Sustainable Construction in Practice

Performance of Sustainable Buildings in Leeds

Consultancy Report

By

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Management Summary

The consultant carried out the study to ascertain the actual performance of case studies listed in Leeds City Council's Supplementary Planning Document (SPD) entitled *Building for Tomorrow Today* (2011). The case studies were selected basing on their cutting edge sustainability targets when being initiated. The case studies were at different stages when the SPD was published as such it was yet to be determined if the buildings live according to their expectation. The study also was commissioned to provide raw data on the sustainable buildings for the council's online database; the Leeds Datamill.

The consultant contacted developers and building occupiers, visited some of the buildings and conducted desk studies to get data for analysis. Important energy performance data was also used in the study and was sourced from the Department for Communities and Local Government's Domestic and Non-Domestic Energy Performance Register database. The comparison was a combination or one of the following two; the buildings' own targets against actual performance and performance of industry's conventional buildings and practices.

The study finds that the building envelope's energy performance is commendable and sustainable while the use of the buildings is seeing significant amounts of energy being used other than expected. There are buildings that targeted sustainability rating standards such as BREEAM and have achieved as planned with a few getting lower ratings than planned. This confirms the existence of performance gaps which the industry faces and is a threat for sustainable buildings implementation.

From the observations, the buildings are effectively adapting to climate change through the robust energy efficiency levels, design considerations for flood risk areas and low carbon energy technologies among many. It is therefore imperative that measures be put in place to encourage sustainable construction through planning frameworks, increased individual awareness towards sustainability and utilizing research institutions.

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List of Abbreviations

LCC	Leeds City Council
SPD	Supplementary Planning Document
BREEAM	Building Research Establishment Environmental Assessment Methodology
EPC	Energy Performance Certificate
DEC	Display Energy Certificate

1.0 Introduction

1.1. Background

Leeds City Council (LCC) published a Supplementary Planning Document (SPD) titled *Building for Tomorrow Today*[1] (2011). This was in line with the new England and Wales planning system (2008) that introduced the Local Development Frameworks[2]. The SPD intended to provide practical guidance for sustainable project design, construction as well as operation of buildings in Leeds. The expected result was that it will help the council attain highest possible levels of sustainability by achieving its social, economic and environmental goals. To facilitate the aspiration, the SPD incorporated a checklist for use on planning permission applications through which developers could demonstrate how their applications can foster the councils' policies and goals.

The SPD had specific objectives of supporting developers in initiating and implementing projects that:

a. Reduce greenhouse gas emissions
b. Successfully adapt to climate change
c. Have a minimal impact on overall environmental quality and
d. Provide inclusive development to all users and city residents

As a guideline, the SPD explained the Councils' goals and sustainable construction aspirations through a series of case studies. At the time of publishing, the case studies were at different stages, others completed and in use, others were under construction while others were at planning stages. The case studies were listed as an exemplar in one or more of the following aspects on concern: sustainability/environmental rating standards, site appraisal, energy use and CO_2 emissions, water, building materials, waste and pollution, health and wellbeing, management and ecology.

1.2. Project aims and objectives

[1] Available for download on http://www.leeds.gov.uk/council/Pages/Sustainable-design.aspx
[2] Local Development Frameworks gives spatial and strategic planning control to local councils (e.g. city and district) as opposed to county control. This enables the councils to formulate strategies which determine what type of development they would want to be implemented in their areas of jurisdiction.

On the premise that the case studies were at different stages when incorporated into the SPD, a follow up on how they perform in practice was deemed necessary. The study is therefore an attempt to update the case studies in the SPD to see where possible how the buildings have actually performed in reality. The assessment is based on initial projections at the planning stage to how the buildings have turned out (if built) hence determine if there are any performance gaps (de Wilde, 2014, Kibert, 2012).

Specific objectives of the study include:

a. Provide raw data on the case studies on the council's data mill[3]
b. Map the case studies
c. Assess the performance of the case studies
d. Identify challenges being faced in sustainable construction
e. Update individual case studies for publishing

1.3. Scope of report

The report starts with an introductory background as in 1.1 and 1.2 above. The report then progresses as follows; section 2 details the methodology used in obtaining data and its analysis, section 3 gives a description of the case studies listed in the SPD and provides their locations. Then the findings of the study and subsequent discussions are provided in section 4.0. Section 5 relates the findings to climate change and section 6 identifies the experiences and challenges being faced in the sustainable construction sphere before recommendations and concluding remarks 7.0.

[3] The Leeds data mill is database of raw data run by the council and can be accessed from http://www.leedsdatamill.org/. The data can be used as wished by the user as long as it is legal.

2.0 Approach and Methodology

2.1 Approach and methodology

The study attempted to collect both primary and secondary data using a number of data collection techniques in an effort get to recent data information as much as possible. The collected data is both qualitative and quantitative. Firstly, desk studies were carried on the case studies and related construction issues outlined in the SPD in relation to prevailing issues of climate change and sustainability. The studied material included peer reviewed and grey literature; environmental rating standards' datasets from websites such as BREEAM[4] (2015) and the Passivhaus[5]; energy consumption and certification data from government databases such as the Department for Communities and Local Government's energy performance certificate register[6].

The consultant also sought views and experiences from building occupiers, owners and or developers wherever possible. Contact was first established using the buildings own listed contact information from which the consultant was directed to a responsible officer/individual knowledgeable enough on the specifications and performance of the buildings. This approach eliminated the aspect of the consultant approaching an individual/officer with insufficient knowledge about the building which could have potentially led to inaccurate information. Suffice to mention that this approach is not an assurance that the contacted individuals had all the answers but are probably the most knowledgeable on the issues for those buildings.

One purpose formulated questionnaire was sent to the identified officer per building. The questionnaires were tailored because the buildings had various targets when being initiated and listed in the SPD as such it was not necessary to ask for information that obviously does not apply to each and every building. There however were common questions that were asked to the

[4] BREEAM website available from: http://www.breeam.org/
[5] Passivhaus Standard website available from: http://www.passivhaus.org.uk/
[6] EPC register database contains Energy Performance Certificates and Display Energy Certificates from properties that were built or put up for rent after 2008. The database can be accessed from: https://www.epcregister.com/reportSearchAddressByPostcode.html

respondents especially those related to renewable energy, energy performance, environmental/social provisions as well as those soliciting views.

2.2 Sampling

There are a total of 59 case studies in the SPD and 50 of which are buildings. The consultant made attempts to contact each of the 50 case studies through the phone. The owner or occupier of the building was given the opportunity to give the rightful individual contact to whom the questionnaires on the buildings' performance were to be sent. 29 questionnaires were sent to the respondents for the 33 case studies, 4 less than the number of case studies established because some developers owned more than one building. 9 respondents sent feedback on the questionnaires and these form a bigger basis on views and lessons learnt in addition to information collected from literature. The list of the case studies from which the questionnaires were answered as follows:

Table 1. Case studies who filled in the questionnaires sent to them

Case Study	***Page in SPD***	***Developer/Occupier***	***Location***
1. Energy Research Building	12	University of Leeds	Leeds
2. York Environmental Centre	14	Friends of St. Nicholas	York
3. White Willows – Sheffield	22	South Yorkshire Housing Association	Sheffield
4. Trinity Leeds	27	Land Securities	Leeds
5. LATCH Workshop	37	LATCH	Leeds
6. Leeds Arena	45	Leeds City Council	Leeds
7. Ferns Wharf, Leeds	84	Bracken Developments/Canal & River Trust	Leeds
8. Northern Ballet	88	Leeds City Council	Leeds
9. LILAC	95	LILAC	Leeds

The consultant also conducted site visits to 8 of the buildings that are listed in the SPD. The visits were to some buildings meant to verify the respondents' answers, to ask extra questions and to others to observe how the buildings are being operated. Those that were visited for verification were selected after the respondent of that building had sent back the questionnaires while those that were visited for observation only had had no responses from the questionnaire. Proximity to city centre was a major contributing factor for visiting the sites.

Table 2. Visited buildings

Case Study	Page in SPD	Developer/Owner	Building Type
1. Energy Research Building	12	University of Leeds	Educational
2. Trinity Leeds	27	Land Securities	Commercial
3. LATCH – Hands On	37	LATCH	Community
4. Leeds Arena	45	Leeds City Council	Entertainment
5. Ferns Wharf, Leeds	84	Bracken Developments/Canal & River Trust	Commercial/Offices
6. Northern Ballet	88	Leeds City Council	Entertainment
7. The Broadcasting place	95	Leeds Beckett University	Education
8. The Rose Bowl	24	Leeds Beckett University	Education

2.3 Data analysis

The data collected from the means mentioned above was analysed triangulated with literature sources to come up with information that forms the basis for this report. Since the data was both quantitative and qualitative, the former was analysed using excel and the latter by the consultant's interpretation. The process involved triangulation of literature data to relate to industry trends as well as previous studies' findings.

2.4 Specific areas of study focus

The methods of data collection and analysis mentioned above were devised to specifically gather data that leads to finding out the following aspects;

a. Awareness of the LCC's goals through the awareness of the SPD
b. Environmental targets used for planning developments against the buildings actual ratings
c. Energy performance
d. Water fittings, technologies and use
e. Waste recycling provisions
f. Cycle parking and provision in buildings
g. Experiences and challenges being faced by stakeholders in sustainable construction

3.0 Description of the Case Studies

3.1 Case study classification

One of the purposes of the SPD is to enhance and encourage sustainable construction practices so that the council adapts to climate change, increases its mitigation to the effects of the change and also largely reducing its carbon footprint. The case studies therefore were not restricted to buildings alone but included infrastructure and practices that had the potential of fostering the said goals.

The case studies are either buildings, parks or innovative monitoring and management systems and waste management practices. The consultant however dwelled much on buildings for two reasons:

a. They have measurable planned targets to compare against actual performance and benchmarks
b. They are a significant source of greenhouse gases which contribute to climate change (Mardiana and Riffat, 2015)

The case studies are therefore classified into buildings and other for the purposes of this study with the former accounting for 85% of the total case studies in the SPD. A list of all the case studies in the booklet is provided in appendix I with their classification as explained above, the page they are listed on, their location and developer/occupier.

3.2 Case study locations

The SPD has a total of 59 case studies, 49 of which are in the Leeds general area and the rest outside Leeds as can be seen from table 3 above. Figure 1 illustrates the location of all the case studies that are in the Leeds area. The map was generated from Google maps through Google fusion tables.

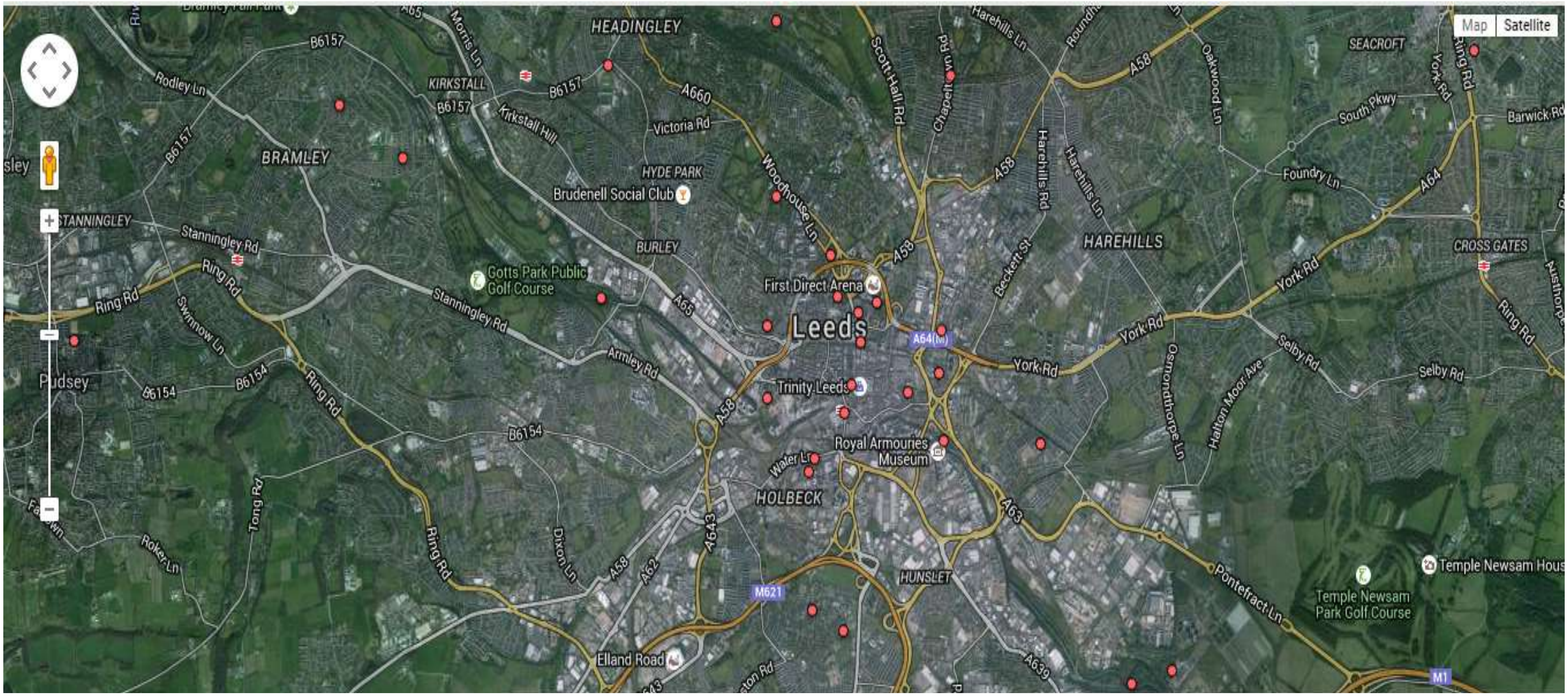

Figure 1. Location of the Sustainable buildings that are around the Leeds general area denoted by red dots.

4.0 Study Findings and Discussion

This section provides findings of the study and a brief discussion is also given to put the findings in context.

4.1 Awareness of the SPD by industry stakeholders

The respondents were asked of their knowledge of the SPD since they are in one way or another involved in decision making on how buildings are built, managed/operated and or maintained. The options given to them were whether they ever heard of it, read it, used it or if it was their first time. A relatively higher number of the respondents, 55.5% (5 out of 9) indicated that it was their first time hearing of the SPD's existence. Figure 2 below illustrates the scenario.

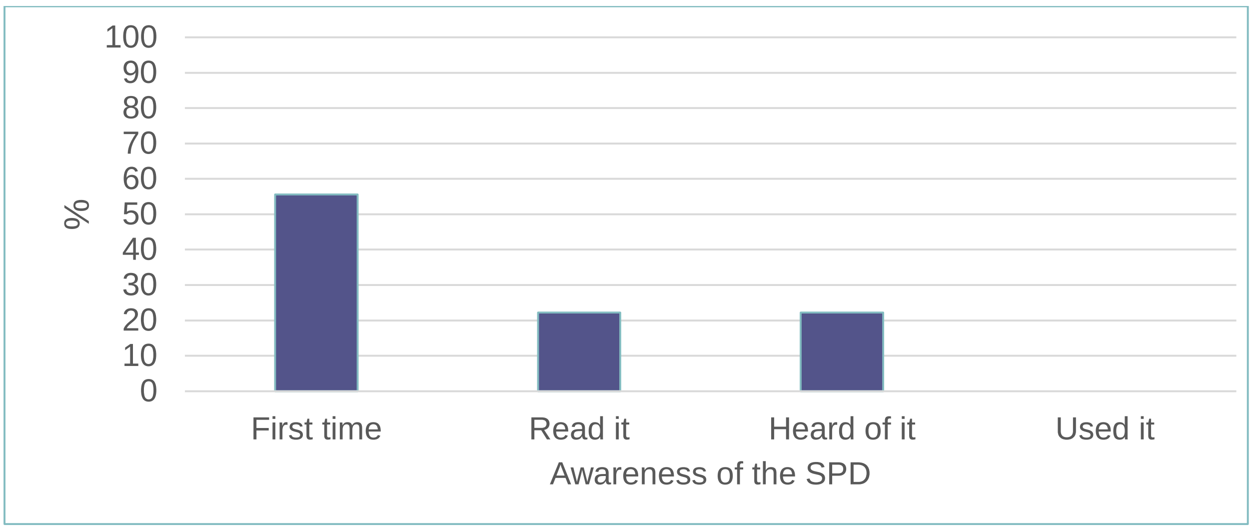

Figure 2. Awareness levels of respondents of the existence of the SPD

The respondents are in one way or another involved in decision making be it for maintaining, running and or managing the green buildings. It is in the interest of the council that the running of the buildings should be a reflection of and in line with sustainability targets of the buildings themselves and the council's own goals which are well stipulated in the SPD. The levels of awareness on the other hand may be justified that the respondents were not aware of the SPD as their buildings were commissioned and or built before the SPD itself. In addition to that, because individuals and or organisations have the knowledge, capacity and resources to undertake adaptation, this does not guarantee that they will act as is expected unless they have motivations for doing so (Tompkins et al., 2010, Repetto, 2008). However, their increased knowledge of how the council expects them to manage the buildings through the SPD would be one such motivation as it may help realise the economic and intrinsic cases of sustainability.

4.2 Environmental and sustainability standards rating targets

There were different environmental/sustainability standards that some of the buildings in the SPD targeted when being initiated. Notable standards include the following;

a. BREEAM
b. Code for Sustainable Homes (formerly eco-homes) and
c. Passivhaus standard

4.2.1 BREEAM

BREEAM (Building Research Establishment Environmental Assessment Methodology) standard was initiated 1988 and first published by the Building Research Establishment (BRE) in 1990 (Aubree, 2009). It has since grown and is widely used in Europe and other cities. It is a voluntary standard that developers use to attain levels of sustainability in various aspects of their development at design, construction and post occupancy levels. It is one method and tool that allows developers and controlling authorities to get a transparent comparison of buildings as well as measure any performance gaps if all the stages are assessed (Aubree, 2009, Colombo et al., 2015, Tuohy and Murphy, 2014).

There were a total of 21 buildings that targeted a BREEAM rating in the SPD. 18 buildings targeted an excellent rating and 9 were verified as having been certified as such. The consultant could not verify the actual rating of 6 buildings out of the 18 that targeted the excellent rating. 2 buildings out of the 18 targeting an 'excellent' rating got 'very good'. 2 buildings targeted a 'very good rating' from the onset and one was verified to have attained such a rating while the other could not be verified yet. Table 2 below shows the name of the buildings and the actual rating they attained.

Table 3. BREEAM targets and actual ratings of some buildings in the SPD

Building Name	***BREEAM Target***	***BREEAM Actual***
Innovate Green Office	Excellent	Excellent
White Willows	Excellent	Excellent
Rose Bowl	Excellent	Excellent
Trinity Leeds	Excellent	Excellent
Fearns Wharf	Excellent	Not yet verified
Town Centre House	Excellent	Excellent

York Eco-Depot	Excellent	Excellent
Broadgate, The Headrow	Excellent	Excellent
Carnegie Village	Excellent	Excellent
Energy Research Building	Excellent	Excellent
Broadcasting Place	Excellent	Very good
Northern Ballet	Excellent	Very good
City House	Excellent	Not yet built
Greenhouse	Excellent	Not yet verified
The Green Building	Excellent	Not yet verified
New Bewerley School	Excellent	Not yet verified
Rutland Lodge Medical Centre	Excellent	Not yet verified
Carnegie Pavilion	Excellent	Not yet verified
Leeds Arena	Very good	Not yet verified
Pudsey Grangefield School	Very good	Very good
The Rose Bowl	Excellent	Excellent

4.2.2 Code for Sustainable Homes

The Code for Sustainable Homes was prior to 2008 known as the EcoHomes standard. It was then voluntary; as such it was the prerogative and the drive of the developer that mattered on its adoption and implementation. Since 2008, it was adopted as a minimum standard for residential houses into the planning frameworks of England. Four projects in the SPD targeted the standard and they all achieved as per their levels. The projects are as follows:

a. LILAC – achieved level 4
b. Council houses in West Leeds – level 3
c. Allerton Bywater Millennium Community - EcoHomes excellent
d. St Mary's Close, Leeds – EcoHomes excellent.

4.2.3 Passivhaus standard

The Passivhaus Certification Scheme is derived on low carbon and low energy performance buildings which relies on attaining highest energy efficient fabric and fittings if any (Cotterell and Dadeby, 2012). Three projects – LILAC, the Denby Dale Passivhaus private home and Richmond Primary School were all built on this standard. The Denby Dale private house and Richmond Primary School were certified while the LILAC project's status could not be verified but the project attains some of the highest fabric energy efficiency as well as socially responsible low impact living accomplishments.

4.3 Energy performance

Energy performance of a buildings is defined as "the amount of energy actually consumed or estimated to meet the different needs associated with a standardized use of the building" (Poel et al., 2007). Worldwide, 30-40% of all primary energy is used in buildings (Huovila, 2007). In UK, typical of the developed world, the built environment alone contributes to about 50% of energy demand, 45% of which is for running them and 5% for building them (Pitt et al., 2009, Edwards, 2010). Most of the energy in the UK is from fossil fuels which are a significant culprit to increasing CO_2 emissions. Reduction or stabilisation of this trend is crucial to reducing CO_2 emissions and hence climate change (The Carbon Trust, 2009). To achieve this objective of reducing energy inefficiency in buildings, a mandatory rating system was introduced from 2008.

There two categories mainly focus on:

a. Building fabric energy performance which are expressed on energy performance certificates (EPC) and
b. Building use energy performance, denoted on Display Energy Certificates (DEC)

The two ratings show different aspects of a building's total energy performance. A Display Energy Certificate (DEC), or operational rating, records the actual energy use vis-à-vis CO_2 emissions from a building over the course of a year, and benchmarks them against buildings of similar use. EPCs on the other hand, also referred to as asset rating, models the theoretical, energy efficiency of a specific building, based on the performance potential of the building itself (the fabric) and its services (such as heating, ventilation and lighting), compared to a benchmark (The Carbon Trust, 2009, Cotterell and Dadeby, 2012). The EPC is significant as it illustrates the quality of the building fabric but it falls short of all the energy that is used in the building hence the DEC's use.The two certificates, wherever available, can be accessed from the databases from The Department for Communities and Local Government. Availability of the two certificates is dependent on whether an assessment was carried out and the building having been leased, sold or is built after the year 2008

4.3.1 Building performance (Based on EPCs)

The exemplar buildings in the SPD targeted the stringiest levels of energy efficiency and that is one of the factors that made them sustainable buildings. Attempts were made to access the EPCs of all the buildings for analysis. Analysing the EPCs of those case studies that are available revealed that most of the buildings are on average energy efficient.

Using the Government's energy efficiency rating system[7] where ***A*** denotes a very efficient and ***G*** the least efficient building, the study finds that 59% of the case studies are rated ***B***, 36% are rated ***C*** while 4.5% are rated ***D.*** Figure 3 below illustrates an example of a building's rating. The assessment includes the environmental impact of the specific building where the higher the score the less the impact.

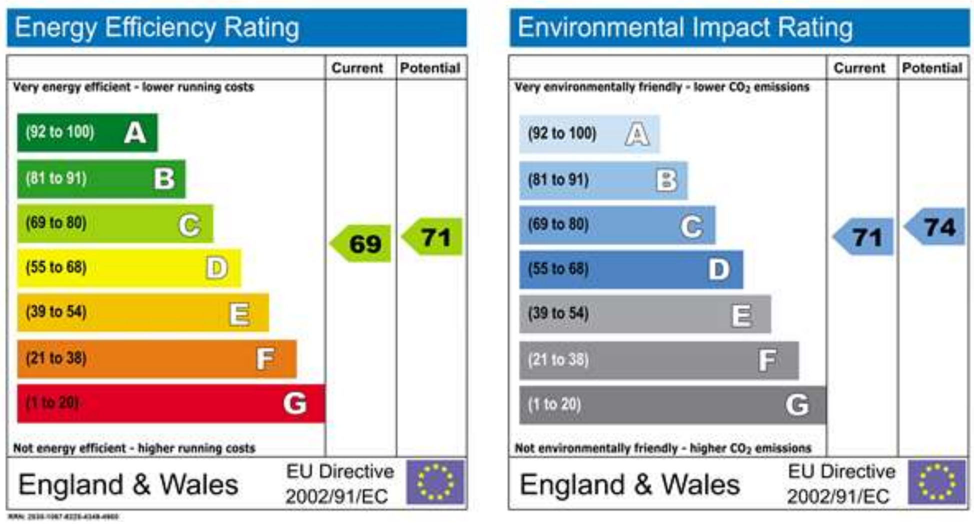

Figure 3. An example of energy rating (image sourced from Energy Apprise, available on http://energyapprise.co.uk/epc-bristol)

[7] The rating system is an implementation of the EU's directive No 2002/91/EC

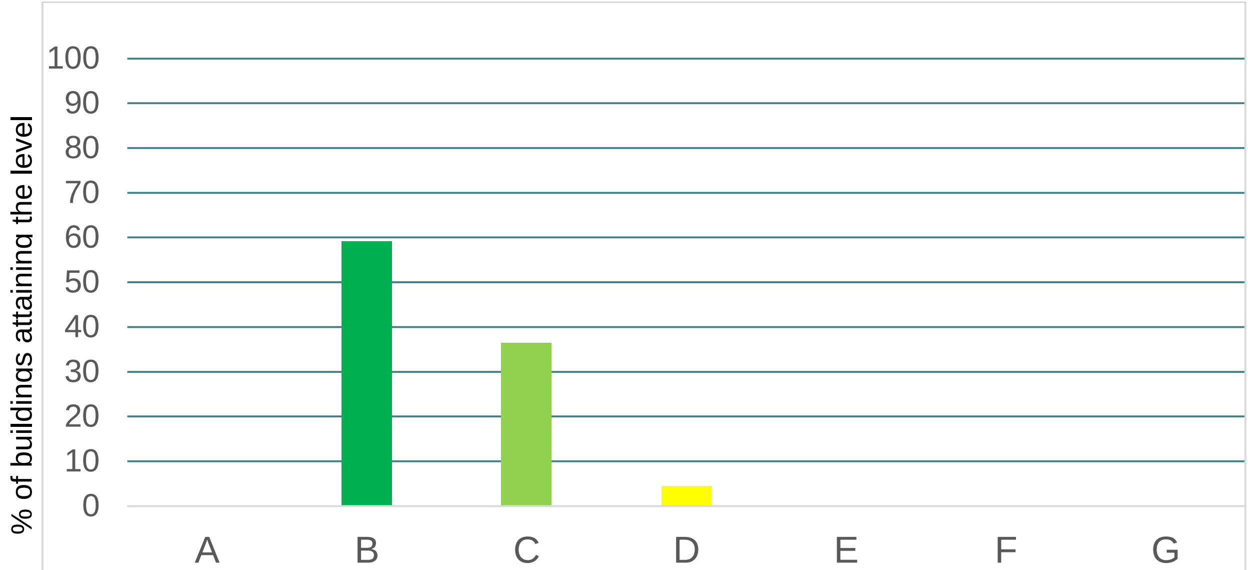

Figure 4. Energy performance of buildings in the SPD

Figure 4 above shows the findings as explained above. It can be noted that the buildings are on average performing well considering that many of them are rated B followed by D.

The contributing factors to such high levels of efficiency have been denoted as structural specifications, façade treatment and prudent orientation among many in design and construction. The type of materials being used of late have increased the likeliness of attaining higher efficiency levels (Kibert, 2012, Chatterton, 2014).

The most effective strategies strive on the prevention of excessive gain or loss of heat and energy before any other means are considered (Halliday, 2008, Poel et al., 2007). This is normally achieved through improved insulation in walls and roofs as well as solar shading. Figures 3 to 5 below show three buildings with very good energy ratings, the common feature in their facades is that they utilised solar shading devices on their south facing elevations.

Figure 5. Solar shading devices on the Fearns Wharf building.

Figure 6. Design considerations to reduce solar gain on the Northern Ballet building. Natural shading also in use.

Figure 7. Solar shading devices on the Energy Research building at University of Leeds

Structurally, less insulated areas on buildings are the most source of energy demand hence increasing inefficiency. Openings and roofs are the culprits of this phenomenon (Cotterell and Dadeby, 2012). Proper type and right fitting of windows entails good barrier to heat loss/gain (Menezes et al., 2012). One of the case studies that has a good energy rating, the houses at LILAC project, used triple glazed windows which further increased its efficiency (Chatterton, 2014). This therefore conspicuously illustrates the importance of material selection and most importantly the subsequent workmanship which are both significant sources of performance gaps (ARUP, 2013).

It is important to mention that the case studies do not mention the exact amount of efficiency they targeted, but targeted the best there is. Planning targeting a sustainability standard such as

BREEAM could help in coming up with exact transparent targets. Other studies have found that newer buildings, though they are efficient if compared to conventional buildings are consuming 2 to 3 times their design target (Board, 2015).

4.3.2 Energy use in buildings (using DEC)

The consultant then looked at the use of energy in the buildings and the findings are however different if compared to how efficient the fabric (asset rating) is as in section 4.3.1 above. Following the same rating system where ***A*** is the most efficiently used building and ***G*** the least. It was found that almost 60% of the buildings are rated ***D*** (compared to a better rating of ***B*** in building performance). Figure 7 below displays the performance of buildings in their energy use (derived from the buildings' DECs).

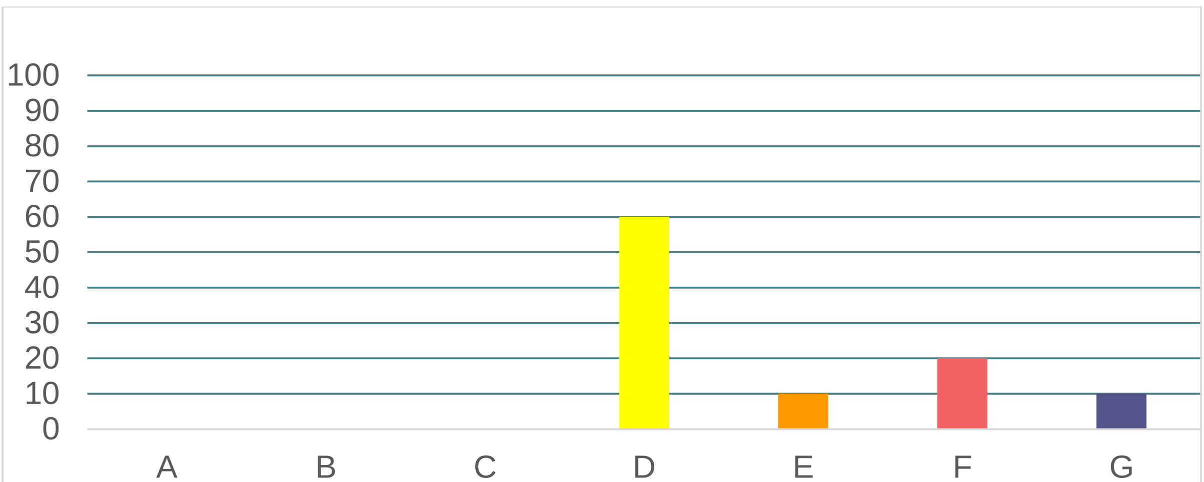

Figure 8. Building use energy performance rating

There are a number of reasons that are leading to this trend; notably;

a. Increased gadgets being used in buildings
b. Use of less energy efficient fittings and equipment
c. Increased number building users
d. Acting in business as usual i.e. having artificial lighting turned on when it is possible to use natural ventilation provided by the design of the building

Figures 9 and 10 illustrate the scenario observed at Leeds Trinity, one of the buildings in the SPD, and the Northern Ballet building. The buildings have abundant natural lighting for the spaces on which the photos were taken. However, it can be noted that they have lighting bulbs turned on despite the natural lighting.

Figure 9. Northern Ballet reception area that naturally well-lit but has its bulbs always turned

ing in the ng atrium

Figure 10. Northern Ballet's entrance interior illustrating the glazed facade meant to provide natural lighting

4.3.2.1 Specific examples of energy efficient case studies

The houses listed in section 4.2.2 of this report are by far some of the most energy efficient houses if compared to conventional ones. For instance, the LILAC project houses could attain an average cost of gas and electricity of £8 a week for a 3 bed house (2013 – 2014 rates). A conventional house that is not as efficient can meanwhile cost more than £20 a week. Each house on the project has a 1.25kw photovoltaic (PV) installation making a total of 28 KW generated on site. Houses have solar thermal panels for domestic hot water and Mechanical Ventilation Heat Recovery systems. The windows are triple glazed filled with argon to reduce heat gain or loss. The walls are well insulated and built with the newer technology of straw bale materials and insulated sheep's wool. The materials are not energy intensive in manufacturing as they are from renewable sources that can be locally sourced (Chatterton, 2014).

The St. Mary's close project, which was completed in 2005 targeted a combined energy cost of about £3 a week. Data from its energy performance however shows that they cost at around £9 a week. There is a visible performance gap that is however visible due to the target set in the first place. If the developments are compared against conventional buildings, they for sure are better off and worth being in the sustainable homes category. A critical look identified that the houses are very well insulated but the electrical heating fittings are not as efficient as expected. Figure 2 below shows an extract from one of the houses on the project which illustrates the areas that the occupiers spend more on energy costs than planned.

Element	Description	Current performance	
		Energy Efficiency	Environmental
Walls	Cavity wall, filled cavity	Good	Good
Roof	(another dwelling above)	-	-
Floor	Solid, no insulation (assumed)	-	-
Windows	Mostly double glazing	Average	Average
Main heating	Electric storage heaters	Poor	Very poor
Main heating controls	Manual charge control	Poor	Poor
Secondary heating	Room heaters, electric	-	-
Hot water	Electric immersion, off-peak	Poor	Poor
Lighting	Low energy lighting in 86% of fixed outlets	Very good	Very good
Current energy efficiency rating		D 63	

Figure 12. St. Mary's single house energy performance extract.

4.3.3 Renewable energy sources

There are a number of buildings that targeted incorporating less carbon or other innovative ways of energy generation. These range from solar panels (including PVs), wind, airsource heat coils as well as underground heat pumps. The following were verified as buildings that implemented their plans:

a. Danby Dale
b. Council homes – planned 5000, have done 11 and targets 1000 by end 2015
c. LILAC
d. The Green house
e. York Eco-deport
f. York environmental centre
g. White Willows

The Fearns Wharf building was planned with intentions of using geothermal heat pumps for heating but did not materialise as such the building uses normal gas heating system.

It has been noted that quantifying the amount of energy supplied by the renewable energy sources on site has been a problem to many buildings. As such the owners and or developers are not aware if the technologies are being utilised to their capability on not, with an exception of the LILAC project. There are also reported issues of ineffectiveness of some technologies, for example wind turbines that are installed on buildings where the very building they are installed has been a source of buoyance that ended up affecting the efficiency of the technology. This could however be rectified with proper citing and modelling.

4.4 Water use

Most effective means of preserving water in most of the buildings is reliance on fittings that use less water. Previous research has shown that installing such fittings could improve buildings water use efficiency by more than 20%. There are however 6 buildings that targeted to harvest and or recycle water for reuse but the consultant has not yet verified to this effect. Figure 13 below illustrates some of the buildings' fittings.

Figure 13. Water saving installations

5.0 Climate change resilience, adaptation and mitigation

5.1 The built environment and climate change

The built environment is responsible for a significant amount of CO_2 emissions into the atmosphere which is one of the greenhouse gases that contribute to climate change. Business as usual activities in every carbon emitting sector is likely to lead to a global average temperature increase of about 2°C by 2100 which will have catastrophic consequences on the global and micro level ecology (IPCC, 2013). Measures to curb the greenhouse gas emissions are core to sustainable construction interventions being propagated by LCC.

Leeds is committed to reducing CO_2 emissions by 80% by 2050 in the long term and a 40% reduction from all sectors from 2005-2020 (Leeds Climate Change Strategy 2012-15). The council has already achieved a reduction of 15.2% for the five years from 2008-09 to 2013-14 (Council, 2014). Achieving the 40% milestone requires innovation in all sectors of the city, infrastructure included (Council, 2013). Carbon is emitted from buildings through; direct use of fossil fuels for heating, cooking etc.; use of electricity which has been produced through high carbon emitting procedures; construction of the said buildings; the type of materials used. The SPD considered and provided guidance on all these.

5.2 Resilience, adaptation and mitigation

Climate change is already having ramifications on Leeds as a city evident with occurrences such as floods which are being caused by rising sea levels which are directly linked to climate change (Houghton, 2009). Leeds and the Humber region lies in a high and increasing flood risk (Government Office for the Humber and Yorkshire, 2008). The various case studies listed in the SPD have different means employed in improving climate change resilience, while adapting to the changes and encouraging mitigating factors. Energy efficiency, renewable energy, design considerations and material use are some of the interventions observed from the buildings in the SPD towards climate change resilience, adaptation and mitigation.

Energy efficiency and renewable energy

All the buildings I the study targeted better energy efficiency levels using various techniques. Thermal mass construction, orientation of buildings, façade treatments, energy monitoring systems and use of insulation materials are some of them just to mention a few. Reduction of energy use is directly linked to reduction in CO_2 emissions as already mentioned above as such these measures are quiet commendable.

Buildings such as the Energy research building at the University of Leeds applied the thermal mass and façade treatment for its energy efficiency measures. The LILAC project used cavity wall of straw bales which are highly insulated with sheep wool for its energy efficiency attainment. The Greenhouse by Citu has a network based energy monitoring system that occupants can see how much energy they are using per specific time as means of getting the occupants to minimise on usage wherever necessary.

Most of the buildings also planned and some implemented renewable sources of energy as mentioned in section 4.3.3 above. Having a source of low carbon energy is a great stride to reducing CO2 emissions from fossil fuel based energy sources. For instance, the council has a project to install 1,000 homes with solar panels which would save about save around £4.4 million in electricity costs over a 20 year period, working out at around £136 a year for each tenant (Leeds City Council, 2015)[8]. Individual projects like LILAC benefits more on having their own low carbon energy generation with high energy efficiency building fabrics.

Design considerations

The threat of climate change has seen some building being designed and built with adaptation measures being core to the whole project. The Fearns Wharf is a good example of how a design was informed with threat of flooding. The building is on the banks of river Aire which runs across the city centre and was the source of the flooding in the area in 2012. The building has a garage on most of its ground space and habitable rooms start on the first floor except the reception. Figure 14 illustrates the setup.

Material use

Materials are the spine of construction and their specification and how they are used greatly affect the built environment. Each material has to be extracted, processed and finally transported to a construction site where it is used. All these processes and stages require energy and different pollutants and greenhouse gases such as CO_2 are released. The energy and contaminant emissions such as CO_2 may be regarded as being ‘embodied’ within the materials (Hammond and Jones, 2008). Embodied energy is the quantity of energy required to process and supply to the construction site, the material under consideration and its embodied emissions are the subsequent amount of pollutants and greenhouse gases released on all those stages. Materials

[8] The project has since installed the solar panels on 11 homes by July 2015. Information available from http://news.leeds.gov.uk/free-solar-panel-project-steps-up-a-gear

that are processed with low energy intensity and locally made are better off compared to the opposite.

Timber for instance is one good material that is renewable, can easily be worked on to reduce site waste, found locally in many regions and can be processed with less energy compared to other materials was used in a number of buildings used it from the SPD. LILAC, the Gledhow Bank Eco-Houses, the Carnegie village and many others are some examples of such buildings. This is in contrast to other sustainable buildings which relied on heavy concrete aggregate where the focus is on energy efficiency other than recyclability of the materials. There are buildings that also utilised materials that are already on site, including part use of old walls for new builds. The Broadgate and the Greenhouse are two good examples.

Figure 14. The Fearns Wharf building, built on a raised platform to adapt to floods

6.0 Experiences and challenges to sustainable construction

6.1 Experiences

The sustainable construction arena is still developing and location specific as such the experiences of stakeholders in Leeds ae specific although they in some aspects share with the global environment. For example, the cost of renewable or low carbon energy may be high in the UK but low in Spain or USA due to different policies and locality perspectives. The following are some of the experiences that the consultant could identify.

Cost of sustainable technologies is deemed high

There is an observed scenario where the cost of sustainable technologies is deemed high than conventional alternatives. Installing a solar panel for instance is sometimes deemed as an extra cost because it is an amount a developer or homeowner has to part with knowing that they can do without. The benefits of installing the technology on the other hand are not immediately realised as the payback period for the technology is longer, however, it is in the interest of sustainability and reduction of greenhouse gas emissions.

Need for more sustainability awareness

Most respondents to the questionnaire indicated that they would want to see more awareness of sustainability issues being put forward to the general public. This will increase demand for sustainable buildings, homes and technologies alike. It will also increase the individual level awareness to act and live sustainably. It is noted that the respondent expects the council to do more of this, but the council can utilise local, university and school sustainability pressure groups to carry out this activity which the consultant sees it being a win-win situation for the council and the groups mentioned above.

Sustainability and low impact living has social cohesion benefits

The study found out that low impact living projects like the LILAC or the Gledhow housing schemes increases social inclusion as it gives the people of different status a choice of coming together for a cause and happy living. Inclusion is one of the strategy areas of the council and the said projects are living examples.

6.2 Challenges

The following are some of the identified challenges that prevent the implementation of sustainable construction:

a. The cost of renewable technologies is still not economically viable in the short term – for instance, the repayment period of solar installation is just coming down to less than 20 years of which many people would want to be less
b. There is not much land and room for experiment on new technologies – Some respondents feel LCC should be flexible in providing an environment where sustainability projects can be carried out with its support in planning permissions.
c. There is a huge gap between the building designing team and the building users – resulting in sometimes different agendas on sustainability
d. People still feel that cycle and other low carbon transport infrastructure are not enough to warrant increased structural inclusion in buildings
e. Individual and society behaviour and general consumption behaviours are far from the climate change mitigation and adaption agenda as it may need individual awareness for a sustainable cause to be successful
f. Unwillingness to provide resources for post-occupancy assessment – developers are not willing to provide further resources for post occupancy evaluation of their buildings. This is in one way seen as a way of fending off negative outcomes of the evaluations if compared to the plans. Or that it is an extra cost they can do without.

7.0 Recommendations and Conclusions

7.1 Recommendations

The consultant recommends the following in light of the issues discussed in this study.

a. The Council should set in place mandatory frameworks for all new developments to have one or more low carbon energy technology. This will make the low carbon technology part of the development other than an added cost.
b. The council has its own projects involving installation of solar panels on its housing, such projects in essence increases visibility of the technology which is very important for the public. The council however has to do more monitoring, up to date data collection and publicising the information (outcomes) to encourage more home owners to go for the technology which can increase demand. An increase in demand is likely to reduce the collective cost as the technologies will be appealing to businesses and suppliers.
c. The council should be prepared to listen and pave way for implementation to experimenting developers by further involving respective research institutions such as universities for further due diligence and monitoring for befitting projects.
d. The council should engage key industry stakeholders such as engineering and architects bodies, contractors association as well as universities on finding means of reducing the gap between design teams, contractors and end users. This is an industry wide problem as such it requires and industry wide approach.
e. The council should encourage detailed commissioning building handbook be available for every occupant. This will help occupiers of sustainable buildings to know how they are expected to operate the building.
f. Future council housing projects should pave the way for cycle parking facilities as an exemplar and other developers encouraged doing likewise.
g. The council should encourage cycle clubs to have visible cycle week promotion that is highly publicised for visibility.
h. The council should increase awareness efforts on sustainability on individual households. The council is already doing tremendously well by encouraging recycling etc. but individual behaviours are critical to achieving sustainability. Community and different associations/clubs can be utilised for this purpose.

i. The council should hold best practice fairs for sustainable construction in a 3 or 4 year interval and give information on any of the city's sustainability goals. This will also entail maintaining good contacts for building managers.

j. The council should consider making post occupancy evaluation mandatory and be the responsibility of a developer with fees/penalties for non-compliance. This should be initiated with well laid out planning permission conditions where an application should give expected targets of the development in measurable units, for instance fabric energy performance in KWh etc.

k. There is need to encourage installation of low energy consumption lighting fixtures i.e. LED bulbs in buildings. This is in light of most buildings having their lighting always turned on even though the buildings are naturally well lit.

l. A follow up study should be done on buildings that were planned after the publication of the SPD to ascertain the impact of the guidelines as provided in the SPD.

7.2 Conclusion

The following conclusions were drawn from the study.

There are low levels of awareness of the SPD among current building occupiers and managers which has the potential of derailing sustainable operation and maintenance practices of sustainably built buildings. Some of the recommendations mentioned above can directly address this problem.

The study finds that there are performance gaps with the buildings in relation to BREEAM ratings. There are buildings that targeted higher levels of sustainability but achieved relatively lower ratings. There are others however that equally attained their targets. Meanwhile, although the buildings have the said industry wide endemic performance gaps, they are performing better than conventional buildings when it comes to building fabric energy performance. They mostly have better fabric energy performance which saves a lot of energy hence reducing carbon emissions into the atmosphere. The building usage however has shown that more energy is being used than is expected as most buildings performed badly on energy in use.

There are visible changes to the construction industry in response to climate change in order to adapt to its effects and the buildings in the SPD have done very well on that front. Material use, increased need for energy efficiency, design considerations and low carbon energy technologies incorporation into buildings are some of the prominent interventions found in the buildings that have been looked into.

Sustainable construction is still faced with higher costs of low energy technologies due to among other low demand, which can be addressed with some recommendation mentioned earlier. In addition to that, there is need for the council to actively engage and involve research institutions, profession associations, community clubs etc. to advance the sustainability agenda among their collective individuals.

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APPENDIX I

List of case studies in the SPD

Case Study	Page in SPD	Type	Location	Developer/Occupier
1. Energy Research Building	12	Building	Leeds	University of Leeds
2. Innovate Green Office,	13	Building	Leeds	Innovate/Pure Offices
3. York Environmental Centre	14	Building	York	Friends of St. Nicholas Fields
4. Greenhouse, Citu	16-17	Building	Leeds	Citu
5. Gledhow Bank Eco-Houses	19	Building	Leeds	Private/LEDA
6. White Willows – Sheffield	22	Building	Sheffield	South Yorkshire Housing Association
7. City House	23	Building	Leeds	Bruntwood
8. Rose Bowl	24	Building	Leeds	Leeds Beckett University
9. Carnegie village	25	Building	Leeds	Leeds Beckett University
10. Broadcasting place	25	Building	Leeds	Leeds Beckett University
11. Trinity Leeds	27	Building	Leeds	Land Securities
12. The Green Building,	28	Building	Leeds	Ingloo
13. Allerton Bywater Millenium Community	33	Building	Leeds	Fleming Developments
14. Ice Works	36	Building	Leeds	Urban Edge/Yorkshire Housing
15. Round Foundry	37	Building	Leeds	CTP
16. LATCH – Hands On	37	Building	Leeds	LATCH
17. Back to Back in Leeds	38	Building	Leeds	-
18. Zero-Carbon Victorian Semi,	39	Building	Manchester	Urbed
19. Mill Green Place, Leeds	39	Building	Leeds	Leeds City Council
20. Broad Gate, The Headrow, Leeds	40	Building	Leeds	Highcross
21. Skelton Grange Environmental Centre	43	Building	Leeds	BCTV
22. Park Lane College	44	Building	Leeds	Park Lane College
23. Leeds Arena	45	Building	Leeds	Leeds City Council
24. Pudsey Grangefield School	46	Building	Leeds	Leeds Education Partnership
25. Carnegie Pavilion	52	Building	Leeds	Leeds Beckett University

26. Hockerton Housing Project	53	Building	Nottinghamshire	Hockerton Housing Project
27. Oxford Eco-House	54	Building	Oxford	-
28. Dalby Forest Visitor Centre	55	Building	Leeds	Forestry Commission
29. Tao Housing, Magbate, Leeds	56	Building	Leeds	Citu
30. Morgate Crofts Business Incubation Centre,	57	Building	Rotherham	Rotherham MBC
31. Council Housing	58	Building	Leeds	Leeds City Council
32. Potternewton Housing Leeds	59	Building	Leeds	Connect Housing
33. Crossway Passivhaus	59	Building	Kent	Hawkes
34. Denby Dale Passivhaus	60	Building	Leeds	Private/ Geoff & Kate Tunstall
35. Richmond Hill Primary	60	Building	Leeds	Education Leeds' Primary Capital Program project
36. Garforth Library	61	Building	Leeds	Leeds City Council
37. St Margaret's Church Hall	68	Building	Leeds	St Margaret Church
38. Thwaite Mills and Armley Mills	69	Building	Leeds	-
39. Hollybush School	72	Building	Leeds	Leeds City Council
40. Meanwood Valley Urban Farm	73	Building	Leeds	Leeds City Council
41. York Eco-Depot	74	Building	York	York City Council
42. Town Centre House	75	Building	Leeds	Town Centre Securities
43. Ferns Wharf, Leeds	84	Building	Leeds	Bracken Developments/Canal & River Trust
44. Northern Ballet	88	Building	Leeds	Leeds City Council
45. BedZED	92	Building	London	BedZED
46. LILAC	95	Building	Leeds	LILAC
47. Rutland Lodge Medical Centre	96	Building	Leeds	Rutland Lodge Medical Practice
48. St Mary's Close Live/Work Studio	96	Building	Leeds	Yorkshire Housing
49. Gipton Housing, Leeds	97	Building	Leeds	Leeds City Council
50. New Bewerley School	102	Building	Leeds	Education Leeds
51. Solar panels on Council houses	38	Other	Leeds	Leeds City Council
52. Cockburn High School, South Leeds	48	Other	Leeds	Cockburn High School
53. Proposed CHP plant at Eastgate Quarter,	63	Other	Leeds	Hammerson UK Properties Plc

54. Blackhill Quarry, Bramhope, Leeds	71	Other	Leeds	-
55. Proposed movable weir	85	Other	Leeds	-
56. Reducing waste to landfill sites	87	Other	Leeds	-
57. Wellington place	97	Other	Leeds	MEPC
58. 'ENVAC' Mobile Vacuum System	99	Other	Stockholm, Sweden	-
59. Monitoring Systems	101	Other	Leeds	Citu