	0.20
Pitched roof [1] with insulation between joists	0.16
Flat roof [3] or roof with integral insulation	0.25
Walls, including basement walls	0.35
Floors, including ground floors and basement floors	0.25
Windows, roof windows and personnel doors (area weighted average for the whole building), glazing in metal frames[4]	2.2
Windows, roof windows and personnel doors (area weighted average for the whole building), glazing in wood or PVC frames[4]	2.0
Rooflights [5, 6]	2.2
Vehicle access and similar large doors	0.7

Diagram 1 **Standard u-values for non-domestic buildings**



[a] if windows have wood or PVC frames
[b] if windows have metal frames
[c] includes the effect of the unheated space

Figure No. 18/ Standard U-values for non-domestic buildings (UK Government Planning Portal, 2002.)

The building used to link the two old warehouses in 1816 collapsed during the construction. This fact brought not only the need of constructing a new one, but also the opportunity to design a natural ventilation system through this element. This method was selected due to the predicted disruption of the ductworks of a mechanical system in the building elements and the lack of ceiling high, but also as a way to achieve an environmentally sustainable approach. The designers described this decision as one that they would had taken in a new building as well, as proven in their Manchester offices´ new building which was the first naturally ventilated office building in Manchester to achieve an "excellent" BREEAM rating (Davies, 2012b). This decision also allowed the avoidance of mechanical cooling systems in the building, which benefits for the building fabric, reduced costs and energy savings have been described before in this work.

Figure No. 19/ Linking building skylight. (Davies, 2012)

The heating system of the building is provided by a radiators system fuelled by natural gas. Other distribution systems were discarded due to the restricted ceiling high. The fuel was decided not to be achieved by any renewable energy system; solar panels were considered detrimental to the historic character of the building, and the available space was another issue for systems like ground source heat pumps and biomass. This decision though, is questionable, as the space required could have been found in the surrounding area.

3.6.3 Resulting comfort and usability

The BUS questionnaire was performed within the occupants of this building (see Appendix 3 for full results).

The comfort is the building is high (5/7 average score being 7 comfortable, 1 uncomfortable) although in winter

the comfort was scored as 4/7, meaning that it is not always comfortable, the users reported that the windows, controlled by the building management by an automatic system, opened automatically in winter providing cold. Nevertheless, the fact that the building is not fully occupied at the moment and so is not using the estimated heat generated by other occupants/computers can be the reason for this discomfort as well. In addition, the controls can have influence on the building energy use as "the use of energy-efficient building automation and control functions saves building operating costs, existing energy resources and lowers CO2 emissions" (Siemens, 2012), furthermore, the building is sectorized so the occupants of each part can reverse manually the computer functions.

In summer the comfort score was 3.8/7, the air conditioning being the factor identified as the cause in the occupants comments as the discomfort reason in specific hot days.

3.6.4 Conclusions

The major achievement in this project is the energy achievement despite the restrictive measures taken to respect the principles of the existing building. The "B" rating in the EPC shows that on one hand, the building is predicted to have high energy performance comparing with similar benchmarks and on the other hand, it could had been improved more, some restrictions arisen during the process due to historic and economic constraints.

In the designer´s opinion, the key element of this kind of processes is to make an analysis of the significance of the different elements of the building in order to establish priorities in the intervention and design process. When a building is listed it is as a whole, so it is on the designers hand to decide where are the less important parts or which is the real significance, that can rely not only on the image but in other elements of the building like the scale, pattern followed or others, identifying elements where other factors can predominate this way creating a balance. Another important fact in this project was that BDP architects have an in house engineer's team, so these two disciplines worked complementing together from the beginning.

3.6. The Granary–new needs in an old fabric for corporation image

This ambitious project in West London (UK), which has won numerous awards (see Appendix 4 Table 4 for more details about the project), demonstrates that a balance between historic, environmental and economic dimensions can be achieved in historic buildings as a positive contribution to the society.

Figure No. 20/ The Granary exterior view. (Archdaily, 2012)

3.6.1 Typology and key features

Constructed in 1866, the Granary is a five-storey Victorian style industrial building. It was erected by Randells Malt Producers for storage purpose and has been vacant during years and left to derelict. It is locally listed as it is considered, alongside with the adjacent Malthouse, as part of the town´s industrial legacy and so the landmark of the riverside regeneration. It used to have three chimneys from which only one remains. Made from London Stock bricks

and slate roof, the interior was very well conserved(PTEa, 2012).

The brief was to comprehensively restore the old building making an extension to convert it on the Rooff Ltd. Headquarters. The aim was to make a sensitive restoration of the building respecting the original fabric and creating a space able to satisfy contemporary needs whilst respecting and celebrating their integrity (PTEa, 2012).

The use of space was optimized adding new layers, the historic references were preserved and non original elements and extensions were removed to highlight the building character. In terms of environmental design passive principles in both, old building and new extension, optimized systems and renewable energies were implemented.

3.6.2 The process

In 2009 London Thames Gateway Development Corporation obtained detailed planning consent on a scheme designed by Schmidt Hammer Lassen (SHL) for a new Creative Industries Quarter centred on the former Granary and Malthouse buildings (Glenny, 2012, Cooperconcept.org, 2012).

Roof Company, acquired the site in March 2010, located on a Olympic Park possible planning area, running a family business always operating from the east of London, they decided to move to the Granary after a visit to the building in which the character and potential of the site inspired them (Jones, 2012b). The building was sold to them on the undertaking that they would restore the building for their own occupation and add a modern extension for letting to creative industries.

The main focus of this project was to retain the historic significance of the building, achieving, in addition an environmentally friendly intervention while maintaining a good value for money. The project aimed to be not only a sensitively approached building to host the enterprise base and be proud of, but also a showcase of the compromise and experience of the enterprise on this kind of projects. Furthermore, the functionality and practicality were very important.

Thus, the energy efficiency in the project was not to be improved just to meet the basics standards, but to be as high as the economic costs and the historic integrity of the building allowed it, as the aim was to show the possibilities of these buildings to future clients. Despite this focus, the building was rated with a “B” rating in the EPC with 48 point scored (see appendix 4, fig 39), meaning not only that it could be improved to an A, but also that in is in the lower part of the range (B ranges from 26 to 50 points). Nevertheless, according to the EPC assessment, new buildings with similar characteristics to this one have achieve average scores of 44 while existing stock achieves 81 points, which means a predicted improvement of an historic building to new built standards.

As the aim was to retain as much as possible the character of the building, passive designs systems were chosen, however, this was not only an heritage lead decision, it was a combination of economic, environmental and historic factors, this can be seen in the fact that the new extension follows exactly the same passive principles.

The approach to the existing fabric was to maintain it as it was, without adding insulation or extra layers. The influence of this decision was that the basic principles of breathability, moisture balance and thermal mass of the building were maintained. In the Part L report, the U value of the walls of the new building are 0.24 W/(m2.k), better than design limits for 2006 regulations 0.35 W/(m2.k). The old brick wall is approximately 0.4m and did not meet the required U value standards (Macarthur et al., 2012b). Thus, the thermal values for the building envelope where achieved as a balance of the old and the new building and the extra insulation added to the roof (new U value 0.19 W/(m2.k), meaning that the old fabric walls lower the energy performance of the building envelope (see insulation details below).

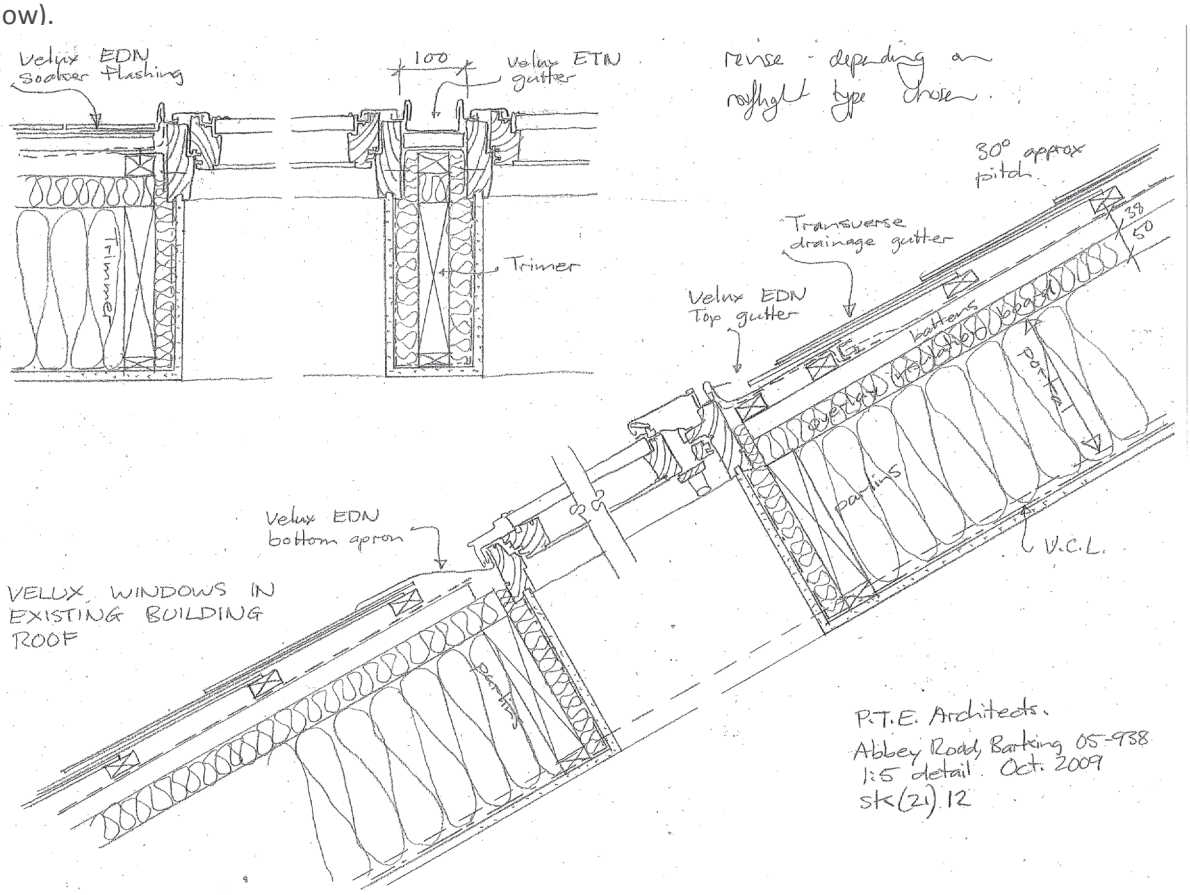


Figure No. 21/ Roof insulation detail. (Macarthur, 2012)

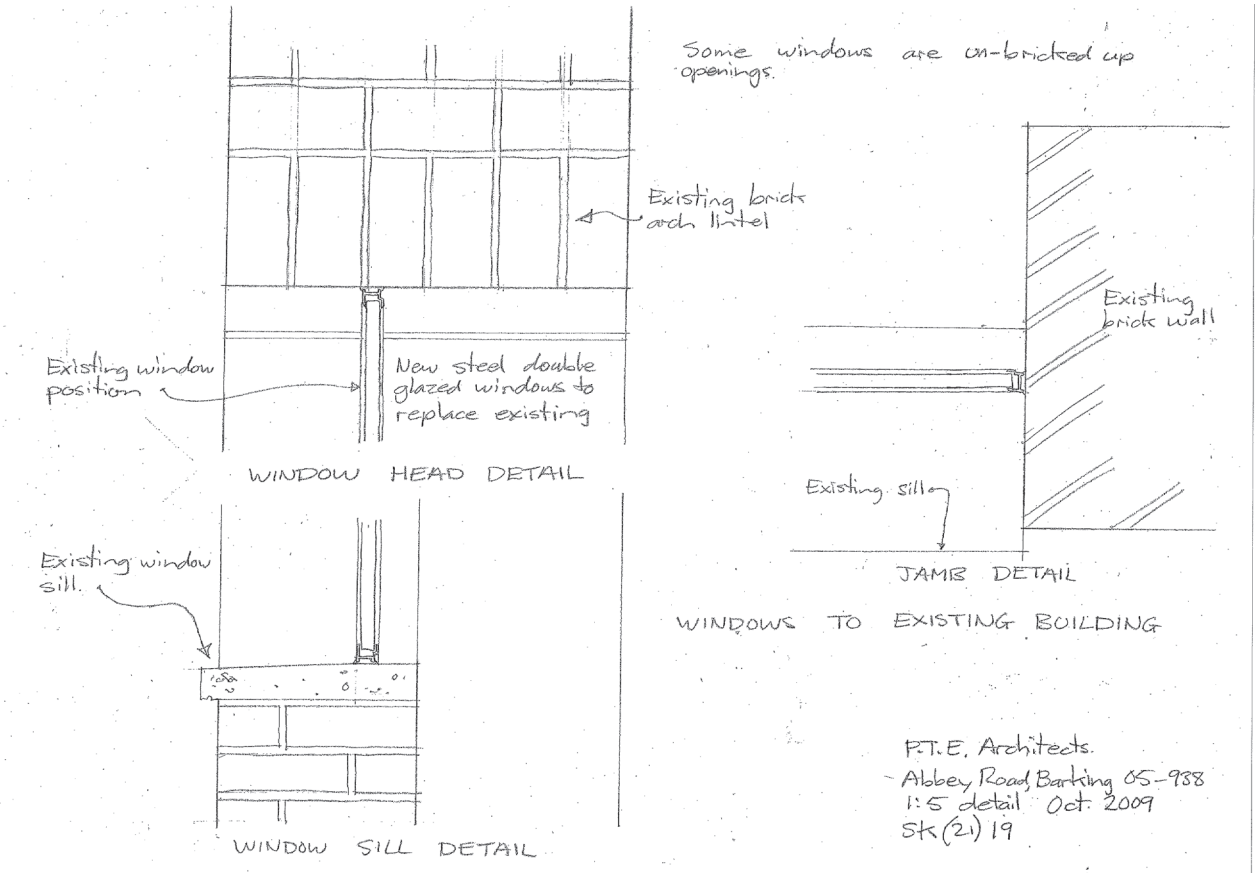


Figure No.22/ Window/wall detail. (Macarthur, 2012)

The old windows were not in a good state and so the decision was taken to replace them by a double thermal glazing more efficient windows but maintaining the character of them by selecting the same model and the same company (Crittall TM) which made the original ones. This decision was feasible due to the building was not listed resulting in an increase in energy performance; while the estimated value of a single glazing window rounds the 4.81.98W/m2k, the new value in this case is 1.98W/m2k, better than the 2.2 W/m2k limit in the regulations.

The system chosen for the ventilation is the natural ventilation, which alongside with the use of the thermal mass of exposed walls, allowed the avoidance of the air conditioning on the building, this was a decision in consonance to the historic, environmental and economic approaches of the project (Carbon Trust, 2012).

The heating system is provided by a radiators system fuelled by natural gas. The heat source efficiency was 0.9, which means that is over the limit of 0.85 established in the regulations. However, although the client stated that

the use of renewable energy systems implementation for fuel this system were discarded due to the cost and lack of space, only PV panels were used (the roof of the old building was new built due to its state), this decision was also conditioned by the cost, and so, even if there was more roof surface to install PV panels only 80m2 were installed which was the amount subsidized by the government (Macarthur et al., 2012b).

3.6.3 Resulting comfort and usability

The BUS questionnaire was performed within the occupants of this building (see Appendix 4 for full results).

The comfort is the building is high (5.75/7 average score being 7 comfortable, 1 uncomfortable). In winter it was scored as 5.75/7, while in summer the score was lower 4.75/7 as there was a mention about some specific days during the summer in which due to the unfortunate pattern in windows opening during the night, some overheating arisen.

The occupants also reported that the building meets well their needs (6.7/7 scored), they were very satisfied with the building, a major target set by the client when confronting the design of it.

3.6.4 Conclusions

In this project despite the leading factor is the historic significance of the building, the balanced interaction between the economic, environmental and historic values is the main achievement. The key element of this process, in the designer´s opinion, was the early understanding and the sympathetic client with whom they had worked before, another key element being the historic research of the building.

The designers also stated that dealing with existing building is more difficult and so more time and money are needed in order to reach the desirable solution, being the historic factor the leading one. Nevertheless, when a client commit to an historic building this risks are assumed from the beginning and they are prepared to expend more resources and to maintain a sensible approach to achieve a good result.

On the other hand, from the energy point of view, the economic factor was a great constraint in this case. Although the building has shown a predicted improvement of an historic building to new built standards according to the EPC assessment, it is also true that with a B score in the EPC there is still room for improvement. Although the decisions in the first stages were encouraged to achieve this target, the economic restrictions were detrimental to the use of a range of possible renewable energies “non-visible” such as ground source heat pumps or a biomass boiler or CHP or even more PV panels, which would had help to reduce the heating consumption of the building.

chapter 4

DISCUSSION

From the analysis of the case studies, historic buildings can in theory be very energy efficient energy rating (see EPC ratings in appendix figures 2,15,27 and 39) in the case studies comparing to benchmarking) adopting at the same time sensitive approach to the historic value of the building and achieving good economic value and reasonable comfort parameters (see figures 12,24,36 and 49 in the appendix) However, there are a number of issues which constrain performance discussed below as well as best practice strategies for overcoming these.

4.1 Problems identified in Historic Buildings

Analyzing the information from post occupancy evaluation procedures (BUS questionnaire and interviews to occupants) and the analysis trough the direct observation of the building, several problems that can be an issue for the energy performance of historic buildings have been identified.

As stated in the literature review, the heat loss is the main issue when reusing historic industrial buildings. In the analysis of the case studies, this fact has been identified by the designers as the first concern (see case study 1 and thermal analysis) and also reported by the occupants after the intervention as the main discomfort motive (in listed buildings average discomfort in winter was rated 4/ and 4.83/7 while in non listed buildings the score was 5.75/7 and 6.4/7).

Overheating, as reported by the occupants, is an issue that also arose in the questionnaires. However, as this happened only in some specific days of the year in England, it can be the result of a conscious decision making in terms of avoiding the environmental, historic and economic impact of using stronger measures like the air conditioning in such buildings.

Finally, the amount of natural lighting in historic industrial buildings was reported to be very adequate as shown in all the case studies (4.3/7, 3.8/, 4.8/7 and 4.5/7, being 1-too little and 7-too much), although only two typologies had been analysed (warehouses and manufacturing buildings). This is a factor that can have substantial impact on the energy consumption as light accounts for 20% of all electrical energy usage (Neweys, 2012).

4.2 Best Practice strategies:

Not all the case studies follow the same insulation strategy. While the Toffee Factory and Butcher Works used interior insulation for the walls, the Warehouse and The Granary did not use any insulation at all, a very detrimental measure considering that it is estimated that a third of the heat loss in uninsulated buildings happens through the walls (Peak District National Park Authority, 2011, National Energy Foundation, 2012, Energy Saving Trust, 2012d). Nevertheless, this decision allowed them to use the thermal mass capacity of the walls, which is especially relevant

as the cooling strategy of the buildings relied on natural ventilation. In addition, although the estimated U value of the walls in the case studies were far from the ones on the regulations, it is also true that "regulations U values are not usually suitable for the evaluation of the thermal conductivity of permeable materials[...] Dynamic calculation programmes for the assessment of hygro-thermal behaviour over time do exist, but are not well tested for use on existing buildings" (D. Pickles et al., 2012, p.46).

On the other hand,extra insulating the roof was common to all buildings, in order to balance the loss through the walls and windows, as it is estimated that in uninsulated buildings a quarter of the heat is lost by the roof (Energy Saving Trust, 2012c).

Other important elements to improve are the windows, as they can represent a big surface of heat loss. According to unpublished data from the BRE, is that "if the half million or so listed buildings in England had all their windows replaced by double-glazing, it would save up to 0.36 per cent of total energy used in this country" (Crhis Wood, 2004) As shown in Butcher Works and The Navigation Warehouse, it is difficult to get consent for replacing windows in listed buildings, what has considerable impact, as it is estimated that 10% of the heat of the building is usually lost by them. However, other measures like repairing the windows or using blinds and shutters, that can reduce the heat losses per window up to 51% (see table 1 in case study nº2) have not been considered either.

The use of natural ventilation and the avoidance of air cooling systems are also consitent in all the case studies. In the Uk, where there are relatively few days per year when the temperature is very high (over 28ºC), using mechanical cooling systems can cost the equivalent of a whole year´s heating. Additionally, the energy costs and associated CO2 emissions of a typical air-conditioned building are 30% higher than a naturally ventilated one(Carbon Trust, 2012). This decision, considered as a low energy measurement, is steadily being implemented in new built buildings, the main barrier being usually the users attitude, as revealed by the case studies, where the lack of cooling system was identified as the cause of overheating in summer. In historic buildings, the interior air quality generated by these systems (see BUS results in the appendix) has a positive impact on the building fabric.

The heating distribution choosen for all the case studies were the radiators, the reason for this being mostly the space restriction and the heritage value preservation in the case of Butcher Works, alongside with the lower disruption of the building fabric that generated pipes generated in comparison whith ductwork. Whenever possible, underfloor heating can result a good strategy as it provides better quality heating without drying the air, a especially sensitive fact with the building fabric. furthermore, also due to its low operating temperature, it can be easily linked in with alternative heating sources that output at the same low temperatures such as solar/thermal panels or ground source heat pumps (Greenspec, 2012c).

As shown in all the case studies, the use of renewable energy systems application is still very limited in historic buildings. Only the non-listed buildings have incorporated any source of renewable energy, and yet their use is low if compared with their potential. In the case of the Granary, for example, the use of PV panels was conditioned to the cost of installing them, as they only installed the amount of panels that were subsidized by the government. In the Toffee Factory, the approach was more conscious towards the most energy demand in the building. In listed buildings, the renewable energy systems were discarded as the designers prioritize to maintain the integrity and character of the building. Nevertheless, there are reasons to suggest that the considerations towards these systems were influenced by the economic costs and installation difficulties rather than their disturbance.

4.3 The decision making process

The obligation to meet the regulations is the major opportunity to introduce energy efficient measures in historic buildings. However, during the analysed processes, when conservation and energy efficiency crashed, limitations in the scope of energy efficiency improvements arisen. While the Toffee Factory and The Granary were equipped with new windows and extra renewable energy systems, in Butcher Works and The Warehouse less effort was made to improve the energy efficiency, measures being more focused on just meeting the basic standards, what reflects that the fewer level of protection the building has, the more likely there are energy efficient measures to be implemented in historic buildings.

As one of the Directors of an important UK development company who has intervened in a number of similar processes all over UK identified in the interviews, the energy efficiency is an issue that made the financial appraisal more difficult to be viable in historic buildings, due to the lack of direct benefits for the investors. In The Toffee factory, the BREEAM “excellent” rating was achievable under an additional cost of £50k. However, as the “very good” rating target was set by the funder (One North East Regional Development Agency), there was not additional reward for the clients, as they already met the funding criteria, they would not receive any the benefit from the running cost of achieving a more efficient building as they were not the final managers of it. By contrast, when the running costs benefit directly the client (see The Granary), more effort is made in achieving a good performance.

The understanding between building industry, developers, practitioners and local authorities is also vital in order to achieve an advanced energy standard in historic buildings. The increased complexity of buildings has lead to a fragmentation of the design process,. This problem was identified in The Toffee Factory and The Warehouse where an early collaboration with the engineers was the key to achieve a high energy efficiency. This was also noticed in information recovery process for the case study analysis, where it was difficult to relate the measures implemented in the projects to real measured data of the consequential improvements that should have shown the reasons why the decisions were taken.

chapter 5

CONCLUSION

5.1 Summary

This dissertation contributes to the identification of the main challenges when introducing energy efficiency in the re-use of historic buildings, the role that different disciplines play in this process and the achievements and failures of current best practices.

In order to achieve these objectives, a case study methodology has been followed. The research was focused on multi-storey urban industrial typology, analysing buildings that have been completed in the last 10 years usingbest practice architecture. These buildings being currently at risk due to the change in industrial processes represent the paradox between protection and re-use, demonstrating the complexitie of working with historic buildings.

The case study methodology offers the chance of analysing the the whole decision making process rather than just addressing the results and objectives. The selected research methods, also offered the possibility of evaluating the projects from different perspectives.

5.2 Limitations

There are a number of limitations in this dissertation which include;

01. The limited time available to complete this thesis (4 months). This type of fieldwork requires enough time to gather primary source information and cross reference it. The problems included the adjusted response time for the participants and the clash of the research with holiday period of both practitioners and occupants.

02. The lack of comparative data on the predicted performance of different energy solutions and consequently ability to cross reference information.

03. The lack of updated performance data for the case studies.

04. The introduction of energy efficient strategies in this building typology is relatively recent, which means that the examples that are incorporating the most advanced solutions are in design or construction process at the moment.

05. The geographic limitation did not allow case studies outside the UK in addition to the restricted number of case studies that was possible to analyse.

5.3 Key Findings

5.3.1 Passive strategies

The passive design strategy is a low energy approach that can fulfil not only the environmental but also the economic and historic needs of historic buildings. It responds to local climate and site conditions to maximise the comfort and interior air quality while minimising energy use (Level, 2012). In historic buildings it represents a good converging point between energy performance and historic value preservation as the lack of ductwork avoids disruptions in the building fabric (Rogic, 2009) while the indoor air quality maintains the balance between materials, moisture transfer, ventilation and thermal performance in historic assets (English Heritage, 2004, Historic Scotland, 2007) .

This has been the major approach in all the analysed case studies, being passive design combined with other strategies through all the design phases to achieve a coordinated result.

5.3.2 Economics

From the economic standpoint, it is usually more expensive to deliver a building with better energy performance (RICS, 2012a, Hunt, 2008). In interventions in which the historic significance lead the process, the economic effort were focused on preserving the building leaving the environmental aims in a second plane. Although there are some economic incentives and grants from the UK government to promote energy efficiency (Department of Energy and Climate Change, 2012, Department of Energy & Climate Change, 2012a, Department of Energy & Climate Change, 2012b), the lack of a reasonable return on capital resulted in unwillingness to pay high upfront costs for longer term benefits beyond these measures.

This detachment of the capital costs from the revenue benefits usually leads to a relaxation in the energy efficiency under “the protection of heritage value” argument. The fact is that, even if the practitioners want to deliver more efficient buildings, the demand has to come from the clients, who has to see a benefit on it, just because they are the ones directly benefited by the running costs or because the market asks this parameters. The problem is that until recently, it was a generalized assumption that energy efficiency implementation was detrimental to the historic value of a building. However, policies and programs that increase transparency of building energy performance such as the Energy Performance Certificate (EPC) that is compulsory when marketing a property (UK government planning portal, 2012b) and the future need of achieving a EPC rating of F or G from April 2018 to be able to rent the property by law (Department of Energy and Climate Change, 2012), can also lead the change by making people aware of the real impact of performance of their buildings, giving the developers a reason to made a bigger effort in requesting energy performance.

5.3.3 Decision making

The difficulty of assessing the energy impact of different factors in a complex system in which all the decisions are interrelated, leads to assumptions without any proven evidence with the consequent risk of being exposed to false environmental claims. This process of "green wash" (Greenpeace, 2012, Greenwashing index, 2012) which also happens in new built buildings, is even more harmful in historic buildings where understanding the impact of new systems and methods is more difficult.

Problems such as the fragmentation in the design process caused by the increasing complexity of the buildings due to the consequence of the high standards required and insufficient tools and knowledge to understand both the old fabric and the real impact of energy measures aside from simulated situations and reveal the need of conservation architects with energy expertise which would be able to give more coherence to these processes by assessing the real energy capacities of the buildings and the consequence of the implemented methods giving the possibility to make better informed decisions.

5.4 Lessons learned

A number of lessons have been identified in this study in order to reconcile the synergies of sustainability (economics, environment, social) during the processes when analysing the case studies:

01. The need to develop a rapid understanding and agreement of the requirements in relation to historic buildings between different disciplines through closer collaboration from the beginning of the project.
02. The importance of assessing the significance of each part and element of the building in order to prioritise what is worth preserving and what can be changed in the less relevant parts. This would provide more freedom for the introduction of energy efficient measures in the building.
03. The importance of thermal analysis of the envelope in order to assess the best solutions, very often wrong approaches are selected due to the lack of understanding of the historic building fabric.
04. To achieve best practice solutions, not only be sufficient investment in systems is needed, enough time should be given to professionals in order to understand the problems, do research and using research and test the potential solutions.

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APPENDIX

1. The Toffee Factory

Table No.1	
Project	**The Toffee Factory**
Practice	Xsite architecture LLP
Developer	1NG Ltd
Owner	Maynards- past Newcastle City Council, One North East and the Ouseburn Trust- current
Location	Newcastle
Completion Date	October 2011
Type Number of Units	Office building 26 fully serviced offices
Costs	£4.9 million
Funds	One North East - £2,750,000 European Regional Development Fund - £3m Newcastle City Council - £250,000.
Floor area	2682m2
Rating	BREEAM: Very Good EPC (Energy Performance Certificate): A
Awards	RIBA: **Regional Sustainability Award** **North East Building of the Year Award** **Running for the Stirling Prize** North East RICS Renaissance Awards 2012: **Project of the Year** **Regeneration award** **Highly Commended** in both the **Design & Innovation** and **Commercial Property**
Contact	Toffee Factory 0191 375 9000 info@toffeefactory.co.uk Xsite architecture LLP 0191 287 2161 info@xsitearchitecture.co.uk

Table 1/ The Toffee Factory; Table Resume. Authors own, 2012, based upon (Bailey, 2012, Skyscraper City, 2012, Brims, 2012, Xsite, 2012)).

RIBA

RIBA awards programme: Sustainability Statement

The RIBA is committed to meeting the challenge of climate change and raising the understanding of sustainability within the profession. This document is to provide where possible quantitative and qualitative data on the sustainability credentials of buildings submitted for awards. There may be buildings where it is not possible to produce quantifiable data either because of their size, or because they do not provide climatic enclosure, in which case only the written statement needs to be included.

Gross floor Area	2682 m² *(From EPC Model)*	Treated floor area (eg where energy use can be measured)	2682 m²
Annual energy/CO_2 consumption for space and water heating (excluding any contributions from onsite renewables which should be noted below)		288502.4 kWhrs	1.40 kgCO_2/m²
Annual energy/CO_2 consumption for electrical usage (excluding any contributions from onsite renewables which should be noted below)		56762.7 kWhrs	10.90 kgCO_2/m²
Total Annual CO_2 emissions/m² treated floor area			12.34 kgCO_2/m²
What EPC rating was achieved by the Building on completion			A
Give the basis of calculations/software / measured data used to achieve the above data. Calculation preformed for EPC using IES Virtual Environment v6.4.0 with calculation engine ApacheSim v6.4.0			
Give details of any benchmarking evaluation system that has been completed for the building(e.g. BREEAM , , SAP, CSH, LEED EPC ratings etc) The Toffee Factory was assessed under BREEAM Offices 2008 scheme and achieved a score of 63.63 % which put it into the Very Good category. The Toffee Factory achieved an A rated EPC.			

Where appropriate provide the name of the engineer or engineering consultancy that has validated the above figures. EPC validated on the 6th of December by Dr Tom Bentham CEng MCIBSE on behalf of Max Fordham LLP.
Give brief details of any renewable energy systems that are incorporated into the design. A high efficiency pellet fed biomass boiler provides low carbon renewable heat for heating and domestic hot water. Large areas of the building suffer from poor daylight and ventilation access due to the large retaining walls that surround two sides of the building. These areas formed ideal locations for the plant room and fuel storage area. Making use of an area of the building that had little rental value. Heating is the main energy load in the building so targeting this with a low carbon energy source had a large impact on the CO_2 footprint of the building. Wood pellets are delivered to site once a month during the heating season and are stored in an internal pellet silo. A

Figure 2/ The Toffee Factory Sustainability Statement. (Bailey, 2012)

Temperature in summer: hot/cold

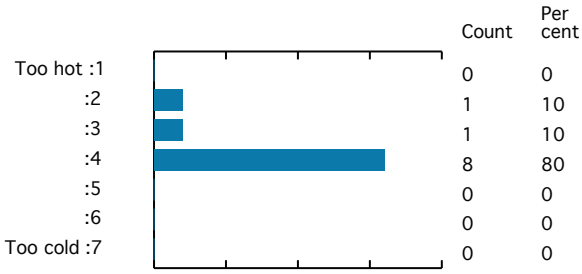
Score: 3.7

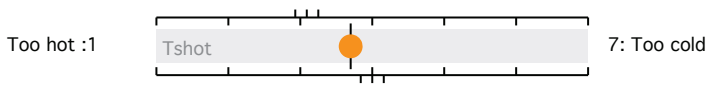
	L	Mean	U
Benchmark	2.93	3.09	3.25
Scale midpoint	3.84	4	4.16

	Study mean	Scale midpoint
Percentile	83	95

B | Tshot

Study mean: 3.7 | Study building percentile: 83 | Quintile: 5
Building code: 12482 | Benchmarks: BUS 2011 UK benchmark
Web content © BUSMethodology 2012





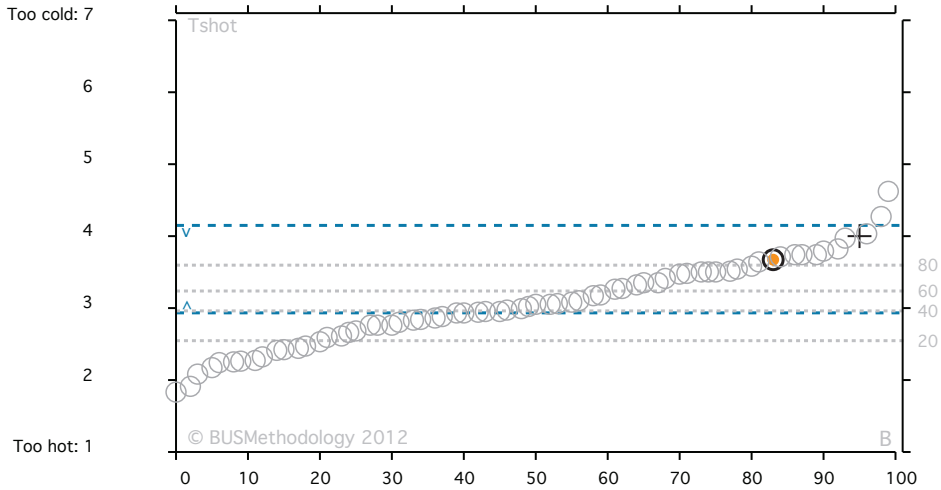


Figure 3/ Toffee Factory BUS results; Temperature in summer. (Leaman, 2012)

Temperature in summer: overall

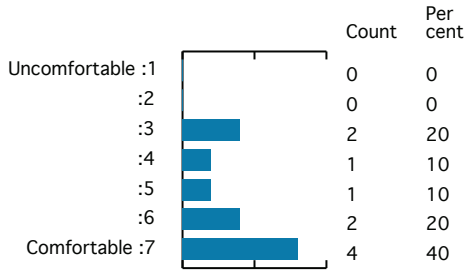
Score: 5.5

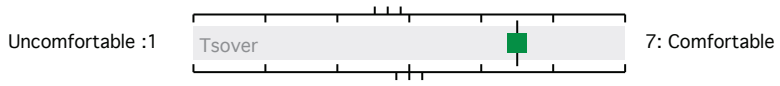
	L	Mean	U
Benchmark	3.52	3.7	3.88
Scale midpoint	3.82	4	4.18

	Study mean	Scale midpoint
Percentile	99	58

A | Tsover

Study mean: 5.5 | Study building percentile: 99 | Quintile: 5
Building code: 12482 | Benchmarks: BUS 2011 UK benchmark
Web content © BUSMethodology 2012





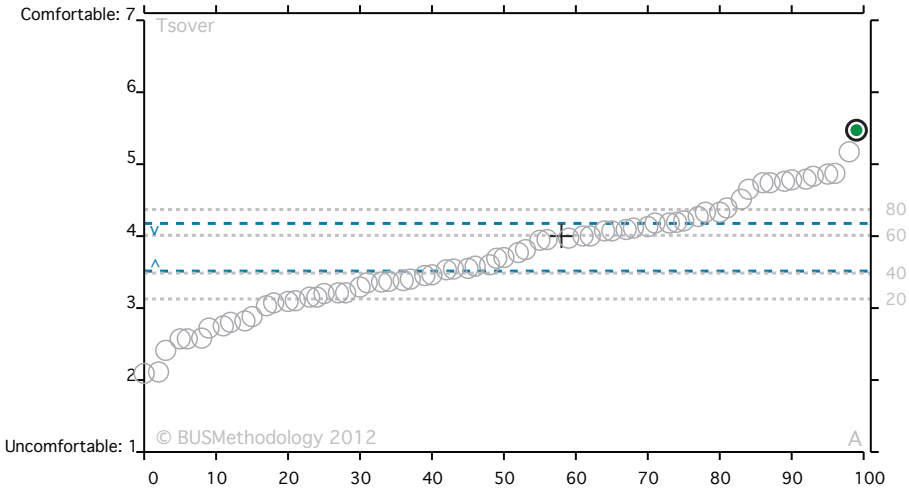


Figure 4/ Toffee Factory BUS results; Temperature in summer overall. (Leaman, 2012)

Temperature in winter: hot/cold

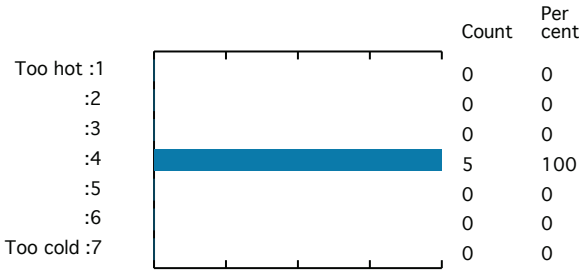
Score: 4

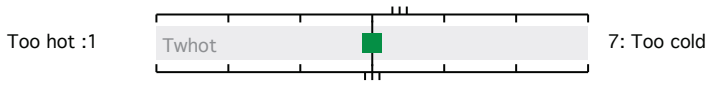
	L	Mean	U
Benchmark	4.28	4.38	4.48
Scale midpoint	3.9	4	4.1

	Study mean	Scale midpoint
Percentile	11	8

B | Twhot

Study mean: 4 | Study building percentile: 11 | Quintile: 1
Building code: 12482 | Benchmarks: BUS 2011 UK benchmark
Web content © BUSMethodology 2012





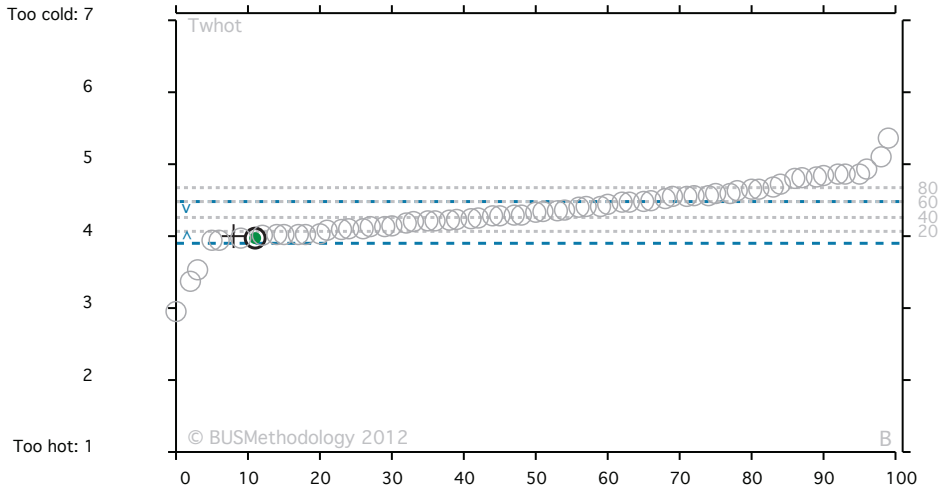


Figure 5/ Toffee Factory BUS results; Temperature in winter. (Leaman, 2012)

Temperature in winter: hot/cold

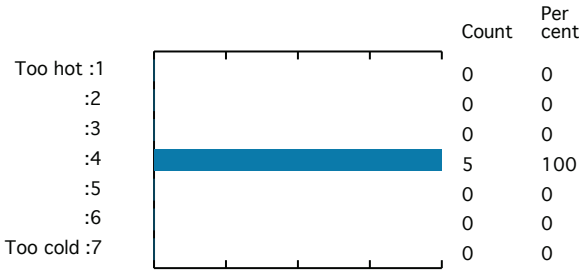
Score: 4

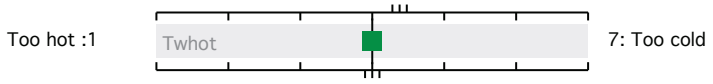
	L	Mean	U
Benchmark	4.28	4.38	4.48
Scale midpoint	3.9	4	4.1

	Study mean	Scale midpoint
Percentile	11	8

B | Twhot

Study mean: 4 | Study building percentile: 11 | Quintile: 1
Building code: 12482 | Benchmarks: BUS 2011 UK benchmark
Web content © BUSMethodology 2012





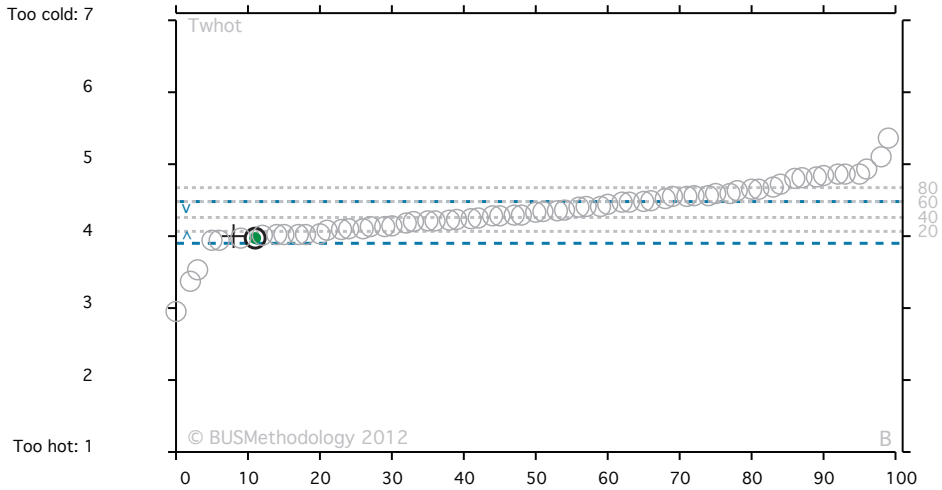


Figure 6/ Toffee Factory BUS results; Temperature in winter overall. (Leaman, 2012)

Air in summer: overall

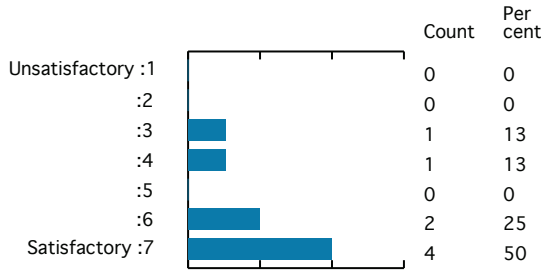
Score: 5.88

	L	Mean	U
Benchmark	3.64	3.82	4
Scale midpoint	3.82	4	4.18

	Study mean	Scale midpoint
Percentile	99	53

A | Airsover

Study mean: 5.88 | Study building percentile: 99 | Quintile: 5
Building code: 12482 | Benchmarks: BUS 2011 UK benchmark
Web content © BUSMethodology 2012



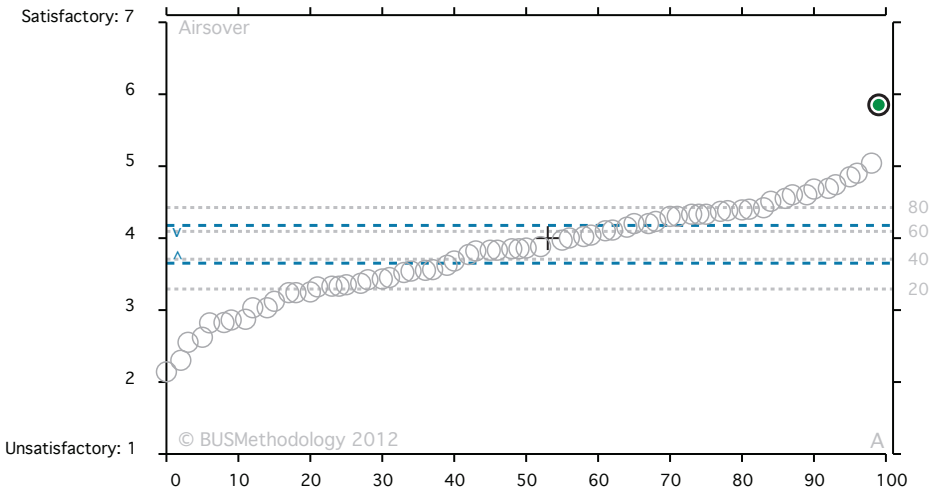


Figure 7/ Toffee Factory BUS results; Air summer overall. (Leaman, 2012)

Air in winter overall

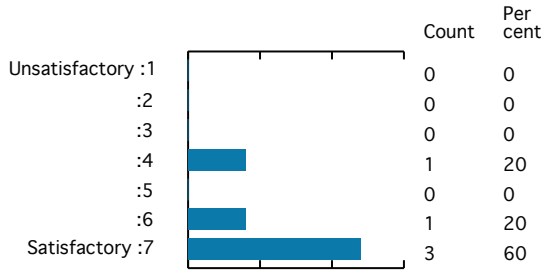
Score: 6.2

	L	Mean	U
Benchmark	3.97	4.15	4.33
Scale midpoint	3.82	4	4.18

	Study mean	Scale midpoint
Percentile	99	44

A | Airwover

Study mean: 6.2 | Study building percentile: 99 | Quintile: 5
Building code: 12482 | Benchmarks: BUS 2011 UK benchmark
Web content © BUSMethodology 2012



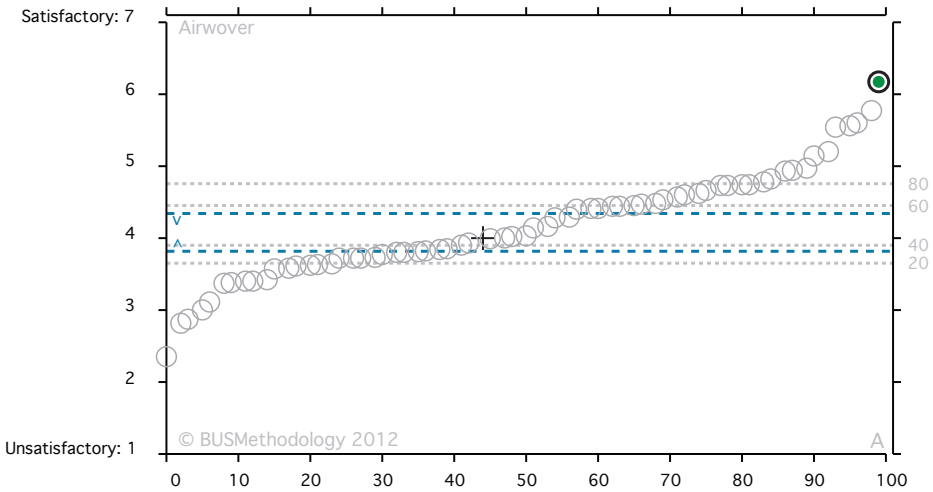


Figure 8/ Toffee Factory BUS results; Air winter overall. (Leaman, 2012)

Air in summer: overall

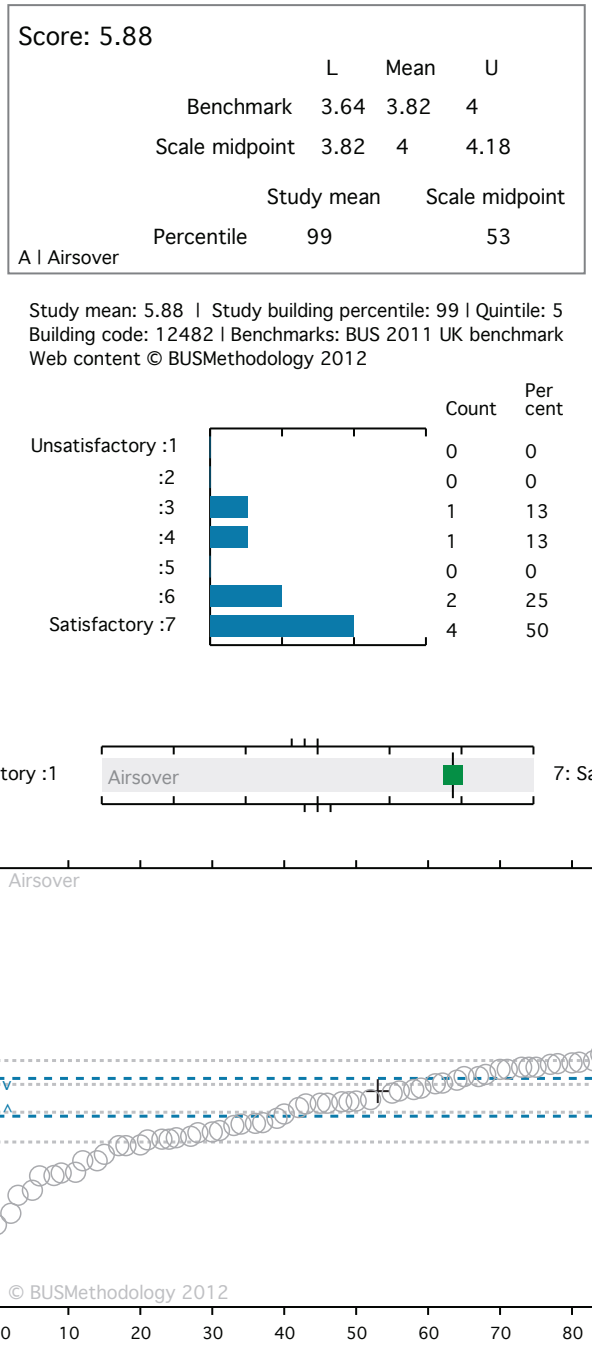


Figure 9/ Toffee Factory BUS results; Comfort overall. (Leaman, 2012)

Lighting: natural light

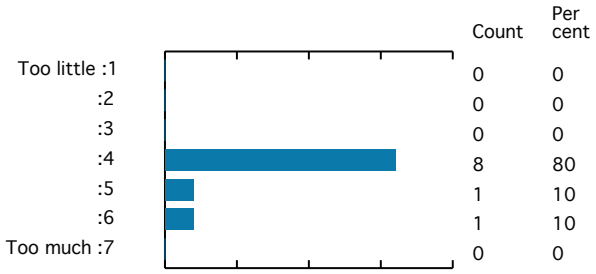
Score: 4.3

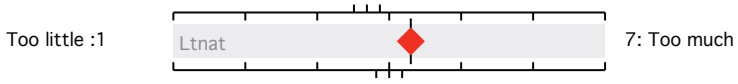
	L	Mean	U
Benchmark	3.51	3.69	3.87
Scale midpoint	3.82	4	4.18

	Study mean	Scale midpoint
Percentile	84	62

B I Ltnat

Study mean: 4.3 I Study building percentile: 84 I Quintile: 5
Building code: 12482 I Benchmarks: BUS 2011 UK benchmark
Web content © BUSMethodology 2012





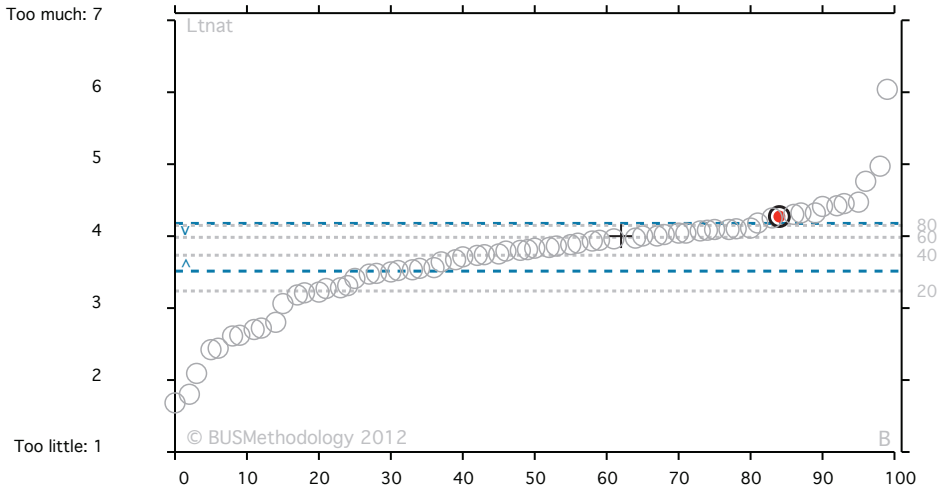


Figure 10/ Toffee Factory BUS results; Natural light. (Leaman, 2012)

Do facilities meet needs?

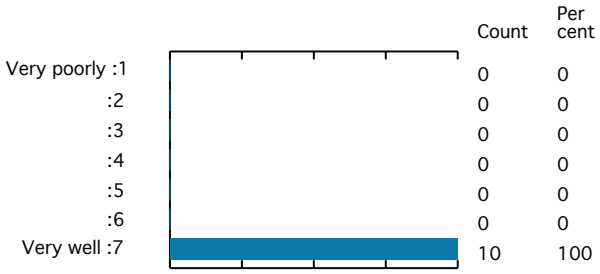
Score: 7

	L	Mean	U
Benchmark	4.86	5.02	5.18
Scale midpoint	3.84	4	4.16

	Study mean	Scale midpoint
Percentile	99	6

A | Workreq

Study mean: 7 | Study building percentile: 99 | Quintile: 5
Building code: 12482 | Benchmarks: BUS 2011 UK benchmark
Web content © BUSMethodology 2012



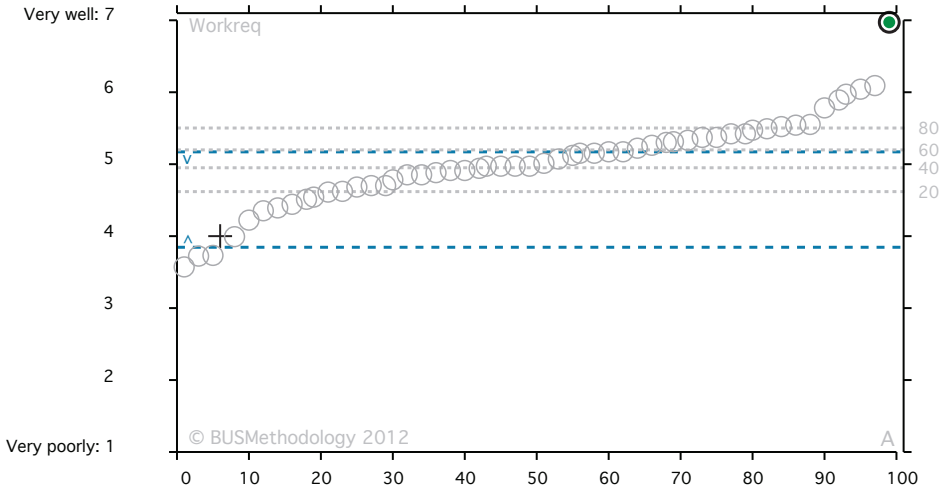
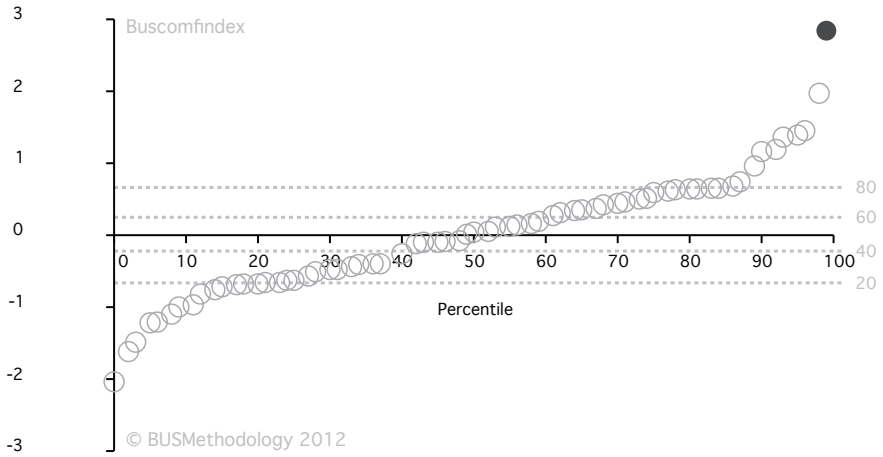


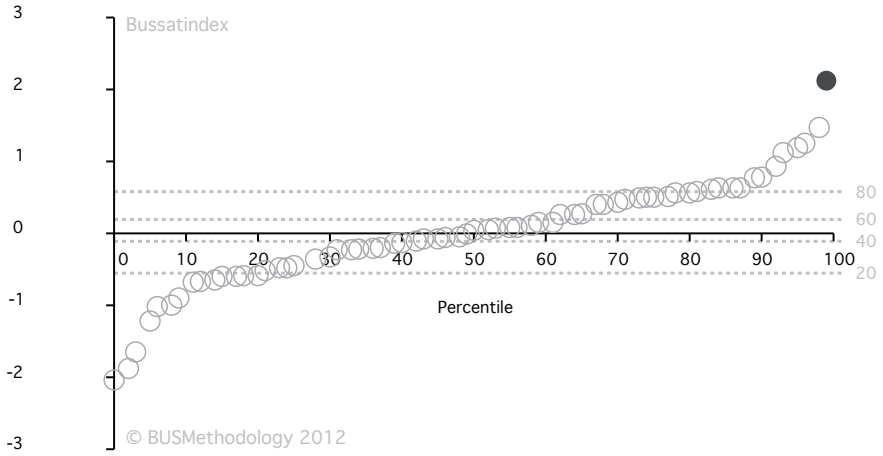
Figure 11/ Toffee Factory BUS results; Needs. (Leaman, 2012)

BUS Comfort Index



Study mean: 2.87 | Study building percentile: 99 | Quintile: 5
Building code: 12482
Web content © BUSMethodology 2012

BUS Satisfaction Index



Study mean: 2.15 | Study building percentile: 99 | Quintile: 5
Building code: 12482
Web content © BUSMethodology 2012

Figure 12, 13/ Toffee Factory BUS results; Comfort index and satisfaction index. (Leaman, 2012)

2. Butcher Works

Table No.2	
Project	**Butcher Works**
Practice	Race Cottam Associates
Developer	JF Finnegan Ltd
Owner	Unknown- unique ownership
Feasibility Study	Donald Insall Associates
Client	Sheffield City Council and Cultural Industries Quarter Agency
Location	Sheffield
Completion Date	October 2007
Type Number of Units	Mixed Use 51 residential apartments, Academy of Makers workshops and gallery, and a cafe
Costs	£5.5 million
Floor Area	6000m2
Rating	EPC (Energy Performance Certificate): C
Awards	Commendation for Best Building at the inaugural Sheffield Civic Trust Design Awards in 2009
Contact	Academy of Makers 0114 252 5882 info@academyofmakers.co.uk Race Cottam Architects 0114 2737050 plake@racecottam.com J F Finnegan Ltd 0114 268 6011 info@j-f-finnegan.co.uk

Table 14/ Butcher Works Table Resume. Authors own, 2012, based upon (Padley, 2012, e-architect, 2009, Cottam, 2012).

Energy Performance Certificate

SAP

45, Eyre Lane, SHEFFIELD, S1 4RB

Dwelling type:	Ground-floor flat	**Reference number:**	0190-2888-6854-9102-4121
Date of assessment:	08 May 2012	**Type of assessment:**	RdSAP, existing dwelling
Date of certificate:	08 May 2012	**Total floor area:**	50 m²

Use this document to:

- Compare current ratings of properties to see which properties are more energy efficient
- Find out how you can save energy and money by installing improvement measures

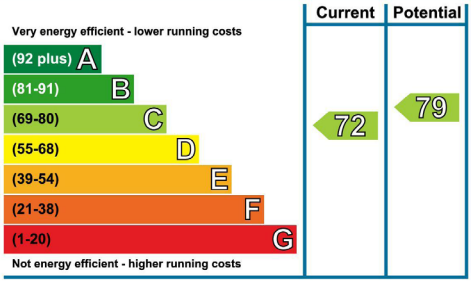
Estimated energy costs of dwelling for 3 years:	**£1,374**
Over 3 years you could save	**£342**

Estimated energy costs of this home

	Current costs	Potential costs	Potential future savings
Lighting	£165 over 3 years	£105 over 3 years	You could save £342 over 3 years
Heating	£858 over 3 years	£627 over 3 years	
Hot Water	£351 over 3 years	£300 over 3 years	
Totals	**£1,374**	**£1,032**	

These figures show how much the average household would spend in this property for heating, lighting and hot water. This excludes energy use for running appliances like TVs, computers and cookers, and any electricity generated by microgeneration.

Energy Efficiency Rating



The graph shows the current energy efficiency of your home.

The higher the rating the lower your fuel bills are likely to be.

The potential rating shows the effect of undertaking the recommendations on page 3.

The average energy efficiency rating for a dwelling in England and Wales is band D (rating 60).

Top actions you can take to save money and make your home more efficient

Recommended measures	Indicative cost	Typical savings over 3 years	Available with Green Deal
1 Low energy lighting for all fixed outlets	£30	£45	
2 Fan assisted storage heaters and dual immersion cylinder	£900 - £1,200	£297	✓

To find out more about the recommended measures and other actions you could take today to save money, visit **www.direct.gov.uk/savingenergy** or call **0300 123 1234** (standard national rate). When the Green Deal launches, it may allow you to make your home warmer and cheaper to run at no up-front cost.

Figure 15/ Butcher Works´ Flat Energy Performance Certificate. (Padley, 2012)

Temperature in summer: hot/cold

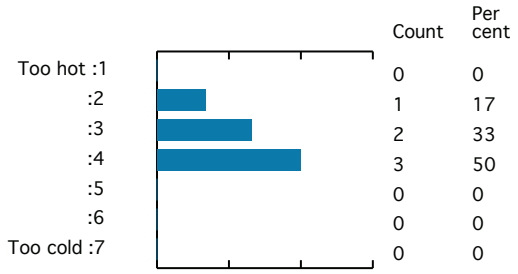
Score: 3.33

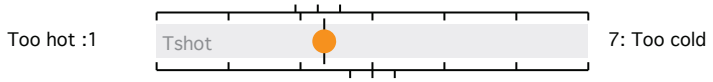
	L	Mean	U
Benchmark	2.93	3.24	3.55
Scale midpoint	3.69	4	4.31

	Study mean	Scale midpoint
Percentile	45	91

B | Tshot

Study mean: 3.33 | Study building percentile: 45 | Quintile: 3
Building code: 12481 | Benchmarks: BUS 2011 UK Housing benchmark
Web content © BUSMethodology 2012





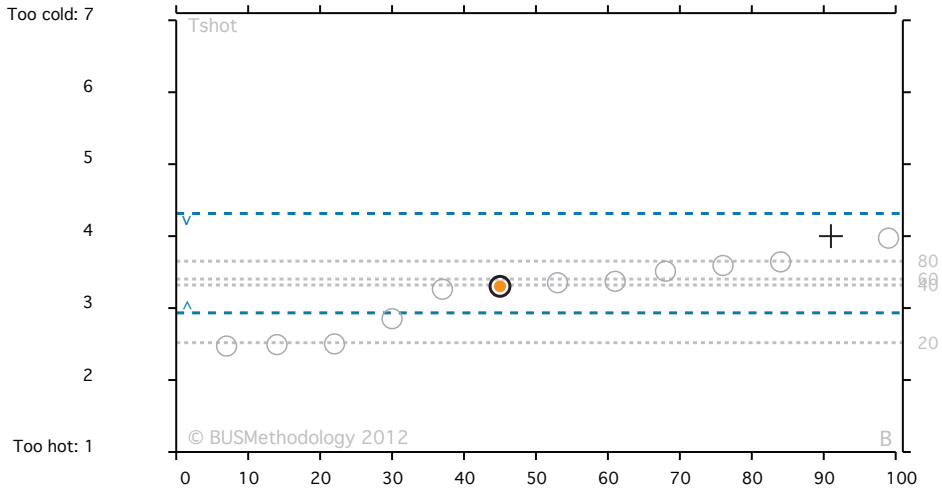


Figure 16/ Butcher Works BUS results; Temperature in summer. (Leaman, 2012)

Temperature in summer: overall

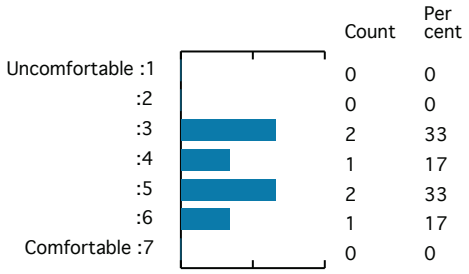
Score: 4.33

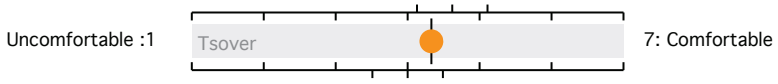
	L	Mean	U
Benchmark	4.13	4.62	5.11
Scale midpoint	3.51	4	4.49

	Study mean	Scale midpoint
Percentile	45	22

A | Tsover

Study mean: 4.33 | Study building percentile: 45 | Quintile: 3
Building code: 12481 | Benchmarks: BUS 2011 UK Housing benchmark
Web content © BUSMethodology 2012





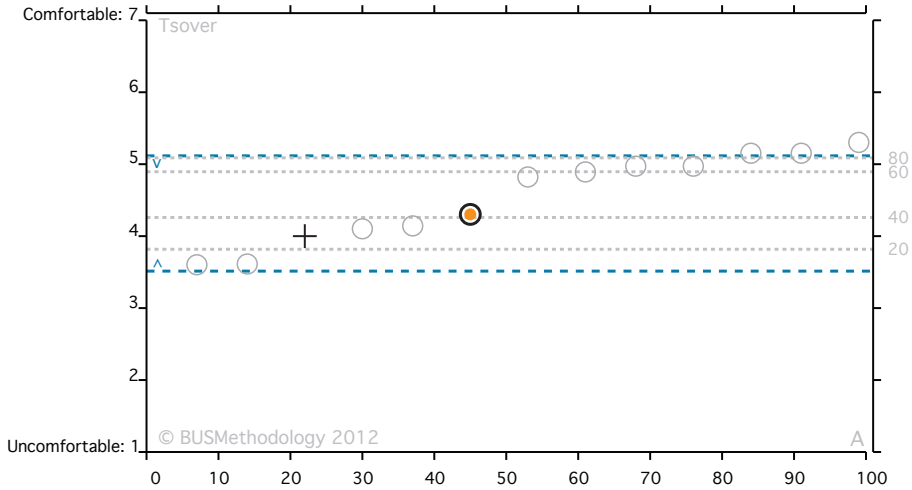


Figure 17/ Butcher Works BUS results; Overall temperature in summer. (Leaman, 2012)

Temperature in winter: hot/cold

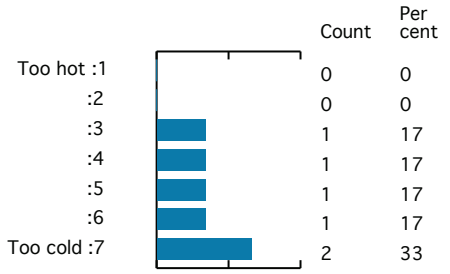
Score: 5.33

	L	Mean	U
Benchmark	4.13	4.42	4.71
Scale midpoint	3.71	4	4.29

	Study mean	Scale midpoint
Percentile	99	22

B | Twhot

Study mean: 5.33 | Study building percentile: 99 | Quintile: 5
Building code: 12481 | Benchmarks: BUS 2011 UK Housing benchmark
Web content © BUSMethodology 2012



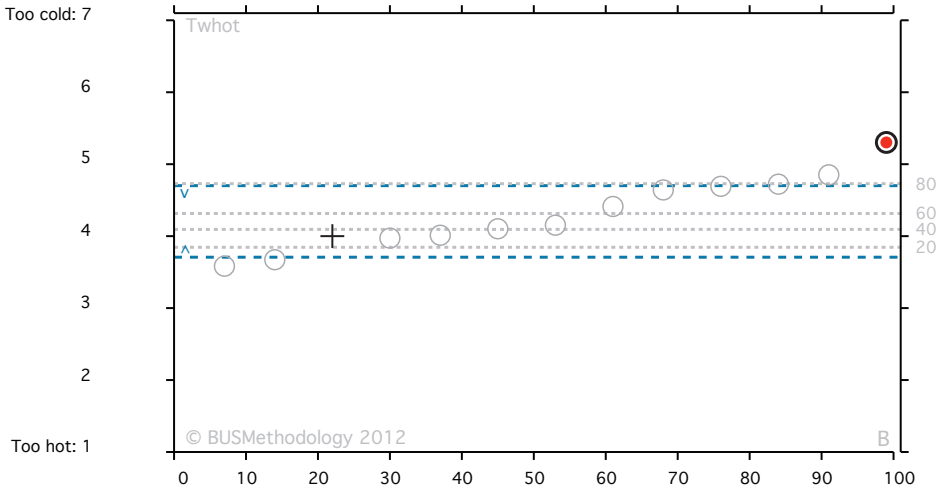


Figure 18/ Butcher Works BUS results; Temperature in winter. (Leaman, 2012)

Temperature in winter: overall

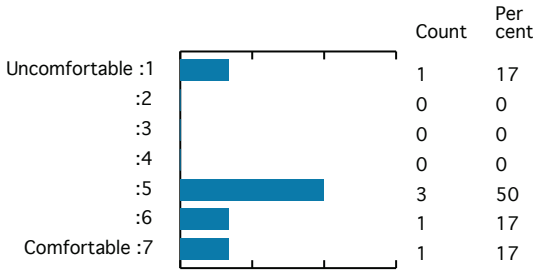
Score: 4.83

	L	Mean	U
Benchmark	4.88	5.19	5.5
Scale midpoint	3.69	4	4.31

	Study mean	Scale midpoint
Percentile	30	7

A | Twover

Study mean: 4.83 | Study building percentile: 30 | Quintile: 2
Building code: 12481 | Benchmarks: BUS 2011 UK Housing benchmark
Web content © BUSMethodology 2012



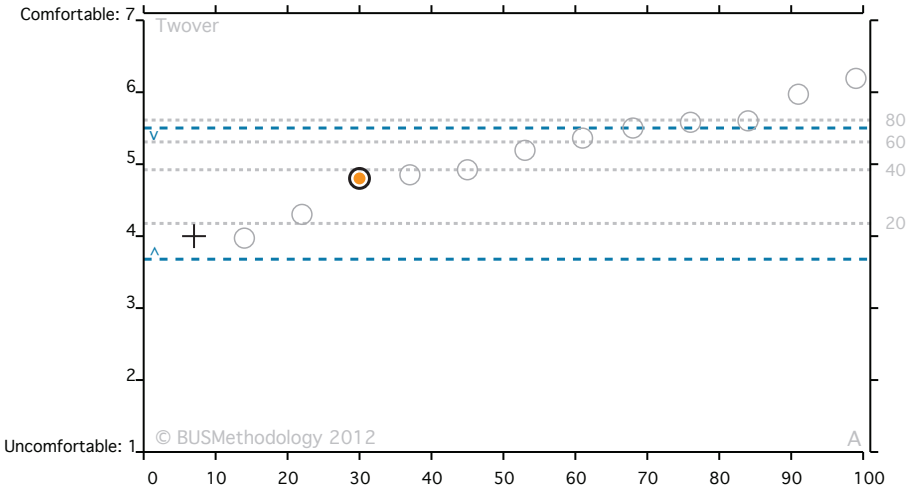


Figure 19/ Butcher Works BUS results; Overall temperature in winter. (Leaman, 2012)

Air in summer: overall

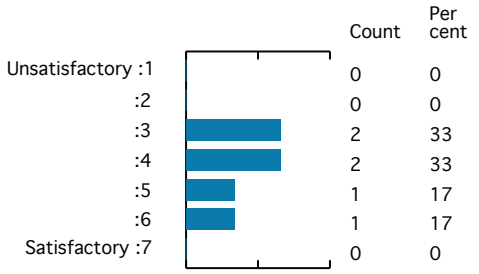
Score: 4.17

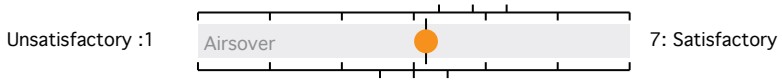
	L	Mean	U
Benchmark	4.35	4.82	5.29
Scale midpoint	3.53	4	4.47

	Study mean	Scale midpoint
Percentile	30	22

A I Airsover

Study mean: 4.17 I Study building percentile: 30 I Quintile: 2
Building code: 12481 I Benchmarks: BUS 2011 UK Housing benchmark
Web content © BUSMethodology 2012





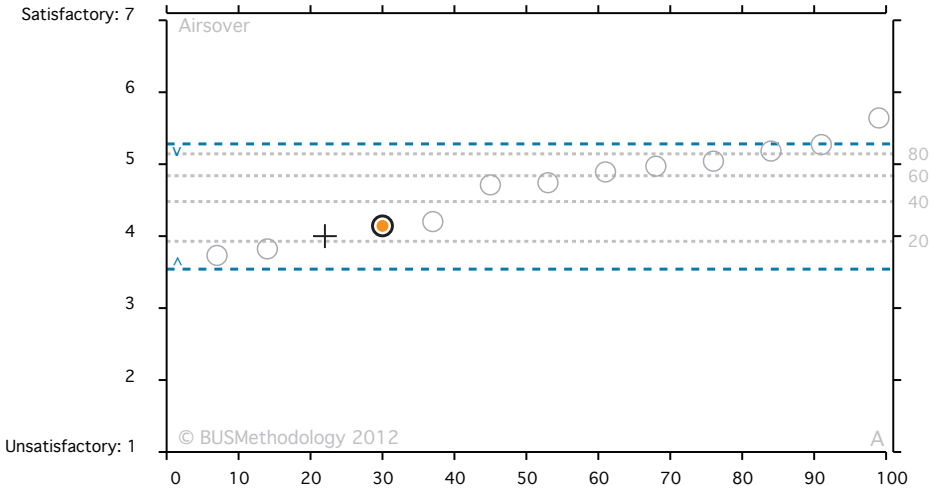


Figure 20/ Butcher Works BUS results; Air in summer overall. (Leaman, 2012)

Air in winter overall

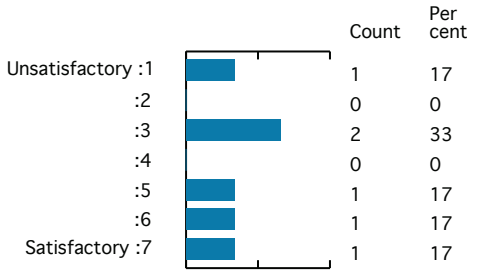
Score: 4.17

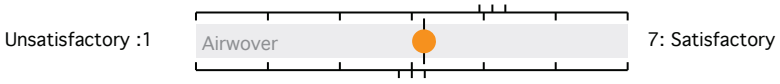
	L	Mean	U
Benchmark	4.94	5.12	5.3
Scale midpoint	3.82	4	4.18

	Study mean	Scale midpoint
Percentile	14	7

A | Airwover

Study mean: 4.17 | Study building percentile: 14 | Quintile: 1
Building code: 12481 | Benchmarks: BUS 2011 UK Housing benchmark
Web content © BUSMethodology 2012





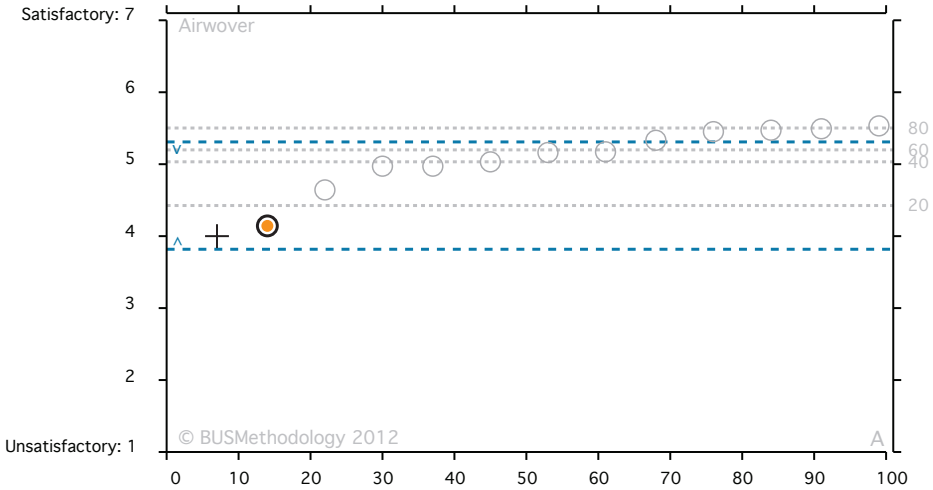


Figure 21/ Butcher Works BUS results; Air in winter overall. (Leaman, 2012)

Comfort: overall

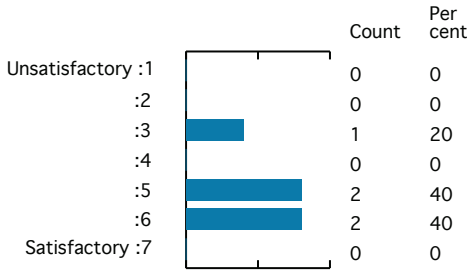
Score: 5

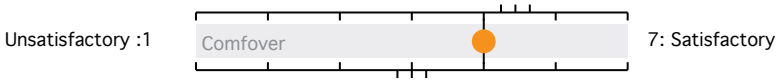
	L	Mean	U
Benchmark	5.24	5.44	5.64
Scale midpoint	3.8	4	4.2

	Study mean	Scale midpoint
Percentile	22	7

A I Comfover

Study mean: 5 I Study building percentile: 22 I Quintile: 1
Building code: 12481 I Benchmarks: BUS 2011 UK Housing benchmark
Web content © BUSMethodology 2012





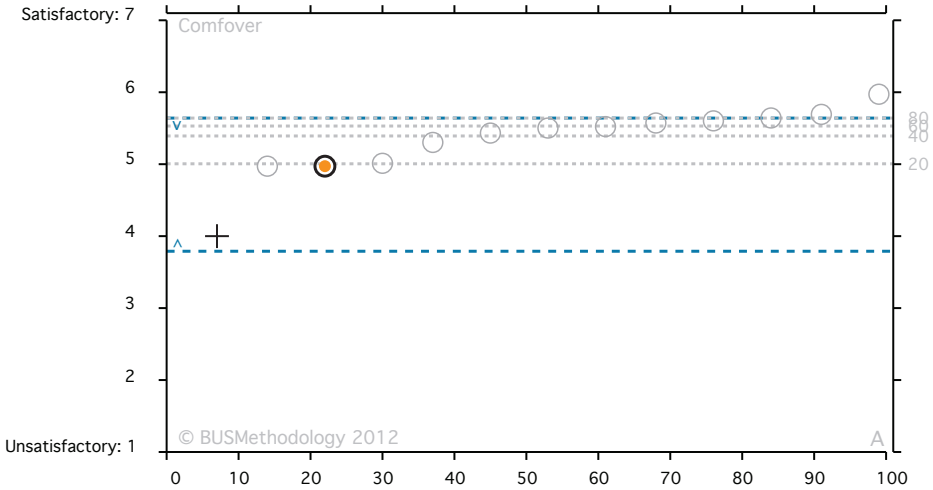


Figure 22/ Butcher Works BUS results; Comfort overall. (Leaman, 2012)

Lighting: natural light

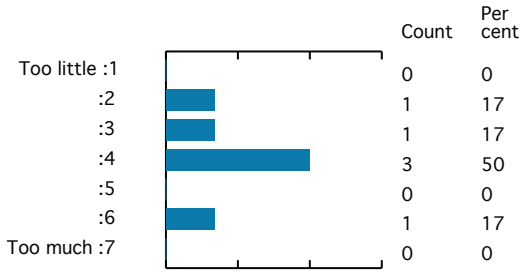
Score: 3.83

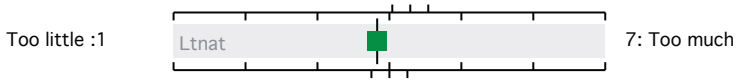
	L	Mean	U
Benchmark	4.04	4.29	4.54
Scale midpoint	3.75	4	4.25

	Study mean	Scale midpoint
Percentile	30	37

B | Ltnat

Study mean: 3.83 | Study building percentile: 30 | Quintile: 2
Building code: 12481 | Benchmarks: BUS 2011 UK Housing benchmark
Web content © BUSMethodology 2012





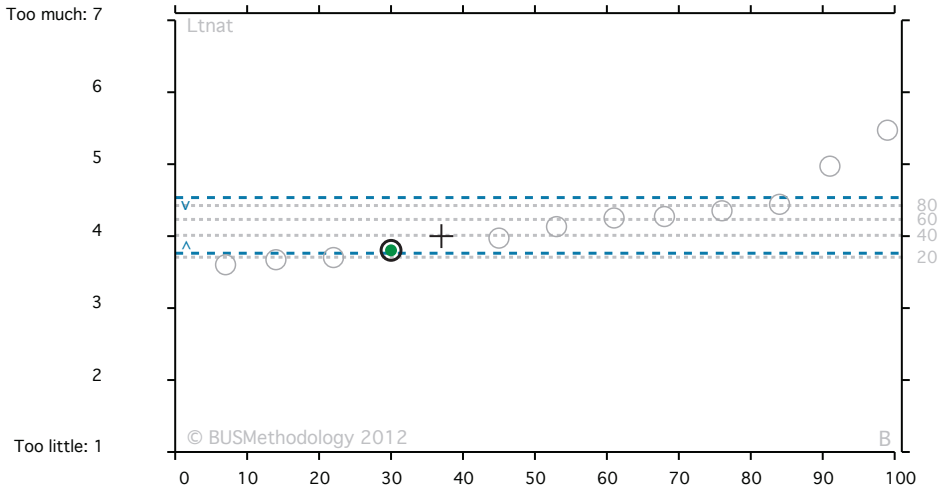
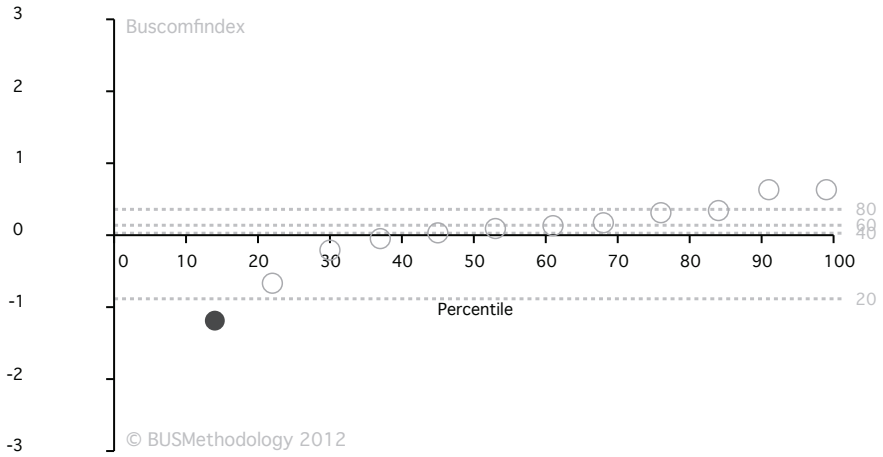


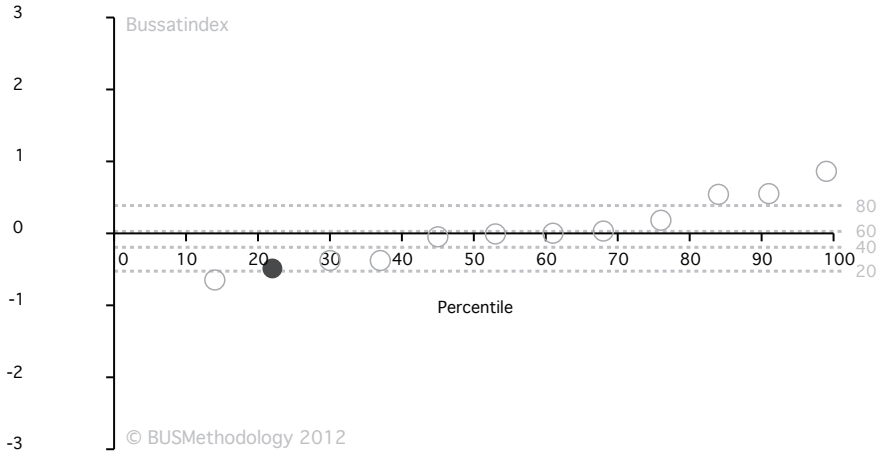
Figure 23/ Butcher Works BUS results; Natural Light. (Leaman, 2012)

BUS Comfort Index



Study mean: -1.17 | Study building percentile: 14 | Quintile: 1
Building code: 12481
Web content © BUSMethodology 2012

BUS Satisfaction Index



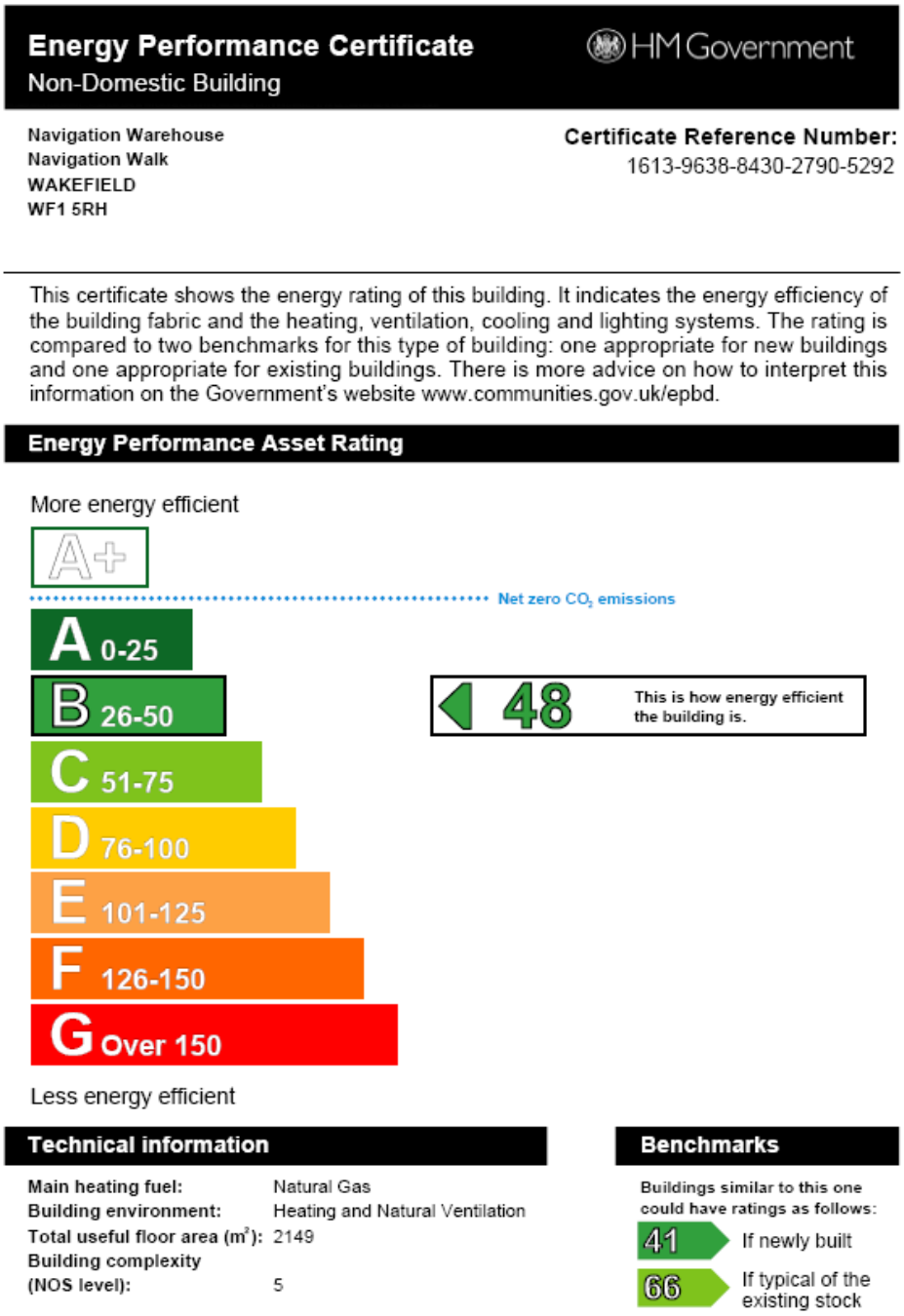
Study mean: -0.47 | Study building percentile: 22 | Quintile: 2
Building code: 12481
Web content © BUSMethodology 2012

Figure 24,25/ Butcher Works BUS results; Comfort index and satisfaction index. (Leaman, 2012)

3. C&H Navigation Warehouse

Table No.3	
Project	**Calder and Hebble Navigation Warehouse**
Practice	BDP
Developer	St James Securities and CTP Ltd joint venture
Owner	Wakefield Council and British Waterways- landowners CTP Ltd-current owner
Location	Wakefield
Completion Date	2008
Type Number of Units	Mixed Use Fully serviced office and A3
Costs	
Funding	Property finance company Investment finance Heritage Lottery Fund European Regional Development Fund English Partnerships Environmental bodies
Floor area	2000m2
Rating	EPC (Energy Performance Certificate): B
Awards	RIBA Award 2010 Civic Trust Commendation 2010 RICS Regional Award 2010 Wakefield Civic Society special award 2009 Manchester Society of Architects Award 2009 Georgian Group Award 20009
Contact	CTP +44 (0) 161 236 3223 dtopham@ctpltd.co.uk BDP +44 [0]161 828 2200 alan.davies@bdp.com

Table 26/ Calder & Hebble Table Resume. Autors own, 2012, based upon (Perks, 2012, Davies, 2012, Princes Regeneration, 2010, BDP, 2012))



Energy Performance Certificate
Non-Domestic Building

HM Government

Navigation Warehouse
Navigation Walk
WAKEFIELD
WF1 5RH

Certificate Reference Number:
1613-9638-8430-2790-5292

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

Energy Performance Asset Rating

More energy efficient

A+

Net zero CO_2 emissions

A 0-25

B 26-50

C 51-75

D 76-100

E 101-125

F 126-150

G Over 150

48 This is how energy efficient the building is.

Less energy efficient

Technical information

Main heating fuel:	Natural Gas
Building environment:	Heating and Natural Ventilation
Total useful floor area (m^2):	2149
Building complexity (NOS level):	5

Benchmarks

Buildings similar to this one could have ratings as follows:

41 If newly built

66 If typical of the existing stock

Figure 27/ C&H Navigation Warehouse Energy Performance Certificate. (Perks, 2012)

Temperature in summer: hot/cold

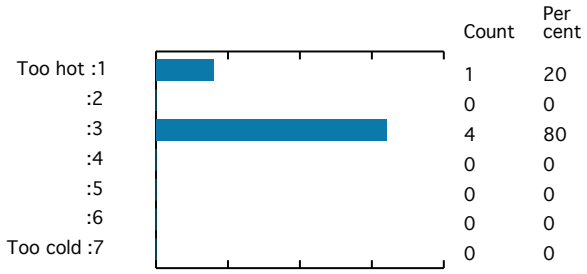
Score: 2.6

	L	Mean	U
Benchmark	2.93	3.09	3.25
Scale midpoint	3.84	4	4.16

	Study mean	Scale midpoint
Percentile	21	95

B | Tshot

Study mean: 2.6 | Study building percentile: 21 | Quintile: 2
Building code: 12483 | Benchmarks: BUS 2011 UK benchmark
Web content © BUSMethodology 2012



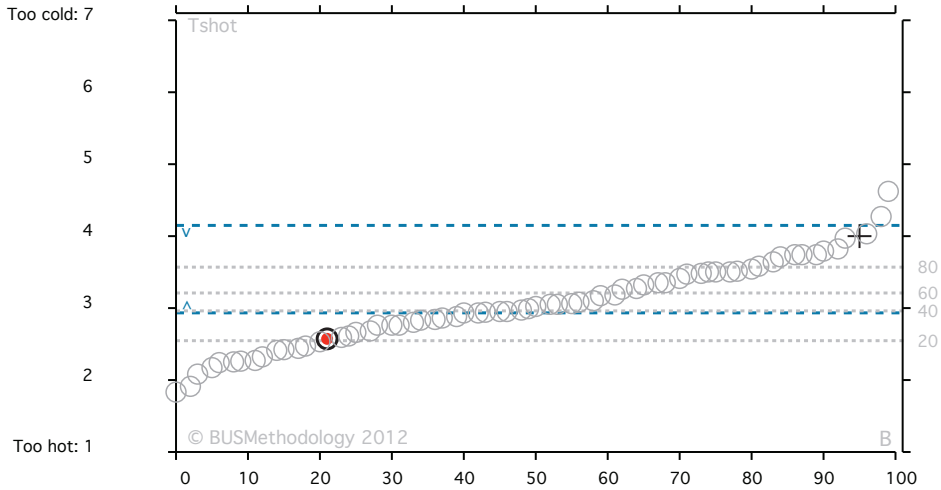


Figure 28/ C&H Navigation Warehouse BUS results; Temperature in summer. (Leaman, 2012)

Temperature in summer: overall

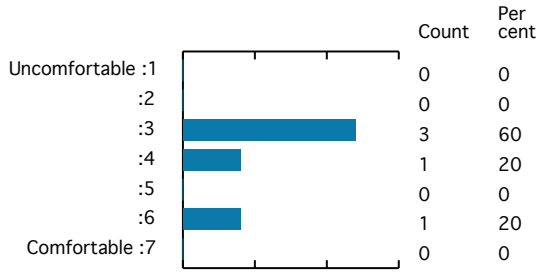
Score: 3.8

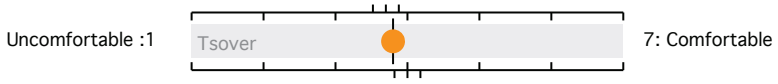
	L	Mean	U
Benchmark	3.52	3.7	3.88
Scale midpoint	3.82	4	4.18

	Study mean	Scale midpoint
Percentile	53	59

A | Tsover

Study mean: 3.8 | Study building percentile: 53 | Quintile: 3
Building code: 12483 | Benchmarks: BUS 2011 UK benchmark
Web content © BUSMethodology 2012





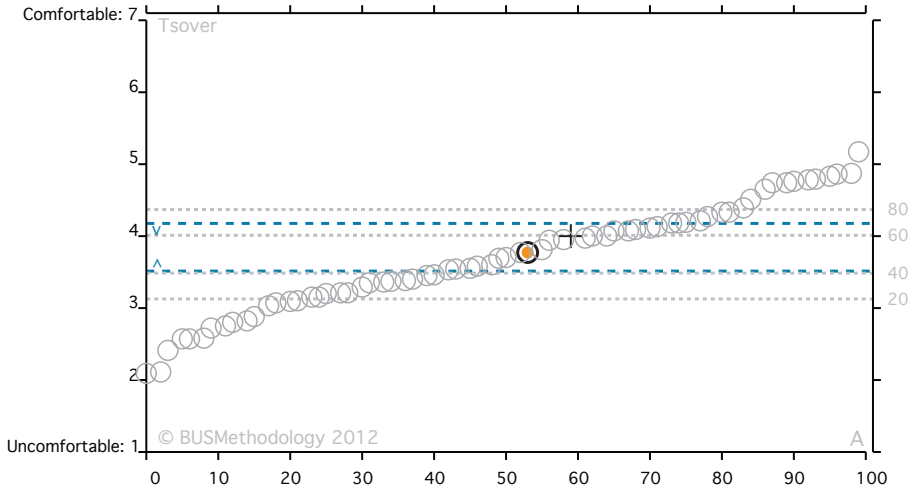


Figure 29/ C&H Navigation Warehouse BUS results; Temperature in summer overall. (Leaman, 2012)

Temperature in winter: hot/cold

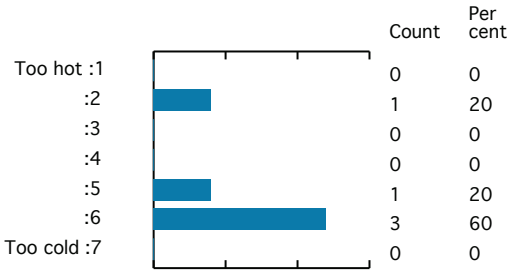
Score: 5

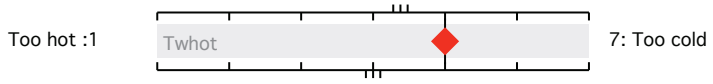
	L	Mean	U
Benchmark	4.28	4.38	4.48
Scale midpoint	3.9	4	4.1

	Study mean	Scale midpoint
Percentile	96	8

B | Twhot

Study mean: 5 | Study building percentile: 96 | Quintile: 5
Building code: 12483 | Benchmarks: BUS 2011 UK benchmark
Web content © BUSMethodology 2012





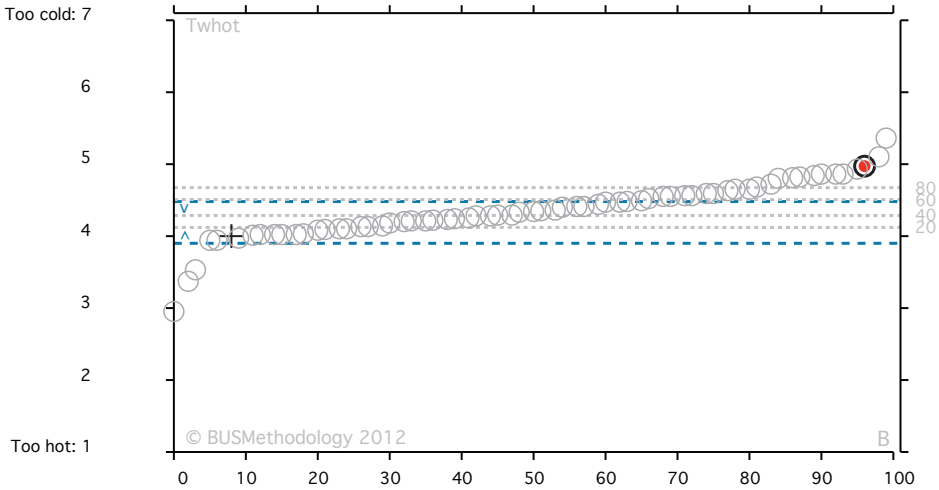


Figure 30/ C&H Navigation Warehouse BUS results; Temperature in winter. (Leaman, 2012)

Temperature in winter: overall

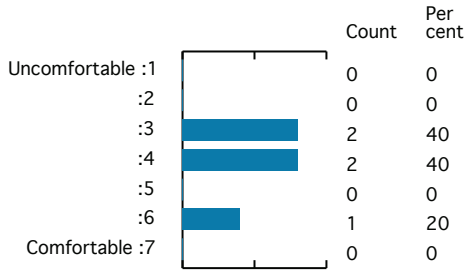
Score: 4

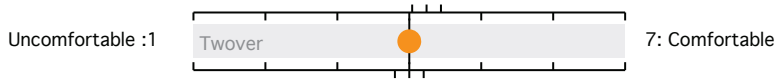
	L	Mean	U
Benchmark	4.04	4.24	4.44
Scale midpoint	3.8	4	4.2

	Study mean	Scale midpoint
Percentile	42	39

A | Twover

Study mean: 4 | Study building percentile: 42 | Quintile: 2
Building code: 12483 | Benchmarks: BUS 2011 UK benchmark
Web content © BUSMethodology 2012





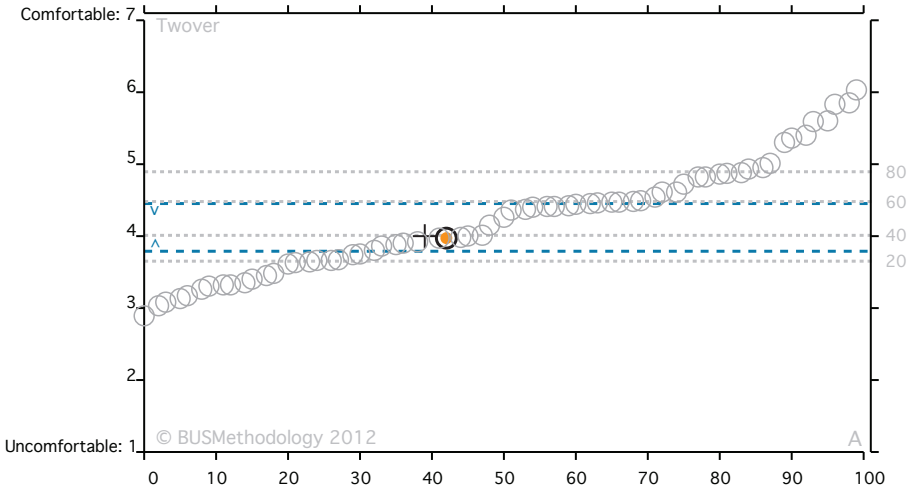


Figure 31/ C&H Navigation Warehouse BUS results; Temperature in winter overall. (Leaman, 2012)

Air in summer: overall

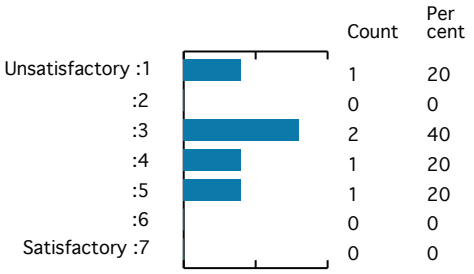
Score: 3.2

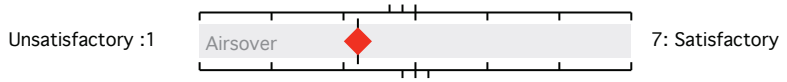
	L	Mean	U
Benchmark	3.64	3.82	4
Scale midpoint	3.82	4	4.18

	Study mean	Scale midpoint
Percentile	17	55

A | Airsover

Study mean: 3.2 | Study building percentile: 17 | Quintile: 1
Building code: 12483 | Benchmarks: BUS 2011 UK benchmark
Web content © BUSMethodology 2012





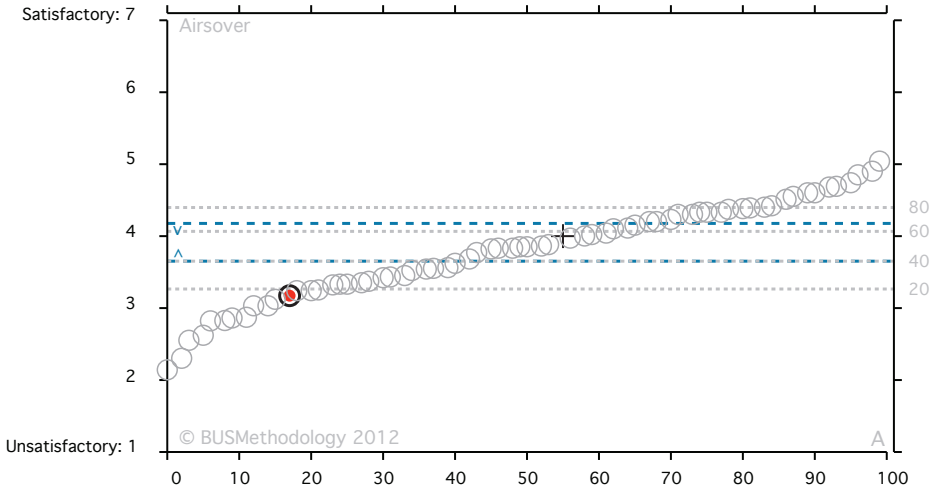


Figure 32/ C&H Navigation Warehouse BUS results; Air in summer. (Leaman, 2012)

Air in winter overall

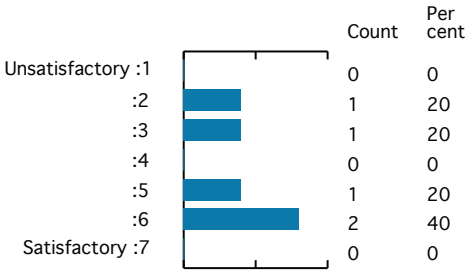
Score: 4.4

	L	Mean	U
Benchmark	3.97	4.15	4.33
Scale midpoint	3.82	4	4.18

	Study mean	Scale midpoint
Percentile	57	44

A | Airwover

Study mean: 4.4 | Study building percentile: 57 | Quintile: 3
Building code: 12483 | Benchmarks: BUS 2011 UK benchmark
Web content © BUSMethodology 2012



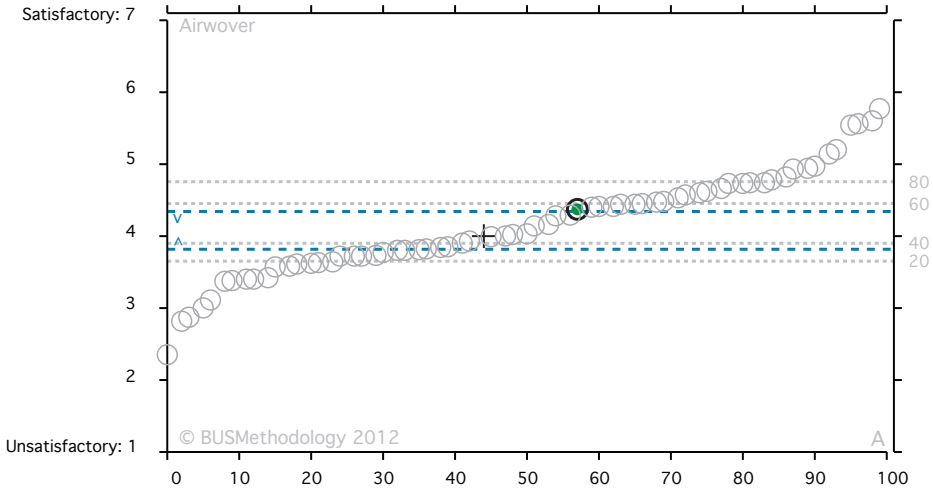


Figure 33/ C&H Navigation Warehouse BUS results; Air in winter. (Leaman, 2012)

Lighting: natural light

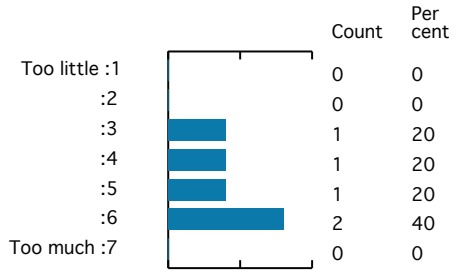
Score: 4.8

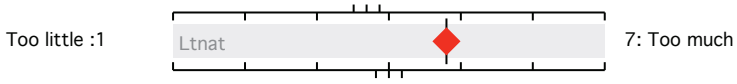
	L	Mean	U
Benchmark	3.51	3.69	3.87
Scale midpoint	3.82	4	4.18

	Study mean	Scale midpoint
Percentile	96	62

B | Ltnat

Study mean: 4.8 | Study building percentile: 96 | Quintile: 5
Building code: 12483 | Benchmarks: BUS 2011 UK benchmark
Web content © BUSMethodology 2012





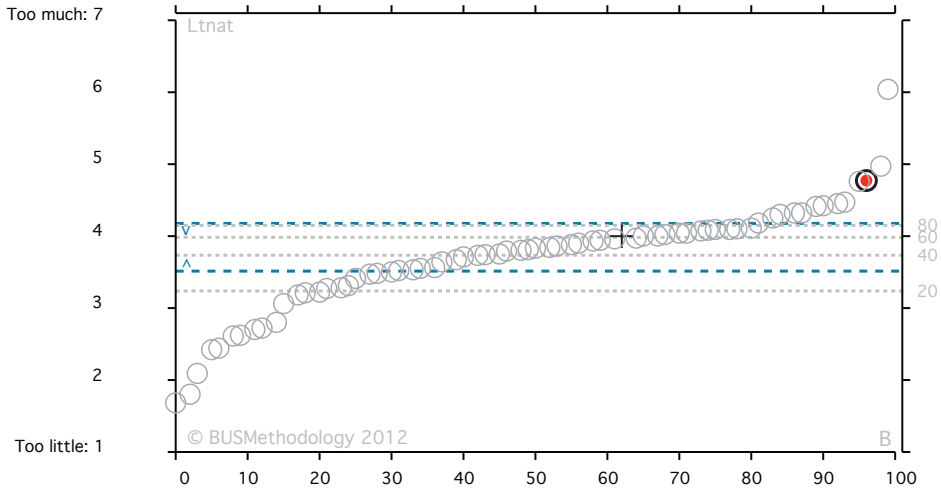


Figure 34/ C&H Navigation Warehouse BUS results; Natural Light. (Leaman, 2012)

Do facilities meet needs?

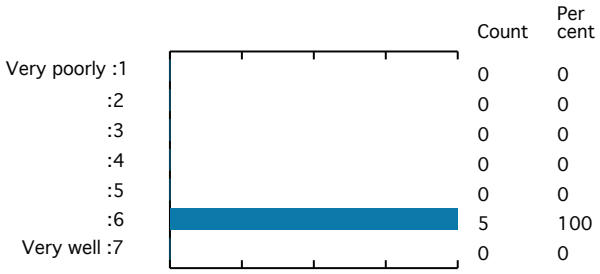
Score: 6

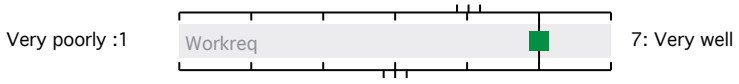
	L	Mean	U
Benchmark	4.86	5.02	5.18
Scale midpoint	3.84	4	4.16

	Study mean	Scale midpoint
Percentile	95	6

A | Workreq

Study mean: 6 | Study building percentile: 95 | Quintile: 5
Building code: 12483 | Benchmarks: BUS 2011 UK benchmark
Web content © BUSMethodology 2012





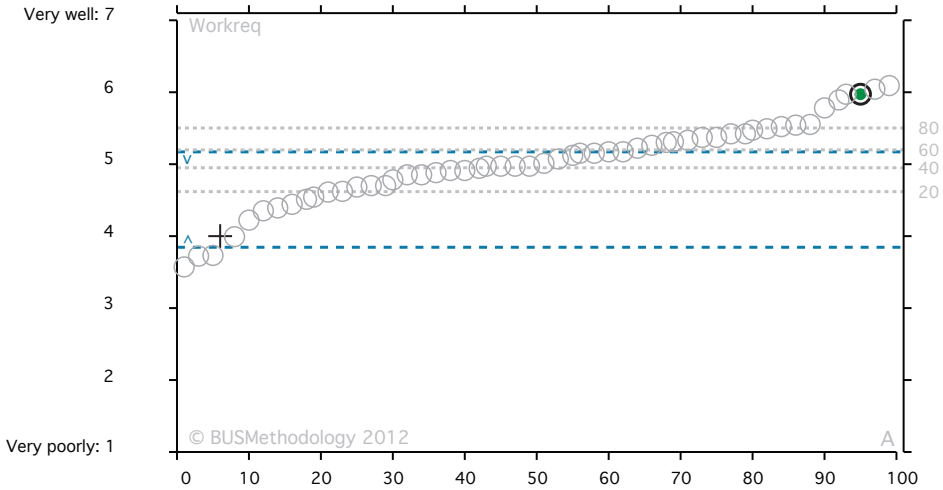
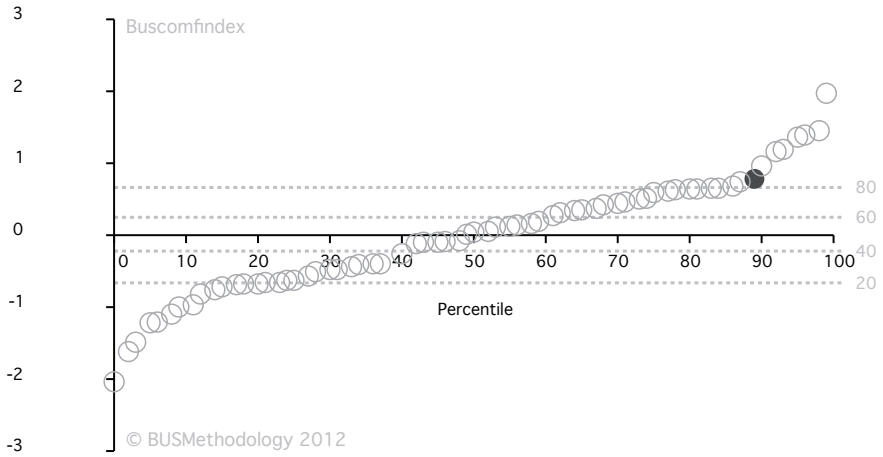


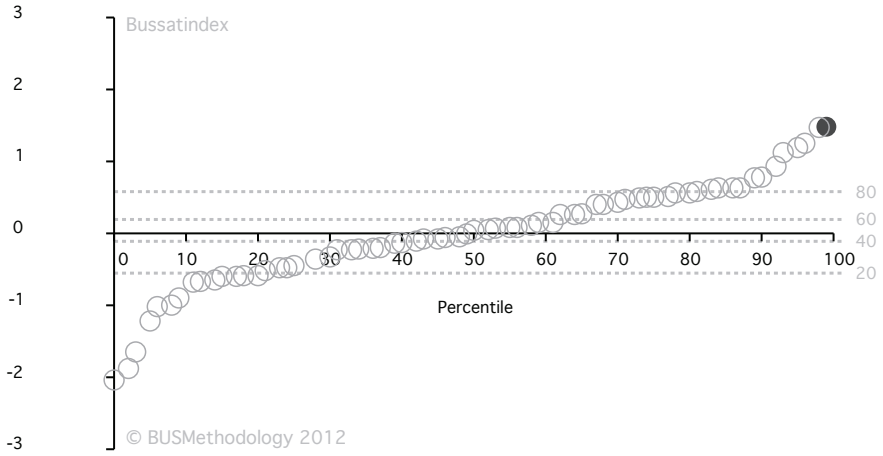
Figure 35/ C&H Navigation Warehouse BUS results; Needs. (Leaman, 2012)

BUS Comfort Index



Study mean: 0.8100000000000001 | Study building percentile: 89 | Quintile: 5
Building code: 12483
Web content © BUSMethodology 2012

BUS Satisfaction Index



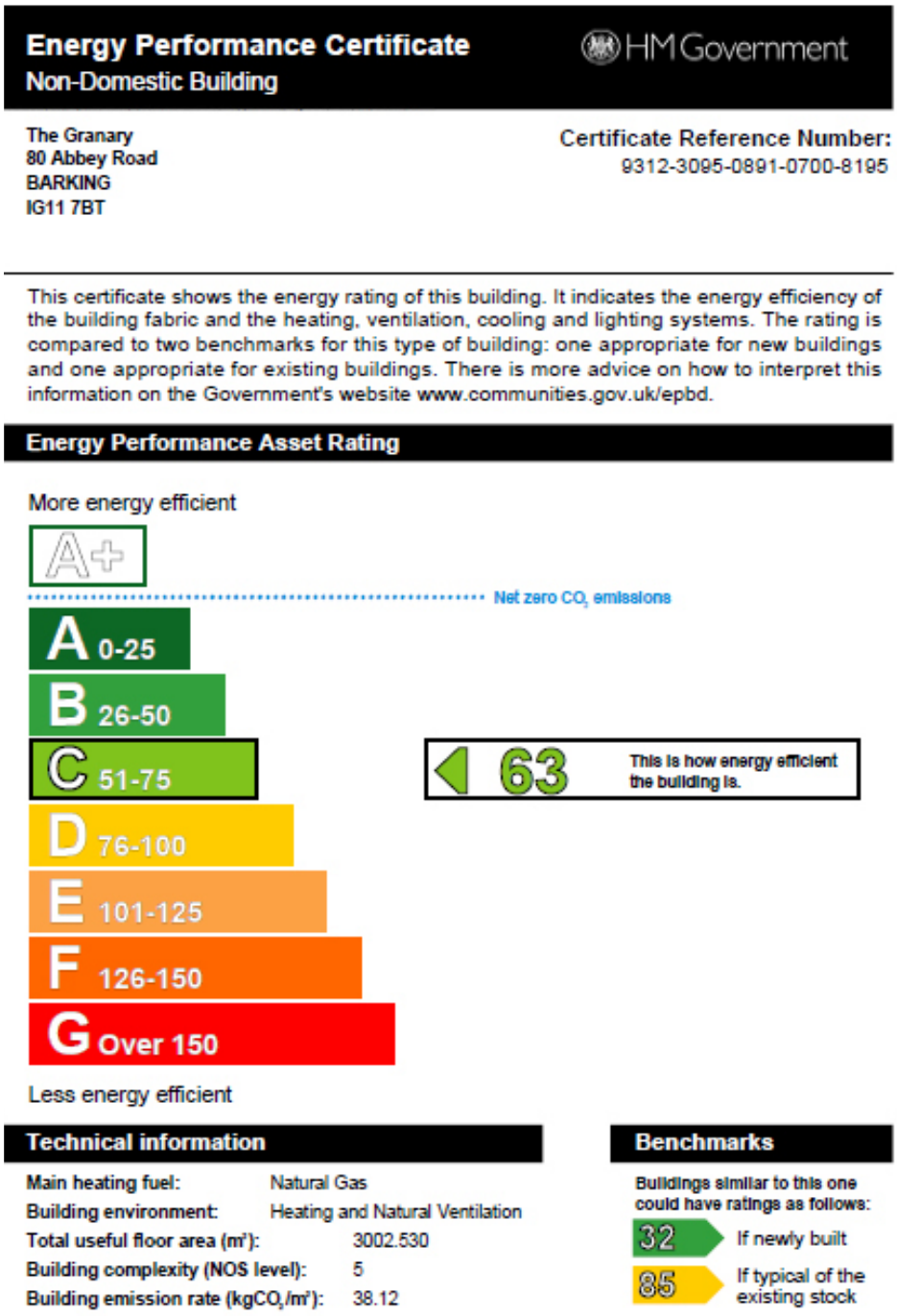
Study mean: 1.51 | Study building percentile: 99 | Quintile: 5
Building code: 12483
Web content © BUSMethodology 2012

Figure 36,37/ C&H Navigation Warehouse BUS results; Comfort index and satisfaction index. (Leaman, 2012)

4 The Granary

Table No.4	
Project	**The Granary**
Practice	PTE architects
Developer	Rooff Ltd
Owner	London Thames Gateway Development-landowners- Rooff Ltd- current owners-
Location	London (Barking) [IG11 7BT]
Completion Date	2011
Type Number of Units	Mixed use Rooff HQ, creative and commercial space
Costs	£3.3million
Funding	-
Floor area	2981m2
Rating	EPC (Energy Performance Certificate): B
Awards	New London Awards 2012: Offices Civic Trust Award 2012 World Architecture News: Commercial Awards 2011
Contact	PTE +44 (0) 20 7336 7777 mail@ptea.co.uk Rooff +44 [0] 20 8709 1777 enquiries@rooff.co.uk

Table 38/ The Granary Table Resume. Authors own, 2012, based upon (Jones,2012, Macarthur, 2012, PTEa, 2012, Glenny, 2012, Cooperconcept.org, 2012).



Energy Performance Certificate
Non-Domestic Building

HM Government

The Granary
80 Abbey Road
BARKING
IG11 7BT

Certificate Reference Number:
9312-3095-0891-0700-8195

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

Energy Performance Asset Rating

More energy efficient

A+

Net zero CO_2 emissions

A 0-25

B 26-50

C 51-75

D 76-100

E 101-125

F 126-150

G Over 150

63 This is how energy efficient the building is.

Less energy efficient

Technical information

Main heating fuel:	Natural Gas
Building environment:	Heating and Natural Ventilation
Total useful floor area (m^2):	3002.530
Building complexity (NOS level):	5
Building emission rate ($kgCO_2/m^2$):	38.12

Benchmarks

Buildings similar to this one could have ratings as follows:

32 If newly built

85 If typical of the existing stock

Figure 39/ The Granary Energy Performance Certificate. (Jones,2012)

Temperature in summer: hot/cold

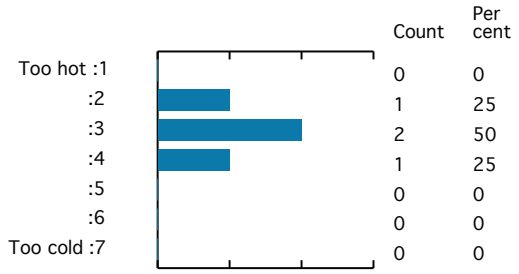
Score: 3

	L	Mean	U
Benchmark	2.93	3.09	3.25
Scale midpoint	3.84	4	4.16

	Study mean	Scale midpoint
Percentile	48	95

B | Tshot

Study mean: 3 | Study building percentile: 48 | Quintile: 3
Building code: 12484 | Benchmarks: BUS 2011 UK benchmark
Web content © BUSMethodology 2012



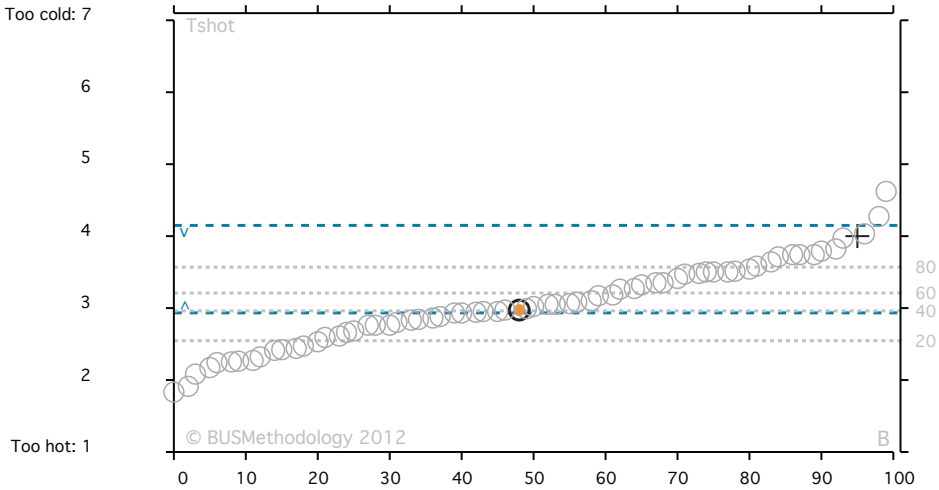


Figure 40/ The Granary BUS results; Temperature in summer. (Leaman, 2012)

Temperature in summer: overall

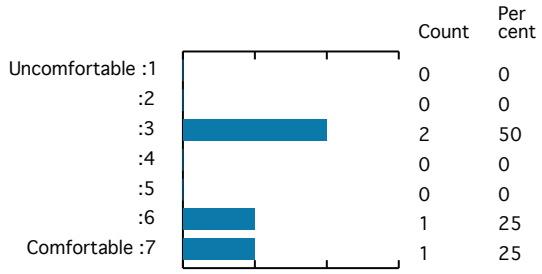
Score: 4.75

	L	Mean	U
Benchmark	3.52	3.7	3.88
Scale midpoint	3.82	4	4.18

	Study mean	Scale midpoint
Percentile	86	58

A | Tsover

Study mean: 4.75 | Study building percentile: 86 | Quintile: 5
Building code: 12484 | Benchmarks: BUS 2011 UK benchmark
Web content © BUSMethodology 2012



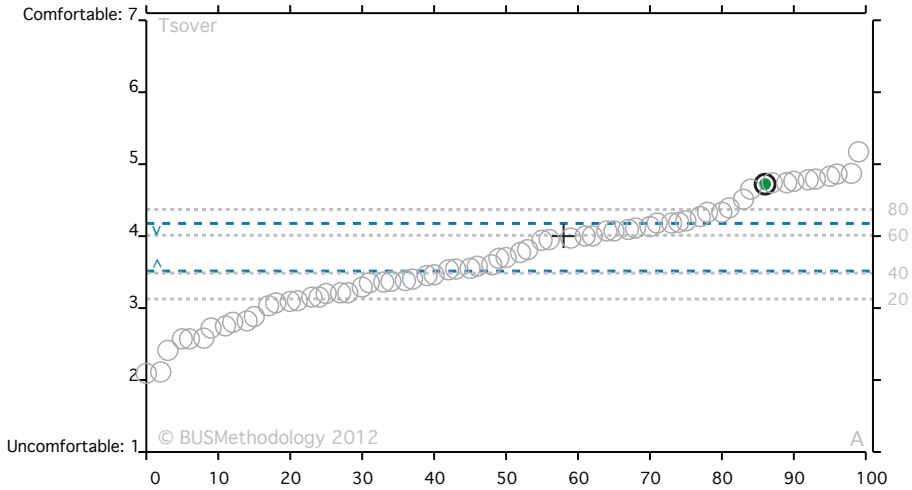


Figure 41/ The Granary BUS results; Temperature in summer overall. (Leaman, 2012)

Temperature in winter: hot/cold

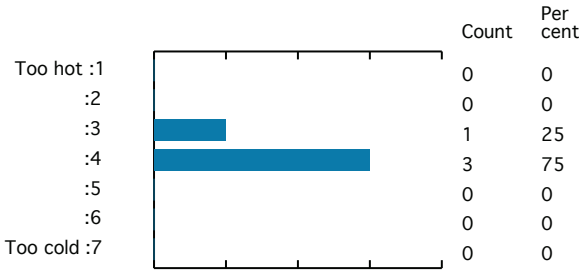
Score: 3.75

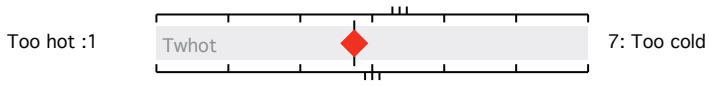
	L	Mean	U
Benchmark	4.28	4.38	4.48
Scale midpoint	3.9	4	4.1

	Study mean	Scale midpoint
Percentile	5	9

B | Twhot

Study mean: 3.75 | Study building percentile: 5 | Quintile: 1
Building code: 12484 | Benchmarks: BUS 2011 UK benchmark
Web content © BUSMethodology 2012





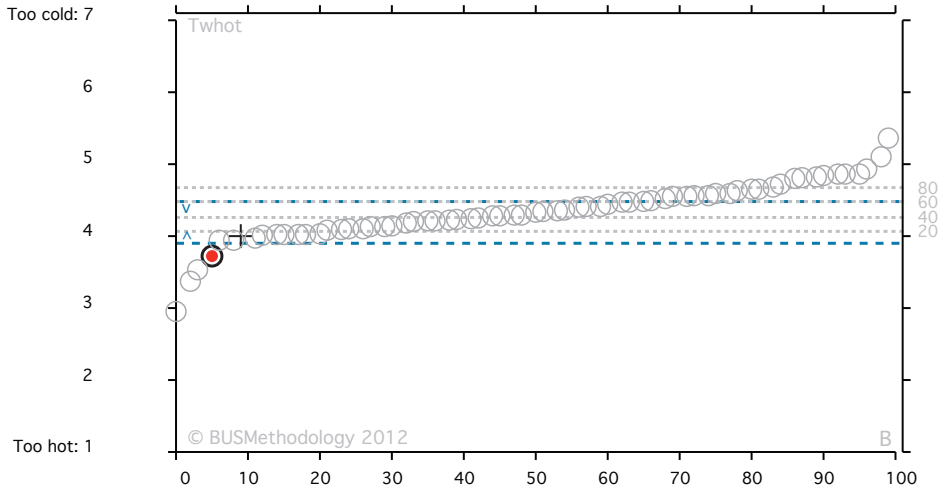


Figure 42/ The Granary BUS results; Temperature in winter. (Leaman, 2012)

Temperature in winter: overall

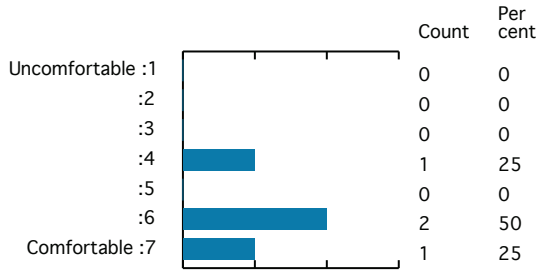
Score: 5.75

	L	Mean	U
Benchmark	4.04	4.24	4.44
Scale midpoint	3.8	4	4.2

	Study mean	Scale midpoint
Percentile	95	39

A | Twover

Study mean: 5.75 | Study building percentile: 95 | Quintile: 5
Building code: 12484 | Benchmarks: BUS 2011 UK benchmark
Web content © BUSMethodology 2012



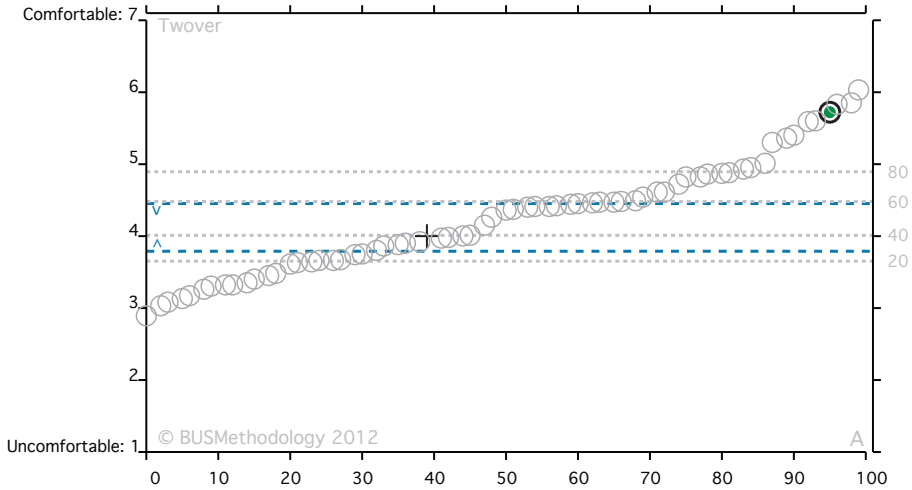


Figure 43/ The Granary BUS results; Temperature in winter overall. (Leaman, 2012)

Air in summer: overall

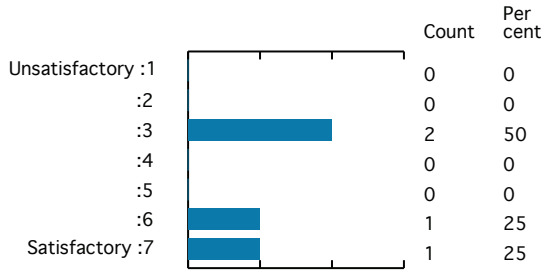
Score: 4.75

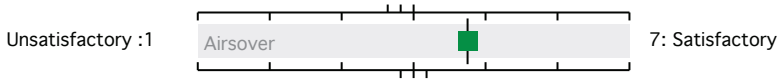
	L	Mean	U
Benchmark	3.64	3.82	4
Scale midpoint	3.82	4	4.18

	Study mean	Scale midpoint
Percentile	93	53

A I Airsover

Study mean: 4.75 I Study building percentile: 93 I Quintile: 5
Building code: 12484 I Benchmarks: BUS 2011 UK benchmark
Web content © BUSMethodology 2012





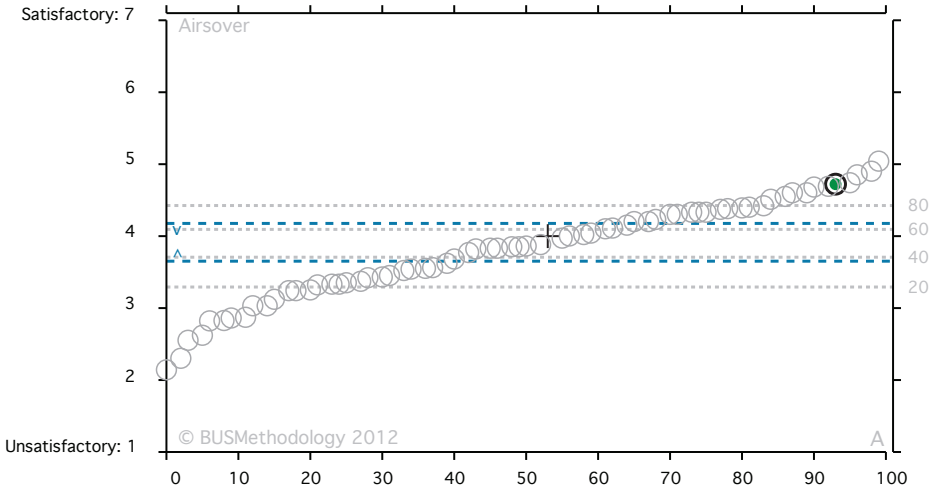


Figure 44/ The Granary BUS results; Air in summer. (Leaman, 2012)

Air in winter overall

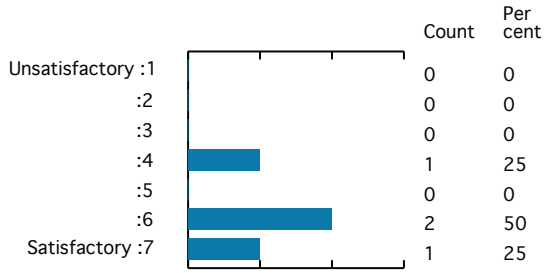
Score: 5.75

	L	Mean	U
Benchmark	3.97	4.15	4.33
Scale midpoint	3.82	4	4.18

	Study mean	Scale midpoint
Percentile	98	44

A | Airwover

Study mean: 5.75 | Study building percentile: 98 | Quintile: 5
Building code: 12484 | Benchmarks: BUS 2011 UK benchmark
Web content © BUSMethodology 2012



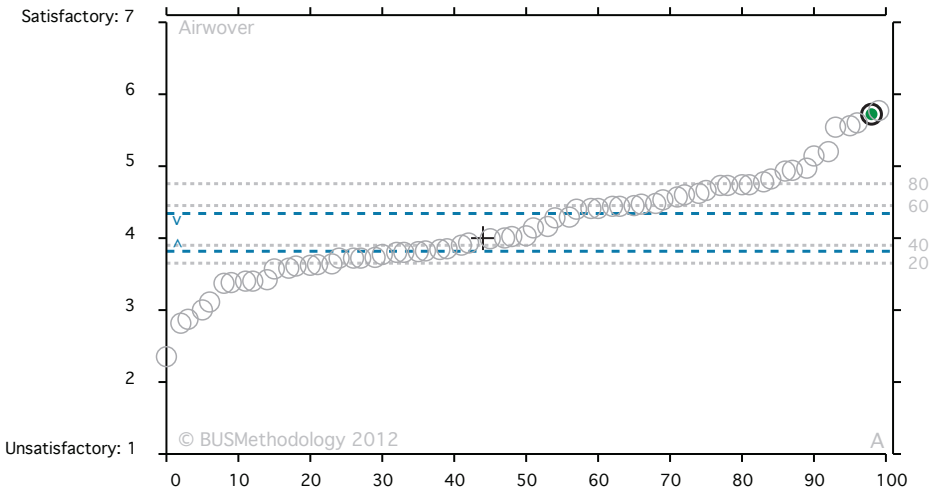


Figure 45/ The Granary BUS results; Air in winter. (Leaman, 2012)

Comfort: overall

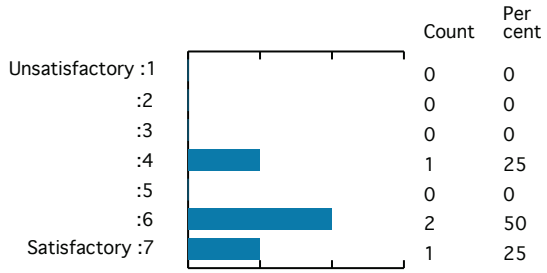
Score: 5.75

	L	Mean	U
Benchmark	4.31	4.51	4.71
Scale midpoint	3.8	4	4.2

	Study mean	Scale midpoint
Percentile	95	20

A I Comfover

Study mean: 5.75 I Study building percentile: 95 I Quintile: 5
Building code: 12484 I Benchmarks: BUS 2011 UK benchmark
Web content © BUSMethodology 2012



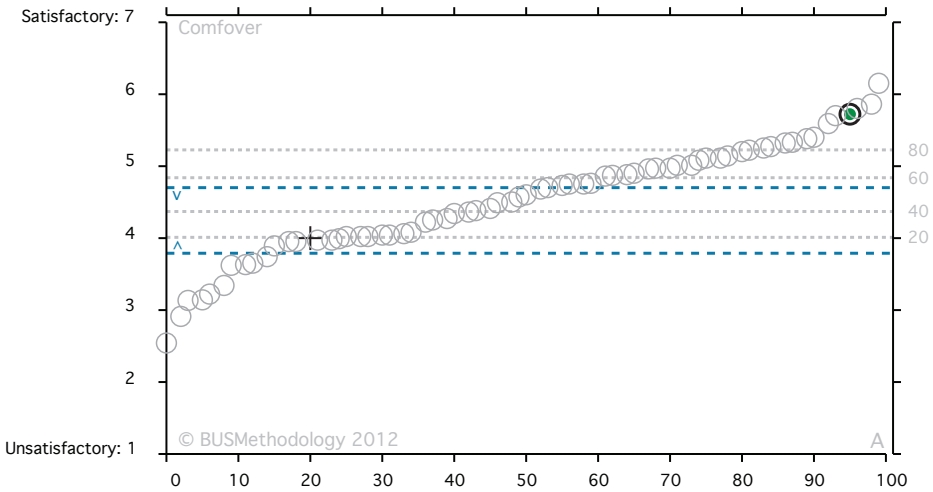


Figure 46/ The Granary BUS results; Comfort overall. (Leaman, 2012)

Lighting: natural light

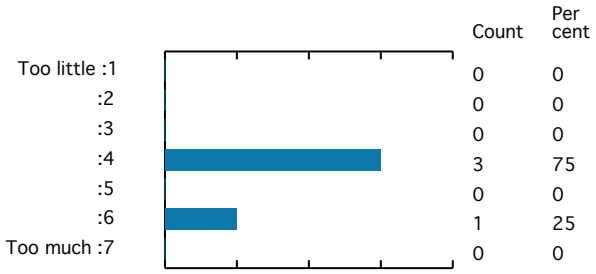
Score: 4.5

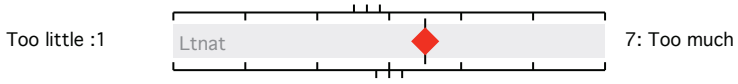
	L	Mean	U
Benchmark	3.51	3.69	3.87
Scale midpoint	3.82	4	4.18

	Study mean	Scale midpoint
Percentile	95	62

B | Ltnat

Study mean: 4.5 | Study building percentile: 95 | Quintile: 5
Building code: 12484 | Benchmarks: BUS 2011 UK benchmark
Web content © BUSMethodology 2012





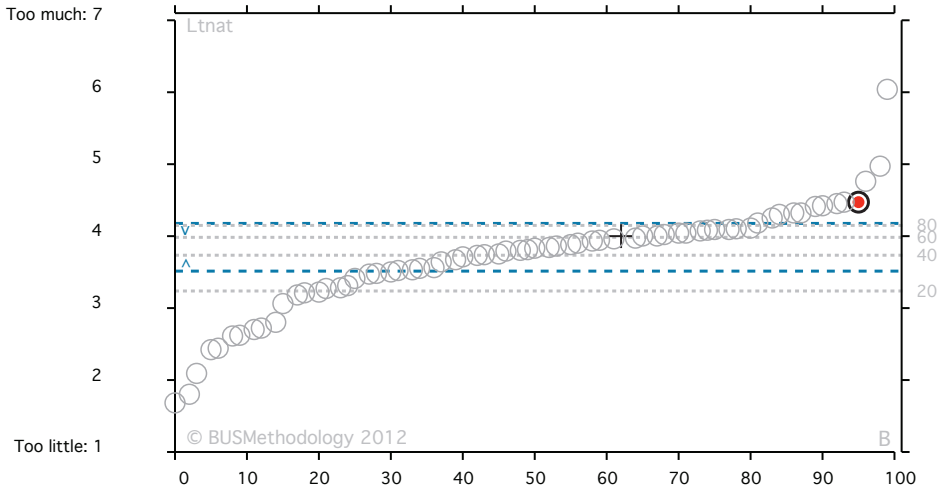


Figure 47/ The Granary BUS results; Natural light. (Leaman, 2012)

Do facilities meet needs?

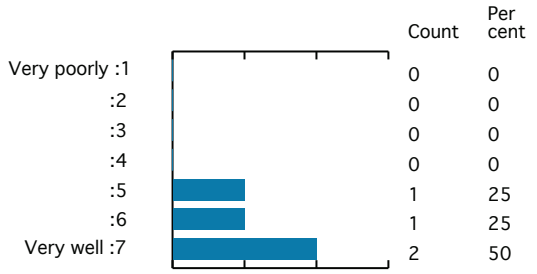
Score: 6.25

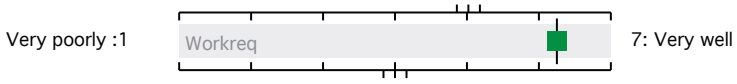
	L	Mean	U
Benchmark	4.86	5.02	5.18
Scale midpoint	3.84	4	4.16

	Study mean	Scale midpoint
Percentile	99	6

A | Workreq

Study mean: 6.25 | Study building percentile: 99 | Quintile: 5
Building code: 12484 | Benchmarks: BUS 2011 UK benchmark
Web content © BUSMethodology 2012





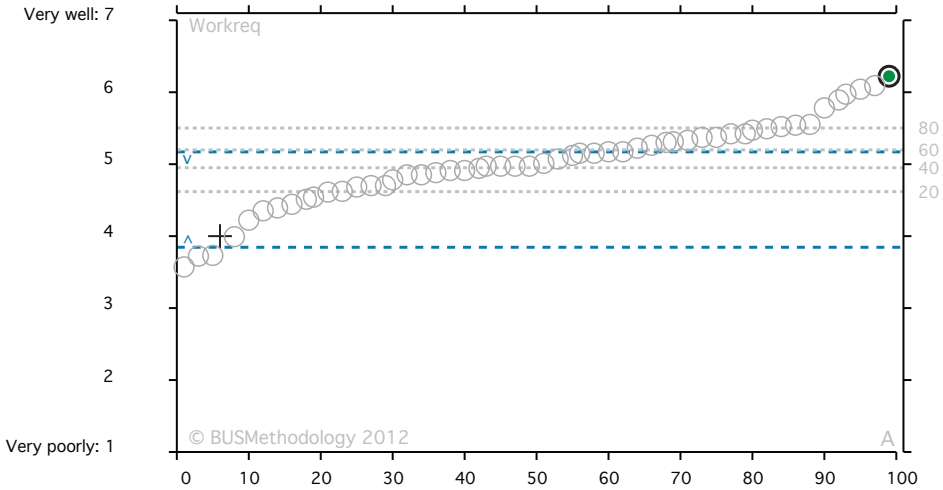
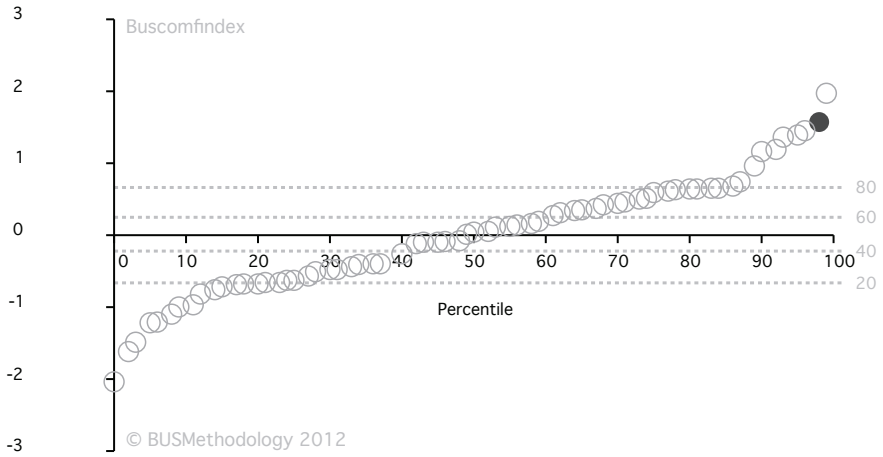


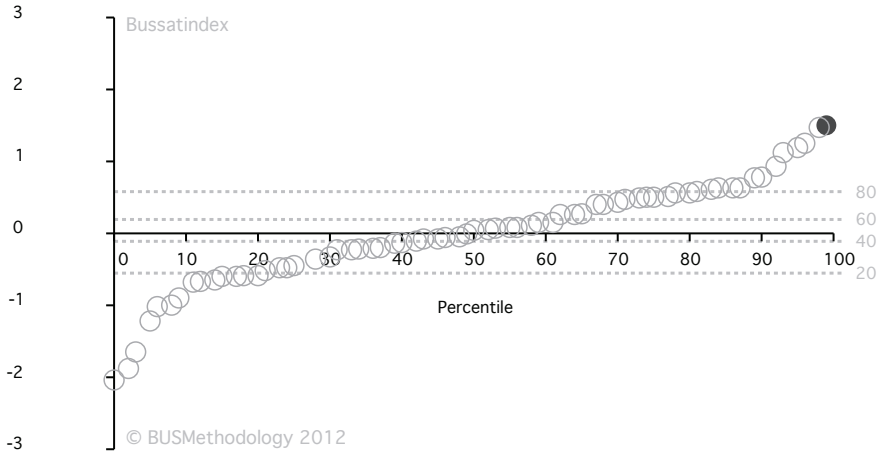
Figure 48/ The Granary BUS results; Needs. (Leaman, 2012)

BUS Comfort Index



Study mean: 1.6 | Study building percentile: 98 | Quintile: 5
Building code: 12484
Web content © BUSMethodology 2012

BUS Satisfaction Index



Study mean: 1.53 | Study building percentile: 99 | Quintile: 5
Building code: 12484
Web content © BUSMethodology 2012

Figure 49,50/ The Granary BUS results; Comfort index and satisfaction index. (Leaman, 2012)

5. Ethics

The University Of Sheffield.

Invitation Letter

Research Project: **Energy balance in the adaptive reuse of historic urban industrial buildings**
Researcher: **Aldana Zabala**

Dear Mr/Ms,

I would like to invite you to take part in an interview as part of my research project. I am currently registered on the MSc. Sustainable Architecture Studies programme at The University of Sheffield. This work is for my Thesis Dissertation. The research focuses on the adaptive reuse of historic urban industrial buildings by analyzing the factors that affect the energy performance in use within the design process and how to address them in practice. The objectives are to identify the problem areas, convergences and divergences between different disciplines, evaluate the decision making process and the opportunities and barriers for the environmental approach, analyze the constraints that affect the environmental strategy, explore different strategies and processes in practice and finally evaluate and consider the impact and benefits of this practice.

The interview will be conducted by me at your convenience.

The enclosed sheet should provide you with all the information you need. In case you have any further questions please do not hesitate to contact me:

Aldana Zabala / Email: azabalapolla1@sheffield.ac.uk / Telephone: +0034 [0] 7500751378

Thank for you for your time and consideration, I hope you would like to take part in this research and look forward to hearing from you.

Yours sincerely

Aldana Zabala, Architect

Figure 51/ Participant invitation letter. Authors own, 2012.

The University Of Sheffield.

Participant Information Sheet

Research Project: **Energy balance in the adaptive reuse of historic urban industrial buildings**
Researcher: **Aldana Zabala**

You are being invited to take part in a research project. Before you decide if you want to be part of it, it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information and discuss it with others if you wish. Ask me if there is anything that is not clear or if you would like more information.

Project purpose

The research focuses on the adaptive reuse of historic urban industrial buildings by analyzing the role of the factors that affect the energy performance in use within the design process and how to address them in practice. The objectives are to identify the problem areas, convergences and divergences between different disciplines, evaluate the decision making process and the opportunities and barriers for the environmental approach, analyze the constrains that affect the environmental strategy, explore different strategies and processes in practice and finally evaluate and consider the impact and benefits of this practice.

Why have I been invited to participate?

The methodology addressed in this project is the case study research. The projects selected for this study have been chosen as exemplars and will be analysed. You have been selected for interview because of your key knowledge about the project which will add considerable understanding to the case study.

What will I have to do if I take part?

You will be asked to provide information about the project selected regarding the decision making during its completion, and to take part in a 30 minute interview in your office or by telephone at a time of mutual convenience.

What are the possible disadvantages and risks of taking part?

There are no foreseen disadvantages or risks in taking part. As your participation is voluntary, you are free to withdraw at any time without giving any reason and without there being any negative consequences. In addition, you are free to decline to answer any question that you do not feel comfortable with.

What are the possible benefits of taking part?

Whilst there are no immediate benefits for participants in the research, it is hoped that the knowledge gained will contribute to identify the key factors that affect the energy in use of the adaptive reuse of historic urban industrial buildings and how to address them in practice. It is also hoped that the study will be of some benefit to the participants in terms of providing recommendations for future best practice.

Figure 52/ Participant information sheet. Authors own, 2012.

What if something goes wrong?

If you are unhappy with the way you have been treated, or with anything that has happened during or following your participation, then please contact Professor Fionn Stevenson (Tel. 44 (0)114 222 0301 e-mail: f.stevenson@sheffield.ac.uk) who is leading the project. If you feel your complaint has not been dealt with satisfactorily then please contact the University's Registrar and Secretary (Tel. 0114 2221104).

What will happen with the results of the research project?

The results of this research will be part of my Postgraduate program's Dissertation in the School of Architecture of the University of Sheffield. The information provided will be used strictly for this purpose as a part of the case study research methodology used in this work. Any information given will not be published without your consent.

Who is supporting the research?

This research is being carried out within the School of Architecture at the University of Sheffield as part of the MSc Sustainable Architecture Studies postgraduate programme.

Who has ethically reviewed the project?

This project has been ethically approved via the School of Architecture's ethics review procedure. The University's Research Ethics Committee monitors the application and delivery of the University's Ethics Review Procedure across the University.

Further information

Dr. Fionn Stevenson
Professor of Sustainable Design

School of Architecture, University of Sheffield

The Arts Tower, Western Bank, Sheffield S10 2TN UK

E-mail: f.stevenson@sheffield.ac.uk Phone:++44 (0)114 222 0301

Figure 53/ Participant information sheet. Authors own, 2012.

The University Of Sheffield.

Participant Consent Form

Research Project: **Energy balance in the adaptive reuse of historic urban industrial buildings**
Researcher: **Aldana Zabala**

1. I confirm that I have read and understand the information sheet/letter dated _____ explaining the above research project and I have had the opportunity to ask questions about it. ☐
2. I understand that my participation is voluntary and that I am free to withdraw at any time without giving any reason and without there being any negative consequences. In addition, should I not wish to answer any particular question or questions, I am free to decline. ☐
3. I understand that my responses will be used strictly for the purpose of this research ☐
4. I agree for the data collected from me to be used in the research ☐
5. I consent to be interviewed ☐

Participant	Date	Signature
_____	_____	_____
Researcher	Date	Signature
_____	_____	_____

To be signed and dated in presence of the participant

Copies: Once this has been signed by all parties the participant should receive a copy of the signed and dated participant consent form, the letter/pre-written script/information sheet and any other written information provided to the participants. A copy of the signed and dated consent form should be placed in the project's main record (e.g. a site file), which must be kept in a secure location.

Figure 54/ Participant consent form. Authors own, 2012.