The role of crowd-sourced energy performance feedback in low-energy building design and management in the context of industry pressures.

Craig Robertson

UCL Energy Institute

Submitted in part fulfilment of a

Ph.D Research Degree in Energy and the Built Environment

[BLANK PAGE]

Declaration

I, Craig Robertson confirm that the work presented in this thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated in the thesis.

Signed:

Date:

Acknowledgements

I would like to thank my supervisor Dr Dejan Mumovic for his guidance and support over the last three years of this project and during my earlier M.Sc. Also, I would like to thank my second supervisor Professor Philip Steadman. To both I am grateful for stepping into these respective roles at a very challenging time.

I am grateful to all of the respondents to my internet survey, those who participated in interviews and those who have uploaded data to CarbonBuzz. I am extremely grateful to the CarbonBuzz team for granting access to both the database and the development process and to Professor Paul Ruyssevelt for his advice.

I would like to acknowledge the work of Harry Bruhns both in setting up this project and in providing the basis for the research within. Like most, I did not get the opportunity to spend nearly enough time with Harry.

I thank my parents, Margaret and Alasdair, for their support. Finally, over the last three years and beyond my partner Chloe has been supportive and understanding beyond reasonable expectation.

This thesis is dedicated to Chloe and Morven.

Abstract

The European Performance of Buildings Directive and the United Kingdom Climate Change Act have resulted in a range of measures aimed at lowering building energy consumption. This framework uses regulatory, market based and other levers to encourage reductions in consumption and associated carbon emissions. Parallel to this is a set of drivers generated by social, economic and broader professional responsibilities. These include reputational pressures, personal and organisation ambitions, economic risks and societal pressures.

This study used a mixed methodology to define this combination of influences as the ‘contextual pressures’. An initial literature review was combined with a phase of empirical research through participant observation in the early stage development of the CarbonBuzz platform to add practitioner insight to the framework.

The role that energy information feedback currently plays in design, construction and management practice was then investigated. Three data collection and analysis phases were carried out: an industry-wide web-based survey; secondary energy consumption data from the CarbonBuzz platform and semi-structured interviews aimed at understanding which pressures have greatest impact on actors’ practice.

A framework is proposed for the future role that crowd sourced energy information feedback could play in design, construction and management practice. The final phase synthesises the quantitative and qualitative data to identify what a future crowd sourced data platform must offer to meet the aspirations and motivations of actors working within the contextual pressures and the macro-aim of lower carbon emissions. This concludes with suggested alterations required to the contextual pressures to facilitate this. Recommendations are made for adjustments to the framework to increase participation in building evaluation targeted at the specifics of the energy gap and the motivations of industrial actors.

Finally, further work is identified to facilitate and evaluate any future changes to the contextual pressures.

Peer reviewed publications

Conference Papers:

Robertson, C and Mumovic, D; *Meeting legislation and enhancing reputation: Working within the contextual pressures of regulatory, social, economic and other drivers to reduce building energy consumption;* ECEEE Summer Study, June 2013, Toulon/Hyères, France;

Robertson, C and Mumovic, D; *Assessing building performance: designed and actual performance in the context of industry pressures;* SB13 Sustainable Buildings Conference, July 2013, Coventry, UK.

Marrone, P; Di Guida, M; Kimpian, J; Martincigh, L; Mumovic, D and Robertson, C; *Development of Evidence based Online Design Platforms: Challenges and Limitations*; CIB WBC, May 2013, Brisbane, Australia.

Robertson, C and Mumovic, D; *Legislation, disincentives and low energy buildings: overcoming barriers in the design process*; PLEA 2013 Sustainable Architecture for a Renewable Future, 2013, Munich.

Forthcoming Publications:

Robertson, C and Mumovic, D; *Crowd-sourced building intelligence: the potential to go beyond existing benchmarks for effective insight, feedback and targeting*; submitted to Intelligent Buildings International

Robertson, C and Mumovic, D*; Building performance in the context of industry pressures*; accepted for publication by International Journal of Energy Sector Management

Table of Contents

Lists of Figures

List of Tables

Abbreviations

AIA	American Institute of Architects
BER	Building Emission Rate
BIFM	British Institute of Facilities Managers
BMS	Building Management System
BPE	Building Performance Evaluation
BRE	Building Research Establishment
BREEAM	Building Research Establishment Environmental Assessment Method
BSRIA	Building Services Research and Information Association
BUS	Building User Survey
CCA	Climate Change Act
CERT	Carbon Emissions Reduction Target
CESP	Community Energy Savings Programme
CIBSE	Chartered Institute of Building Services Engineers
CIC	Construction Industry Council
CO_2	Carbon Dioxide
CRC	Carbon Reduction Commitment
CSDG	CIBSE School Design Group
CSH	Code for Sustainable Homes
D and B	Design and Build
DCLG	Department for Communities and Local Government
DEC	Display Energy Certificate
DECC	Department for Energy and Climate Change
DREAM	Defence Related Environmental Assessment Methodology
DTI	Department of Trade and Industry
DTM	Dynamic Thermal Modelling
EBD	Evidence Based Design
ECA	Enhanced Capital Allowance
EEB	European Environmental Bureau
EIFOB	Environmental Indicators for Buildings
EPBD	European Performance of Buildings Directive
EPC	Energy Performance Certificate
ERM	Environmental Responsible Manufacturing
ESCo	Energy Service Company
ECO	Energy Company Obligation
EU	European Union
FIT	Feed in Tariff
GDP	Gross Domestic Product
GLA	Greater London Authority
IEA	International Energy Agency
IPCC	International Panel for Climate Change
KPI	Key Performance Indicators
$kgCO_2/m^2/yr$	Kilograms of carbon dioxide per metre squared per year
$kWh/m^2/yr$	Kilowatt-hours per metre squared per year
LA	Local Authority
LAF	London Area Frame
LZCT	Low and Zero Carbon Technology
NCM	National Calculation Methodology
PHPP	Passivhaus Planning Package
POE	Post Occupancy Evaluation
PROBE	Post-Occupancy Review of Buildings and their Engineering
PSBP	Priority Schools Building Programme
QUANGO	Quasi-Non-Governmental Organisation
RHI	Renewable Heat Incentive
RIBA	Royal Institute of British Architects
RICS	Royal Institute of Chartered Surveyors
SAP	Standard Assessment Procedure
SBEM	Simplified Building Energy Model
TER	Target Emission Rate
TM (XX)	Technical Memorandum (numeral)
TSB	Technology Strategy Board
UBT	Usable Buildings Trust
UCL	University College London
UNCCS	United Nations Climate Change Secretariat
UNFCCC	United Nations Framework Convention on Climate Change
VDI	Verein Deutscher Ingenieure (Association of German Engineers)

Definition of Terms

Actors

Design, construction or management professionals who make decisions influenced by the contextual pressures that have an effect on building energy consumption.

Crowd sourcing

A web-based business or research model that uses a large network of individuals to develop creative solutions or supply information to address a variety of problems. (Also referred to as ‘citizen science).

Feedback

The modification or control of a process or system by its results or effects.

Contextual pressures

The framework of legislation, guidance, policy professional responsibilities, social obligations, economic imperatives and other influences that impact upon design and management professionals decision making.

Performance gap

The difference between design stage predicted energy consumption and actual recorded in-use energy consumption.

Post occupancy evaluation

Visiting a building following completion and occupation to understand how technical systems are operating and how occupants are using the building to gain insight for future design work or to refine current operational activity.

Operational energy

All of the energy consumed in a building through normal operation, including those end uses not accounted for in building regulations calculations.

1 Introduction and Aims

The evidence that human activity is changing the environment and climate of the planet is clear. In its fifth assessment of the impact of climate change in 2013, the International Panel on Climate Change (IPCC) states that climate system warming is 'unequivocal'. The temperature rises and subsequent environmental changes are unprecedented. They draw a direct link between the causes of planetary warming and human activity:

> *"Human influence on the climate system is clear. This is evident from the increasing greenhouse gas concentrations in the atmosphere, positive radiative forcing, observed warming, and understanding of the climate system."* (IPCC 2013).

According to the International Energy Agency's (IEA) report Energy Technology Perspectives 2010, to be on track to limit global warming to 2°C, global carbon emissions need to be reduced by 33 Gt per annum by 2050. 6 Gt or nearly 20% of these must be achieved in buildings (International Energy Agency 2010). Translating this to an annual target, IPCC figures suggest that limiting temperature increases to less than 2°C requires year on year CO_2 emission reductions of 3% before 2020. Any delay in beginning this reduction will exacerbate the situation, creating a need for sharper decreases, while increasing costs and potentially making the limiting of temperature increases to 2°C unfeasible (Peters et al. 2013). However, in the 2013 edition of the 'World Energy Outlook' report, the IEA suggest that at current emission rates it may already be too late as energy-related carbon dioxide emissions are projected to rise by 20% to 2035. This would lead to an average temperature increase of 3.6 °C, far above the internationally agreed 2 °C target (International Energy Agency 2013).

Action to reduce emissions is therefore urgent and since 2003 European Union (EU) member states have been bound by a directive to reduce the energy consumption associated with their building stock. The Energy Performance of Buildings Directive (EPBD) came into force on the 4th January 2003 (it was recast in 2010) and obliges member states to take measures aimed at improving the energy performance of buildings through standardised calculation methodologies, certification schemes, maintenance programmes and national performance targets (The European Parliament & The Council of the European Union 2010). In response to this Europe-wide directive and broader climate obligations (such as the Kyoto protocol), in 2008 the United Kingdom (UK) government introduced the Climate Change Act (CCA). This commits the country (the first globally to do so) to delivering an 80%

reduction in CO_2 emissions by 2050 relative to 1990 levels (Climate Change Act 2008). This carbon budget figure is periodically reviewed by the Climate Change Committee, whose most recent report states that reduction targets must remain at least as stringent (Committee on Climate Change 2013). The 2013 United Nations Framework Convention on Climate Change (UNFCCC) summit in Poland continued international work towards a new global agreement in 2015 to replace the Kyoto protocol (UNCCS 2013). The Department for Energy and Climate Change (DECC) showed that UK emissions of the 'basket' of greenhouse gases defined by the Kyoto Protocol were estimated to be 3.5% higher than the previous year. CO_2 emissions had a year-on-year increase of 4.5% (Department for Energy and Climate Change 2013a). However, total emissions in 2011 were 25.9% lower than the 1990 base year (Department for Energy and Climate Change 2013).

The Stern review of the economics of climate change emphasised the urgency with which the UK and international communities must act. The report defined the implications of climate change in terms of its impact on current expenditure and future economic growth. Stern calculated potential costs of inaction to be in the order of 5% of GDP whilst the cost of mitigation could be limited to 1%. The report advocated the use of market mechanisms to reduce the causes of climate change, reverting to regulatory levers only where it was evident the market was failing to deliver (Stern 2007). Stern (now Lord) has since suggested in a newspaper interview that the original report did not place enough emphasis on the risks of not acting with urgency (The Observer 2013). In apparent agreement with the original recommendations the Department for Communities and Local Government (DCLG) has justified the need for regulatory mechanisms in the building sector to reduce carbon emissions only where:

> *'it can be shown to be cost effective and that the market would not make these changes of its own accord, or that other measures (regulatory or otherwise) are not already driving this change'* (Department for Communities and Local Government 2012).

In the UK, energy used in buildings accounts for 45% of all carbon emissions with housing accounting for 27% and non-domestic buildings the other 18% (para. 2.103 Department of Trade and Industry (DTI) 2007). The built environment therefore represents a significant opportunity to meet CCA obligations. In the UK the Building Regulations are the primary mechanism for ensuring consideration of building energy consumption in the design of new or substantially refurbished buildings. There are other statutory and voluntary measures in place but these regulatory and other mechanisms have led to reductions in the *anticipated* energy consumption and carbon dioxide emissions of building designs rather than the subsequent *actual* energy consumption of completed and occupied buildings, creating an 'energy gap' (Day et al. 2007). Simultaneously, the increasing introduction of free market principles into the construction industry, the historic removal of local authority design departments, research laboratories and subsequent deskilling of institutional clients combined with procurement innovations such as design and build (D and B) contracts all have contributed to a fundamental and continuing change in the operation of the construction industry (Bordass & Leaman 2013, Hamza & Greenwood 2009).

Delivering the necessary CO_2 emission reductions in the built environment is therefore a complex process. The design, construction and management of buildings is not only a set of economic interactions; the process is carried out by a '*socially regulated'* network of decision-makers (Lutzenhiser 1994). This network of decision-making actors (designers, contractors, developers, regulators etc) has broader professional, cultural, institutional, social, economic and technical responsibilities that affect decision choices (Beamish & Biggart 2010; Lutzenhiser 1994). The combined pressures – mandated, voluntary, perceived and actual – are referred to as the 'contextual pressures' in this thesis.

A number of platforms have been developed to provide a forum for building performance information in this context and to aid the decision-making of industry actors. CarbonBuzz is one such platform which stores and displays detailed building characteristics, occupancy, management and energy data according to user-defined parameters to highlight the discrepancy between design predicted and actual recorded energy consumption. CarbonBuzz aims to enable industry to carry out a range of energy-related analyses to help minimise the risks associated with misunderstood building performance through carbon tracking, benchmarking and trend analysis (www.carbonbuzz.org n.d.).

Aim and contribution to knowledge

In this context, the aim of this thesis is to improve academic and practical understanding of the interplay between crowd-sourced empirical building performance information and design and management practice through identification of the framework of influences on current information flow, investigating how this impacts on industry practice and building energy performance and to suggest changes the framework to ultimately improve information flow and reduce the energy consumption associated with the built environment.

The contribution to the body of knowledge offered by this thesis is broken down into four topics:

1. Defining the contextual pressures.

The 'contextual pressures' are formed from the framework of literature-derived categories and from an initial phase of empirical data collection. This framework uses regulatory, market based and other levers to encourage reductions in energy consumption and associated carbon emissions. Parallel to this framework is a set of drivers generated by social, economic and professional responsibilities. These include reputational pressures, personal and organisation ambitions, economic risks and societal pressures.

2. Analysing the role that energy information feedback currently plays in design, construction and management practice.

The contextual pressures influence the interplay between design and construction practice and energy information. Actors' relationship with the contextual pressures varies depending on their role in the design and management process, which is illustrated by crowd-sourced energy data. Despite this influence, actors' willingness to engage with energy and information feedback depends on their attitude to energy and broader sustainability rather than the contextual pressures. The performance gap exists in part because energy performance assessments do not include all of the end uses found in buildings but as feedback is not habitually used in design, construction and management practice the true cause of the gap is impossible to ascertain. The type and quality of information collected varies with the motivation and role of individual actors and sector.

3. Proposing a framework for the future role that crowd sourced energy information feedback could play in design and management practice.

The relationship between the contextual pressures, building energy data and actors experience can inform the future role of energy feedback. Crowd sourced data could be used to diagnose and resolve problems with building performance and be used to diagnose and resolve problems with actor performance. Whilst the contextual pressures present a set of barriers that hinder effective collection, storage and dissemination of data, feedback platforms can overcome the barriers in the contextual pressures by increasing interest in energy and feedback use by:

- Creating value
- Create a reputational benefit
- Overcoming risk and barriers
- Altering the contextual pressures
- Supporting actors

4. Suggesting alterations required to the contextual pressures to facilitate this.

Changes need to be made to the contextual pressures and actors' behaviour to implement this future role of feedback including alterations to:

- Benchmarks
- Legislation and regulation
- Planning Policy
- Certification
- Incentives
- The procurement Process

Chapter Summaries

The following sections summarise each chapter in turn. Figure 1.1 illustrates the thesis structure and work flow.

Chapter 2 – Literature Review

The literature review is of academic and other documentation around the role of feedback, the ‘energy gap’, building energy performance and actor interaction with energy data. The review was carried out using standardised search terminology and a ‘snowballing’ sample strategy. The review sets up the study through identification of a set of research questions based on the gaps in the literature and aims of this study.

Chapter 3 – What is the context for actor decision making in the UK design, construction and management industries?

This chapter describes the framework of contextual pressures that influences actors’ behaviour when making decisions that can affect building energy consumption. Participant observation was carried out at a series of consultant development meetings and stakeholder focus groups during the early stage development of CarbonBuzz. A review of the legislation affecting building development was also carried out.

The legislation and document review was used to define a formal framework. This is comprised of directives, legislation, certification schemes, tax breaks, planning guidance and other mandatory or voluntary regulatory or market-based mechanisms aimed at controlling building energy consumption, encouraging feedback use or managing the procurement process with particular regards to energy (although these measures are often part of broader ‘sustainability’ targets). The participant observation phase resulted in the definition of an informal framework of ‘informal’ pressures. These can be actual or perceived pressures and include economic and social pressures, aspirational goals, professional obligations, aims and barriers that prevent industry engagement with energy data and building performance evaluation.

The chapter sets out this framework against the typical development timeline for buildings in the UK, identifying when pressures apply, which actors are involved in the process at each stage and what metrics the pressures use, if any. This illustrates a complex network of actors, pressures, decisions, indicators and performance criteria that is used as the basis for the methodological design.

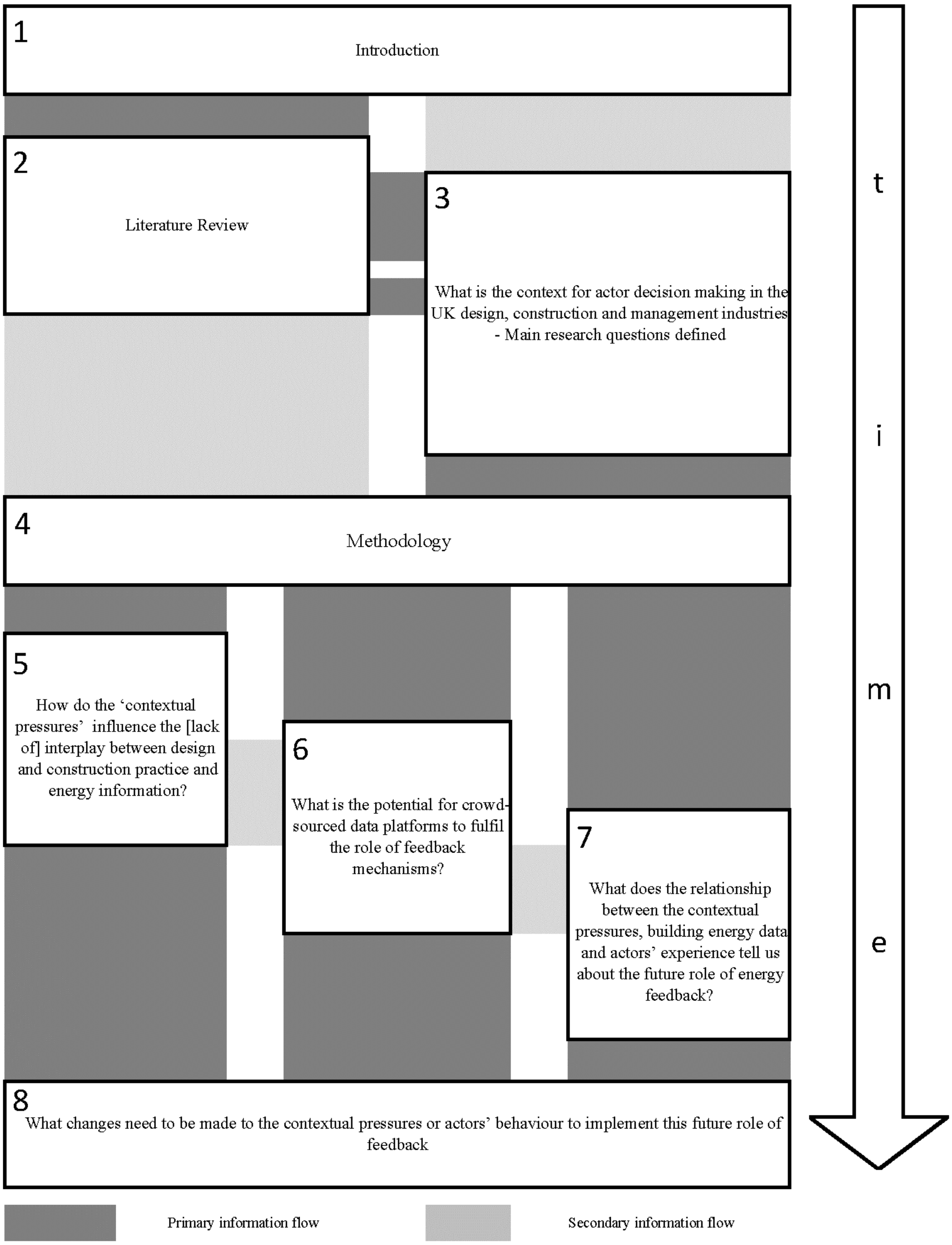


Figure 1. 1 Thesis structure and workflow.

Chapter 4 – Methodology

This thesis uses a mixed methodology for the main empirical research. The use of feedback involves quantitative energy data and qualitative actor interactions; combining quantitative and qualitative research in one study can be complex and contradictory.

The main study uses an internet survey, analysis of energy data from CarbonBuzz and a series of semi-structured interviews. Each strand of the research is given equal weight; the survey was carried out first and then the longitudinal analysis of the energy data and the interviews were carried out concurrently. The chapter describes the data collection, cleaning, quality assurance and analysis procedures implemented in each phase.

Chapter 5 – How do the 'contextual pressures' influence the [lack of] interplay between design and construction practice and energy information?

This is the first data analysis chapter. Data were collected via an internet survey. 503 actors responded to a set of questions based on the themes established in the description of the contextual pressures. The survey used a list and an area frame to generate a sample from across design, construction and management industries. Questions tested the contextual pressures' influence on how actors make decisions that might affect building energy consumption. Actors were questioned on their professional and personal motivations and attitudes as well as the kind of work they were involved in; this profiling was applied to the way that project energy targets are set and how actors interact with energy data.

Chapter 6 – Does building energy consumption reflect actors' experience of working within the contextual pressures?

Following analysis of the survey data, the CarbonBuzz database was analysed to explore the nature of the energy gap, how it relates to both the contextual pressures and if the data are suitable for feedback use. Data were taken from the CarbonBuzz platform annually from 2011, 2012 and 2013. Changes to the database, uptake of the platform and the profiles of the users are recorded. Data was then analysed to explore the energy gap, if it is represented in the database and if it varies between different sectors and energy end-use types and other contextual pressures.

Chapter 7 – What does the relationship between the contextual pressures, building energy data and actors' experience tell us about the future role of energy feedback?

Following initial analysis of both the survey and energy data, a series of semi-structured interviews were carried out to build on this quantitative data and understand in greater detail the issues surrounding feedback. 23 interviews were carried out and were analysed in sequence; data collection ended when the data was felt to have reached ‘saturation point’. The initial semi-structure was based loosely on the themes of the contextual pressures and interviewees were encouraged to speak openly around the subject.

Chapter 8 – What changes need to be made to the contextual pressures or actors’ behaviour to implement this future?

The discussion chapter draws on all of the empirical data collected and used in the preceding three chapters. A future role for feedback is set out as a discussion of the interlocking roles that data, delivered via an interactive database, needs to play in industry to deliver building energy consumption reductions. These roles include encouraging industry to engage with post occupancy evaluation (POE), expressing the inherent value in feedback data itself and the support that feedback must offer actors during the procurement and management processes. The final section of this chapter presents revisions to the contextual pressures aimed at delivering this future role of feedback.

Chapter 9 – Conclusions and further work

The final chapter recaps on the work done and the methodology used and concludes with some ideas for future investigation stemming from the work in this thesis.

2 Literature Review

Using the aim set out in the introduction, this literature review seeks to outline the present role of energy consumption information feedback in the building design and management industries and define further research questions. The chapter is organised by outlining current thinking on feedback and Post Occupancy Evaluation (POE), professional responsibility, benchmarks, building energy consumption, the design process, actor networks, information communication, data quality and existing crowd sourced web platforms.

2.1 Feedback and Post Occupancy Evaluation

Feedback is defined by the Oxford English Dictionary as "*the modification or control of a process or system by its results or effects"* (Soanes & Stevenson 2008). The *process* that this thesis is concerned with is the design, construction and management of buildings and the *result or effect* of interest is the energy consumption of finished buildings. Cohen et al describe the aims and process of using feedback to:

> *"…make buildings better for their occupiers, individual users and the environment; and provide a continuous stream of information for benchmarking and continuous improvement"* (Cohen et al. 2001).

The collection of building performance information, notably by the Post-Occupancy Review of Buildings and their Engineering (PROBE) studies, has revealed that it is typical for the actual energy use of a building to be two or three times that of design predictions (Bordass et al. 2010). The PROBE studies identified a complex network of reasons why predicted energy consumption is lower than recorded end use. These include actors using incorrect assumptions in design calculations, making changes to a building design during construction, a poor design, poor construction, poor management of finished buildings or a combination of some or all of the above and more (Bordass et al. 2010). This discrepancy has been the focus of significant research funding through the Technology Strategy Board's Building Performance Evaluation (TSB BPE) programme which began in 2010 (Technology Strategy Board 2010).

Whilst legislation and guidance attempt to increase awareness of the need to reduce building-related carbon emissions, what is perhaps not explicit is:

> *"the fundamental importance of integrated feedback, feed forward and POE to the development and refinement of new techniques and technologies that are central to ensuring that sustainable strategies work in practice"* Mark Way quoted in (BSRIA 2009).

Bordass et al. argued that the tacit knowledge of design teams is not being integrated into improvements to buildings' performance (Bordass et al. 2001) and where existing feedback loops are in use, they are not often formalised nor do they fully exploit the opportunity to improve matters. Leaman et al recognised this as a problem a decade later:

> *"...most designers base their future design work on a combination of previous experience combined with innovation. However, this experience is usually tacit knowledge that is not formally articulated, transmitted or archived for future use"* (Leaman et al. 2010).

The Department for Trade and Industry identifies information flow as a key component to delivering energy efficiency in the commercial sector generally; this includes provision for making information available to businesses on both current energy consumption and potential improvements in efficiency (para. 2.19, Department of Trade and Industry (DTI) 2007). Faruqui et al. have shown that in the domestic sector, information feedback can reduce electricity consumption by up to 14% depending on the circumstance of use (Faruqui et al. 2010).

It is not just energy improvements that can be made through the integration of feedback: the Royal Institute of British Architects (RIBA) recognises the broader service improvements that could be offered by greater understanding of finished buildings. They said that of all of the interaction between clients, building users and architects, the greatest improvement in the service that architects offer would come from *"the provision of systemised feedback and in instituting POE"* (Jaunzens et al. 2003).

Systematic information flow should allow professionals to admit to and openly discuss problems with systems and building performance. This in turn should raise awareness of energy and occupant satisfaction benchmarks and improve the process of collecting and sharing data. Feedback should therefore occur at all stages of the procurement process throughout design, construction and management (Cohen et al. 1999).

In order to provide information at all stages in the process, feedback must be focussed to delivering the correct information and provide clear outcomes for both building performance and professional service improvement:

> *"Effective feedback needs to provide objectivity, and lead to action and insight. It should improve the performance of the studied building; this is nearly always possible, but needs motivation and commitment to improve the services of those who provided it: this is always possible but needs connection, motivation and knowledge management at the organisational*

> *level to contribute to a wider knowledge base so that insights are disseminated and are more than anecdotal"* (Leaman et al. 2010).

Leaman et al. go on to define what the kind of information should be supplied to offer the 'best kind of feedback':

> *"The best kind of feedback is named case studies backed by extensive data, benchmarked against a national sample, finishing with a list of lessons learned, including reflections on the results by the parties directly involved and especially the design team."*(Ibid.).

Developing a knowledge base with sufficient depth requires systematic data collection. Post Occupancy Evaluation (POE) is the *"the act of evaluating buildings in a systemic and rigorous manner after they have been built and occupied for some time"* and is the starting point of the feedback process (p. 8 Preiser & Vischer 2005). For example, the scope of the PROBE investigations was to assess a range of post-occupancy issues including design and construction, design integration, the effectiveness of procurement, methods of construction and the initial occupation of the building, commissioning and handover procedures (Bordass et al. 1995). The TSB BPE programme aims to understand the performance of different building types, design strategies, construction methods and occupancy patterns, and the relative contribution of various factors to the eventual performance of the building (Technology Strategy Board 2010).

Post Occupancy Evaluation is an essential component of the feedback loop. The practice of POE has been established for many years with varying levels of adoption and success (Riley et al. 2009). The aim of POE is to assess how *"buildings and their services are being operated, controlled and maintained"* (Bordass et al. 1995). POE must allow both building users and designers to understand how buildings operate and provide information that can lead to better management procedures or designs (Leaman et al. 2010). POE could be defined as the starting point; Whyte and Gann were more explicit about the benefits of POE to practice generally. They argue it could help professionals apply skills with greater effectiveness, improve the commissioning process, improve adherence to user requirements, improve management procedures, offer valuable knowledge for guides and regulatory design processes and target refurbishment (Whyte and Gann 2001 cited in Riley et al. 2009).

Preisner and Vischner (2005) identify four simple questions that can lead to the kind of valuable feedback data that Leaman has described: *"How is this building working? Is it intended? How can it be improved? How can future buildings be improved?"* Cohen et al described the process of gathering, storing and applying information to improve buildings as establishing a 'virtuous circle' split into 'successes' and 'problems'. They defined the use of information as ‘diagnosis’ and ‘advocacy’ - identifying and solving immediate problems or sharing information more broadly for wider learning and re-application of successful strategies (Cohen et al. 1999). POE has also been described as a process of learning and continual improvement in the construction industry beginning with diagnostics and improving of immediate functionality, followed by the advocacy of longer term learning that changes organisations’ or individuals’ values, attitudes and modes of operation (Cooper 2001; Roberts 2001).

Cooper identifies three areas in which POE data can be applied as feedback; as a ‘design aid’ to improve building procurement and design stage decision-making; as a ‘management aid’ measuring ongoing building performance and occupant satisfaction; and as a ‘benchmarking’ tool for measuring performance in a broader context and tracking ongoing improvements (Cooper 2001). This categorisation omits the construction phase of building procurement and the broader legislative context that informs all three. According to Stevenson, feedback needs to inform future decision making at all levels of policy, building design and the procurement process (Stevenson 2009).

Investigating buildings and integrating this information into future design and management be carried out through a number of mechanisms: insight – defined as reviewing current performance to make amendments and benefit now; hindsight – to learn from past decisions and performance to benefit now and foresight – to learn from the past or present to benefit in the future (Leaman et al. 2010). While the differences between these mechanisms are subtle and dependent on the point of view of the reviewer and decision-maker, they all require the collection, collation and dissemination of data.

The gathering and dissemination of information is important to producing good buildings, not just from an energy point of view *"sharing information is of paramount importance to achieve good quality buildings."* (Andreu & Oreszczyn 2004). The risks of not instigating effective information flows and management strategies are outlined by Leaman et al:

> *“Without adequate inputs of management and maintenance resources, buildings may quickly assume vicious circles of deterioration and disfunctionality. This process usually starts with poorly executed handover and commissioning, so that chronic performance inefficiencies are built in from first occupancy. Once present, these can become embedded, and then quickly create conditions for chronic failures like occupant discomfort and poor energy performance. This results in a vicious spiral of further performance deficiencies.”* (Leaman et al. 2010).

As a counter this 'vicious circle' and expansion on Cohen et al.'s 'virtuous circles', Roberts suggested that the information generates 'loops of learning', providing the continuous and circular information flows that enable insight to be turned into improvement. Argyris and Schon, (1978) cited in (Roberts 2001) posit that:

> *"real learning takes place when the first loop leads to a second loop which changes an organisation's values, attitudes and mode of operation".*

Roberts puts the onus for carrying out this work with practitioners*: "POE is the responsibility of the industry – NOT the client"* (Roberts 2001). However, there are barriers specific to POE that can prevent it being carried out habitually by industry, summarised as costs, defending professional reputations and a lack of time and skills by (Vischer 2001 in Riley et al. 2009). There is also a potential conflict of interests involved in practitioners evaluating their own work, highlighted by Andreu and Oreszcyn: *"it may be difficult in industries where impartiality is a requirement of assessment for designers to be involved in the assessment of their own work".* However they also recognise the benefits of carrying out POE work and the value inherent in practitioners evaluating their own work: *"...however it is thought that building POE benefits from knowledge of a project through having worked with the brief. Applying critical thought to one's own work is therefore an integral part of POE"* (Andreu & Oreszczyn 2004).

The TSB BPE programme relies on practitioners evaluating their own work. The fact that this evaluation has to be funded by outside agency rather than by industry itself suggests that industry is failing to meet its obligations. This is confirmed by Duffy and Rabeneck (2013) who argue that architects and the related professions are largely responsible for the lack of knowledge base that connects designs with finished buildings (Duffy & Rabeneck 2013). Meeting the requirements for information provision by providing an industrial environment in which actors feel like they can honestly and thoroughly evaluate performance is crucial.

There is an overall impression that POE work has fallen between the many professional responsibilities in the construction industry; that nobody has ownership over the practice and because of this it is easy to ignore. Bordass speaks of the need to counter this through a change in the role of the construction industry professional by creating a *'new professionalism'* and environment in which the use of feedback becomes habitual (Bordass & Leaman 2013). When barriers are overcome, POE can be carried out in two ways, as a:

> *"one-off, at a specific point in time, as a means of quantifying a building's absolute performance in terms of resource consumption* [or other metric]*...longitudinally, during a building's life-time, to identify where and*

> *when its envelope, services or other components need up-grading or replacing in order to improve its performance and extend its longevity."* (Cooper 2001)

The role that feedback needs to play is complex because of the diverse range of collectable data and ultimate use of the information. For example, feedback can be applied to existing or future buildings and needs to reflect the context in which the information is applied. The method and type of information collected depends on the aims of the evaluation, the intended use of the information and other practical constraints such as time and costs. A range of collection methodologies have been developed. They range from informal building walks to structured mixed method studies including energy audits, focus groups, questionnaires and interviews and data from meter readings or bills.

Typically a POE study can include; fabric testing, energy assessment and survey, in-use monitoring of internal and external temperatures, humidity, lighting, CO_2 levels, water consumption, opening/closing of doors and windows using data loggers, wireless sensors and/or whole house monitoring kits, occupant feedback (on behaviour, perceptions, comfort and satisfaction levels), occupant feedback begins with a survey, then an open-ended questionnaire, then appliance energy use surveys, video or photographic analysis (Gupta & Chandiwala 2010; Leaman et al. 2010; Riley et al. 2009)

The selection and use of feedback method may depend on what is being investigated and which problems are being solved.

2.2 Professional Responsibilities

One of the key conclusions from the PROBE studies underlined the need for the conditions of engagement for designers to *"include formally a feedback stage after practical completion (when it can be naively assumed that their job is complete and they should go away)."* (Cohen et al. 1999). While this has not been made compulsory; the 2013 update of the RIBA plan of work – an industry-wide method of organising the procurement process of buildings – has reintroduced a voluntary POE stage after removing it in the 1960's (Sinclair 2013).

The requirements for long-term feedback, the foresight or hindsight identified by Leaman et al are perhaps broader in scope because of the greater range of people that need to share the aims. In Stevenson's review of POE, she discusses the requirements for integrating feedback into the building procurement process. POE should be:

> *"(a) built into the original design brief to ensure that it is carried out (b) implemented during the design process to ensure that the design team is*

> *aware of what is going to happen (c) followed through during the build and commissioning process to make sure that the feedback methods can be implemented (d) and finally linked to the use and maintenance of the building to ensure that the feedback is actioned effectively"* (Watson and Thompson, 2005 cited in Stevenson 2009).

Using feedback to complement existing and new legislation, incentives, tools, and work flows requires an understanding of these mechanisms. Feedback needs to be considered in relation to all stages of the design, construction and management processes (Andreu & Oreszczyn 2004). Leaman et al summarise what feedback needs to positively affect:

> *"The design and building process: including appointments, design, project management, construction, coordination, cost control, build quality, commission and handover. The building as a product, the outputs: what is it like, what it costs, its fitness for purpose, and how professionals and the public react to it. The building performance in use: the outcomes, the technical, for the occupier, for users, financial, operational, and environmental."* (Leaman et al. 2010).

POE and feedback are not part of current habitual professional activity; there is a range of practical, financial and other reasons why this is the case. The disincentives, whether actual or perceived, can perhaps be traced from a cultural shift in industry thinking beginning with the removal of Stage M (Post Occupancy Evaluation) from the RIBA Plan of work in the 1960s. Stage M originally obliged architects to carry out POE on recently completed buildings but was removed after lobbying from the architectural profession itself who believed this was work for which they were unlikely to be remunerated (Way & Bordass 2005).

As the industry and professions have developed from the 1960's, the reasons why POE is not carried have also become more complex. The reasons include: a reluctance to pay for the evaluation to be carried out (BSRIA 2009), which can be because clients cannot see the benefit to themselves or their buildings because they perceive their building to be 'finished' (as opposed to future clients of the design team). There can be a lack of engagement with the building occupiers on the part of commercial clients due to disinterested landlords or buildings being sold soon after completion. Others are uncertain about how to carry out evaluations and there appears to be no immediate and apparent financial benefit (Bordass & Leaman 2005). Industry does not perceive the value in the information gathered through POE, particularly commercial benefits as they are not often clear and are not perceived to match the outlay in gathering information (Jaunzerns cited in

Andreu & Oreszczyn 2004). There can be a perception from within industry that gathering 'evidence' of a building not functioning as was intended might expose practitioners to extra work (and therefore costs) beyond the scope of an initial appointment or even litigation (Jaunzens et al. 2003). There is also the practical issue that POE information is not used to inform designers' work as it is often published in places that are not often accessed by industry (such as academic journals) and practitioners are often left to use previous ideas again or reinvent things blindly (Vischer 2009). Finally, existing standard procurement procedures can mean that the requirements for designing and commissioning more unusual or innovative buildings are not met (Short et al. 2009).

An example of the interplay of these barriers is described by Short et al in the process of commissioning a 'non-standard' innovatively ventilated building through a modern procurement process. In the case of the School of Slavonic and East European Studies at University College London (UCL) in Central London, a complex passive strategy was developed within the constraints of the London heat island with significant design team and academic input (Short et al. 2004). The resultant building suffered from an overly complex procurement process (aimed at reducing risks) where communication between the design team and commissioning engineers was indirect. 'Value engineering' (a process meant to identify cost efficiencies) meant that the contractual allowance for commissioning engineers was an order of magnitude lower than required and the subsequent lack of information, poor communication and resources to solve problems meant that a building that had a significant amount of expertise involved in the design performed below expectations (Short et al. 2009).

These cultural and practical hindrances to POE coupled with the construction industry's reluctance to invest in research and development (R and D) has created a discrepancy between legislative aims, design predictions, industry goals and actual building performance. (The European Commission figures for 2010 show the 'Construction and Materials' sector R and D spend to be less than 1% of annual turnover, whereas comparable industries like 'Automobiles and Parts' spend between 2 and 5% of their turnover on research and development (European Commission - Joint Research Centre 2011)).

In the context of an industry that does not habitually carry out POE, Bordass and Leaman's 'new professionalism' advocates a shared vision, better procurement processes and proper use of knowledge about buildings' performance in use (Bordass & Leaman 2013). The issues that must be overcome if feedback is to be integrated into the procurement process could be characterised as: practical difficulties, financial risks, unclear benefits and technical problems.

2.3 Benchmarks and Building Energy Consumption

Examples of vernacular architecture across the globe demonstrate empirically developed responses to very specific local environmental conditions using locally available materials. These variations include thermally massive homes in North Africa, lightweight houses on stilts in the tropics and low-profiled cottages in the highlands of Scotland. The iterative and progressive process that generated these building models could be described as a circular feedback loop – the occupant possibly being the client, builder, and designer. Problems could be identified and modifications made to the building to rectify them, information on improvements could be passed around small communities relatively easily. In a more complex context, part of the designer's role is to examine the conditions of a site, establish the acceptable and desirable criteria for the conditions within a building and attempt to create these conditions using the fabric of the building and energy-consuming services to make up the shortfall in performance (McMullan & Seeley 2007).

The factors that affect energy use encompass everything from the location of a building to the number of appliances plugged in. Hawkins et al (2012) have identified a number of parameters that influence energy consumption. Some parameters were identified to have more influence on heating fuel consumption, others on electrical energy consumption. The broad parameters, in order of decreasing influence were: heating fuel, building activity, primary construction material, glazing type and ratio, building environment (system type and comfort conditions), building age, geometry (height and aspect ratio), adjacency shading and sheltering and weather conditions.

A composite list of factors that impact on the energy consumption in a building is presented in table 2.1 alongside the information collected in CarbonBuzz that could deliver the same information (gaps show where there is no equivalent in the two lists).

Composite List of Parameters	CarbonBuzz Parameters
Location (climate, weather, exposure, overshadowing Building age	Building Location Building Use Ownership and Tenancy
Building activity Building environment (comfort conditions) Weather data (location)	Building Use Number of Zones Ownership and Tenancy Occupancy rates
Primary material Glazing type and ratio Geometry Building environment (system type)	Embodied Energy Air tightness Dimensions Building Fabric Servicing strategy Low or zero carbon technologies
Heating fuel Building environment (system type)	Number of Zones Servicing strategy Separable Energy uses Air tightness Low or zero carbon technologies
Primary material	Embodied Energy Air tightness Building Fabric
Geometry Primary material Glazing type and ratio Adjacency shading and sheltering Building environment (system type)	Embodied Energy Air tightness Low or zero carbon technologies
Primary material Glazing type and ratio Building environment (system type)	Embodied Energy Air tightness Building Fabric
Building activity Building environment (comfort conditions) Management Controls	Building Use Occupancy rates Facilities management strategies Number of Zones Ownership and Tenancy
Building environment	Ventilation Type
Geometry Primary material Glazing type and ratio Adjacency shading and sheltering	Building Location Building Use Building Fabric
Building activity type Occupancy Levels	Building Use Occupancy rates
Equipment and appliances (how many, of what, when used	Equipment and appliance energy end-use

Table 2. 1 Building factors that impact on energy consumption compared with characteristics captured by CarbonBuzz. (CarbonBuzz.org, Hawkins et al. 2012; Krope and Goricanec in Mumovic & Santamouris 2009).

The interaction of these elements is a complex network of physical, behavioural and climatic factors. The design team must make decisions that create a coherent and efficient design solution. Leaman, Stevenson, Hawkins and others have shown the complexity of issues surrounding POE, data analysis and building performance and therefore required in corresponding feedback data.

Improving building performance through the use of feedback and POE requires comparison with existing and industry-wide performance levels and defined standards. These may be based on previous performance characteristics in order to track changes or may be associated with a peer group of similar buildings to contextualise performance. Rab Bennets of Bennets Associates Architects recognises the importance of being able to definitively recognise good - and poor – performance in the context of a 'green' building:

> *"we're past the stage on environmental thinking where you can just call something green because you believe it's green. We actually have to find some way of quantifying it or rely on some scientific background to say: 'Yes, it really does help'."* (p.9 Roaf et al. 2004) .

In order to identify which measures really help improve building performance, building performance must be defined. Metrics must be established that provide longitudinal comparison, identify where energy is used in buildings and provide a way of quantifying predicted and actual performance as a means of reducing long-term energy consumption. This industry-wide set of key performance indicators (KPIs) must relate all of the energy use factors and provide a robust and scientific background for meaningful analysis and comparison with other buildings (Palmer 2009).

The Chartered Institute of Building Service Engineers' (CIBSE) Technical Memorandum (TM) 46 defines the existing set of energy benchmarks for the UK that are the basis for DEC benchmarking. One of the stated purposes of TM46 is to provide designers and managers with a yardstick against which designs and records can be measured: it is *"all about tracking performance and identifying opportunities for improvement"*(CIBSE 2008). Current benchmarks as described by TM46 set total electricity and fossil fuel consumption figures categorised by building use type. ECON 19 (later ECG 19) established the first set of Office energy consumption benchmarks in 1995, which were introduced on a voluntary basis (Carbon Trust 2003). The TM46 benchmarks are based on this early publication, supplemented with data for other building use types and with some amendments to provide better support to DECs (CIBSE 2008).

Apart from a 2008 update the benchmarks have not changed to reflect developments in other aspects of the legislative framework and building use that impact on building energy consumption. Bruhns et al (2011) have shown that the TM46 benchmarks, while often superficially accurate for total energy use, frequently do not properly reflect the actual energy consumption patterns in some building sectors. They identified a trend for higher electricity use and lower heat consumption than the TM46 benchmark values in school buildings. This is reflective of the legislative move towards improved thermal performance in building fabric and a behavioural shift in users' increased use of electronic equipment: higher than expected electricity use is cancelled out by lower than expected heat consumption (Bruhns et al. 2011).

The use of DECs supported by TM46 has attempted to establish a culture of feedback in UK public buildings. However, Bull et al have shown report and display certificates like DECs to be an effective catalyst for engaging building users with energy reduction but also show that more detail is required to offer the kind of insights that can drive energy consumption down. If feedback mechanisms are to deliver significant reductions they need to be part of a wider strategy complete with more detailed energy-based case studies, utilising a more accessible means of information dissemination (Godoy-Shimizu et al. 2011; Bull et al. 2012).

Setting targets for building energy performance or any other variable therefore requires large data sets and detailed data. Bull et al, Godoy-Shimizu et al. and Leaman and Bordass have shown that benchmarked key performance indicators must go beyond simple energy consumption data and include detailed information made available through detailed POE.

2.4 The Design Process

There is currently no tradition of integrating feedback into briefing, design and management of buildings and no meaningful connection between POE and the design process (Vischer 2009; Szigeti & Davis 2002). The building design process itself must draw together many competing factors into a coherent whole. The aims of design could be summarised as identifying the relevant elements pertinent to a project and understanding how these elements interact with each other in order to arrange the elements in an appropriate or meaningful way so that they create a competent product (Tunstall 2012). There are many theoretical models of the design process and practical models used to organise the building procurement process, starting with a simple linear four-stage model:

1. *"'Exploration' – examining different ways of approaching a problem;*
2. *'Generation' – developing a solution or solutions to the brief;*
3. *'Evaluation' – testing the developed solution against briefing criteria;*
4. *'Communication' – disseminating the final design solution*" (p.36 Cross 2001).

Cross has identified an integral feedback loop naturally present in any design process: the 'evaluation' stage, reflections from which are used to refine the ideas and to revisit the 'generation' stage of the process. A more complex linear process is described by Pahl and

Beitz (1984), with five stages used to carry out a design task (Pahl & Beitz 1984). These stages are:

1. *"'Specification' – used to elaborate on and define the task;*
2. *'Concept' – identifying the essential problem, develop solution principles and evaluation criteria;*
3. *'Preliminary Layout' – the development of preliminary layouts and testing them against evaluation criteria;*
4. *'Definitive layout' – the optimization of the layout, checks for costs and evaluation against criteria;*
5. *'Documentation' – the finalisation of the design and production of construction information. This results in a 'solution'"* (p. 37 Cross 2001).

Both of these design process models describe a linear process with self-contained evaluation procedures. More complex cyclical thinking is reflected in a design process model developed by March. The model is non-linear and attempts to integrate three evaluative methods:

- *"'Deduction' – using theoretical understanding to inform design to make a prediction of performance (informed by and informing data and design characteristics);*
- *'Induction' - making suppositions based on valuations of design characteristics (informed by data and performance predictions);*
- *'Production' /'Abduction' – using data and models to describe a design proposal (in turn informed by design characteristics and theories)"* (p. 41 Cross 2001).

These models of the design process all include a feedback loop, the scope of which is internal to the designers involved and only applies to evaluation and review of the current work against project and organisation-specific briefing criteria. This is not a new idea:

> *"It is critical that we increase the influence of evaluation in the design-evaluation-design cycle. There are a number of ways to do so. (a) Evaluation should be taught to both design students and working professionals. (b) The academic reward system must be changed so that evaluation activities are given due academic recognition alongside the more conventional research and publication activities. (c) More attention needs to be given to the style and format of reports, especially those directed at designers. This might include redoubled attempts to use clear, non jargonistic prose and more extensive use of graphics," (p. 193 Friedmann et al. 1978).*

Friedman also introduces the idea of expanding this evaluation period or introducing information from broader sources as the aim of energy feedback, and the idea of graphic representation of evaluation data.

In industry, the design process is organised around the broader building procurement process. The RIBA Plan of Work is one of the accepted models for organising the procurement of buildings in the UK. The plan of work attempts to integrate the design process into the broader process and has recently been updated to reflect changes in the industry. Both the 2013 version and the previous model are presented in table 2.2 for completeness, although this research was centred on work carried out within the 2007 version. The previous model ran through stages A to L with an optional stage M reintroduced in 2012. CarbonBuzz stages are also shown to contextualise the platform.

2013 RIBA Work Stage		2007 RIBA Work Stage		Summary of Key Tasks	CarbonBuzz Work stages	
0	Strategic Definition	A	Appraisal	Identify project objectives, client business case, develop project brief, feasibility studies and assemble the project team.	Acquisition	The selection and purchase of a site or existing building for development
1	Preparation and Brief	B	Preparing Strategic Brief			
2	Concept Design	C	Outline Proposals	Preparation of a concept design, review the procurement strategy, finalise design responsibility and performance specified design criteria.	Design	Development of a set of proposals to meet the brief on the acquired site.
3	Developed Design	D	Scheme Design and Planning	Preparation of a developed design and project strategies, prepare and submit a planning application		
		E	Detail Design and Final Proposals	Prepare technical design, prepare and submit building regulations submission		
4	Technical Design	F	Production Information			
		G	Tender Documents			
		H	Tender Action			
5	Construction	J	Project Planning and Mobilisation	Progression of specialist design by subcontractors including integration of performance specified work.	Construction	The physical assembly of the design proposals on site or the adaption of an existing building.
		K	Construction to Practical Completion			
6	Handover and Close Out	L	Post Practical Completion	Offsite manufacturing and onsite construction, administration of building contract, resolution of design queries from site, implementation of Soft Landings.	Commissioning	The process, just after completion, of ensuring that the building and in particular servicing systems are set up as intended
7	In Use	(M)	Feedback (Optional – introduced in 2012)	Implementation of Soft Landings and POE, conclusion of administration of the building contract.	Operation	Use of the building.
					End of Life	Decommissioning and disposal of the building, which feeds in to a new ‘Acquisition’ stage.

Table 2. 2 2007 and 2013 RIBA Plan of Work with CarbonBuzz works stages. (Fulcher & Mark 2012; RIBA 2007; RIBA 2013; www.carbonbuzz.org n.d.)

Due to the changing emphasis in the legislative framework surrounding building design, the RIBA acknowledged the need to integrate guidance on ‘sustainability’ into the design process. To this end, in 2011 they published the ‘Green Overlay’ to the Outline Plan of Work in order to:

> *“Amend the succinct wording of the Outline Plan of Work…to clarify the issues, and their timing, in response to the growing imperative that sustainability is actively considered in the design and construction of buildings”* (Gething 2011) .

The overlay suggests a series of assessments that should be carried out and issues that should be considered throughout the existing procurement process. For example Stage D ‘Design Development’ is adapted to read (Green Overlay additions are in bold):

> *“Development of Concept Design including outline proposals for structural **and environmental** strategies and systems, site landscape **and ecology**, outline specifications, preliminary cost **and energy plans**.”(Ibid.)*

The green overlay adds nothing to the construction or post practical completion stages and does not mandate the use of any further expertise or validation of decisions, only consideration of environmental issues. However, the inclusion of these simple statements does imply a requirement for greater knowledge of environmental concerns and therefore arguably moves the profession closer to engaging with feedback independently of obligation.

CarbonBuzz simplifies the design and procurement process and extends it to a six step *circular* process that focuses on the entire lifecycle of a building. Understanding who is involved in this process and where responsibility lies in the design process will help to target feedback.

2.5 Actor Networks

The network of actors involved in the procurement process – the socially regulated network of decision makers - operates within a framework of legislation, economic drivers, professional aspirations and social pressures. Within this overall framework there are individual motivations that can influence the overall performance of the team and the resultant building (Bartlett & Howard 2000; Short et al. 2009). The actors include; the design team, clients, a contractor and various sub-contractors, regulatory assessors and managers and occupants. These are illustrated in table 2.3.

Sub group	Actors
The Design Team	In the UK this is typically made up of an architect, a services engineer, a structural engineer, a quantity surveyor, perhaps a planning supervisor and a sustainability consultant.
The Client Group	May include developers, funders, estates managers, land-lords and owner-occupiers.
The Contractor	Typically comprises a main contractor or a managerial team and numerous trades either employed directly or sub-contracted.
Regulatory Assessors	Can include building control and planning officers as well as some others depending on the building type and funding mechanism such as the Building Research Establishment Environmental Assessment Method (BREEAM) compliance auditors.
Facilities Managers	Can include portfolio landlords, on-site building managers and specialist auditing organisations.
The Occupants	May include tenants, owner/occupiers, institutional occupiers and facilities managers. These different actors have different involvements, interests and responsibilities at different stages in the process.

Table 2. 3 A typical UK project team (RIBA 2007).

These actors engage with each other under a common understanding of industry operation. Biggart describes the collective mental model as a set of '*social heuristics'* that are comprised of three components; the *'consensus heuristic'* reflecting the common and shared understanding of the current market operation which allows actors to make decisions in an assumed and known context; the *'reflexivity heuristic'*, which provides actors with a basis for speedy evaluation and justification of decisions within the understood industry consensual paradigm; and the *'reproduction heuristic'* offering individuals guidance on how their decisions can sustain their reputation and position in the organisational network. Lutzenheiser also argues that this network of influences has an impact on how construction industry actors operate:

> *"[the] behaviour of firms seems to be shaped by a combination of cultural, institutional, macro-social/economic and technical factors…many of these factors are likely to influence the ability of an organisation to innovate"* (Lutzenhiser 1994).

The construction industry is generally viewed as conservative and non-innovative (Håkansson & Ingemansson 2013). Koskela and Vrijhoef argue that this conservatism and the underlying status quo of construction is an impediment to innovation;

> *"the myopic control and the fragmented, unstable organization of supply chains frustrate problem solving and innovation between different actors and stages in the chain"* (Koskela & Vrijhoef 2001).

This myopia and instability can be attributed to the conditions, actual and perceived, that create the reasons that regular POE is not carried out and affects industry. The context for building procurement influences actors' ability to innovate. Janda and Parag argue that the top-down and bottom-up approaches of existing mechanisms are in fact the problem: they miss the decision-making actors in the middle who are often most influential in the process. They advocate a 'middle-out' approach to energy policy and decision making, placing the onus with the decision-makers rather than policy-makers or building-users (Janda & Parag 2013).

CarbonBuzz allows for a project team to be defined by the following eleven actor types: a funder, a client, an architect, a services engineer, a structural engineer, a sustainability consultant, a contractor, a facilities manager, an approved inspector, a planning authority and a tenant Table 2.4 provides brief descriptions of different actors' roles and responsibilities.

Actor	Role
Funder	This may be the same person or organisation as the client but will pay for the building and likely demand a return on investment.
Client	The person or organisation responsible for commissioning and constructing a building and defining the brief.
Architect	The designers of the building, they translate the client's ideas into an acceptable design and then into a buildable building incorporating other planning and regulatory pressures.
Services Engineer	Provides advice, specification and schematic drawings to integrate building service into the architect's design.
Structural Engineer	Design and advise on the structure of a building from ground conditions up to the roof and take into account services.
Quantity Surveyor	Financial management of the project.
Sustainability Consultant	Provides advice, specification and supporting documentation for sustainable aspects of a building design, including energy.
Contractor	The organisation responsible for building the building, in direct contract with the client. Will often employ a range of sub-contractors.
Facilities Manager	Manages the finished and occupied building, looking after everything from cleaning to energy consumption.
Approved Inspector	Evaluates and ultimately approves a building design and completed structure as compliant with building regulations.
Planning Authority	The local authority in whose borough a building is built. They grant permission for development based on a local policy framework.
Tenant	The building occupier.

Table 2. 4 The roles of various actors in the construction industry (Chappell & Willis 2010).

The motivations of each of these actors may be very different. For example, often the only people with a financial interest in a building are the owner and perhaps the tenant and even then, their interests can be very different; a developer's interest in energy efficiency may only be influenced by those measures that have a marketable value in letting or selling a building. Cost to tenants can be associated with the running costs of a building but also can be associated with loss of productivity due to a poor environment. Both developer and tenant can be affected by poor buildings financially and functionally (Bartlett & Howard 2000).

Recognising the limitations of existing actor roles, the PROBE studies reflected on the different roles of actors in the construction industry and provided recommendations for the activities of individuals to ensure that a better quality building resulted from a procurement process. Their recommendations were targeted at broad groups, far beyond the design team, and are summarised in table 2.5.

Actor	PROBE recommendations
Clients	Establish clear ends and objectives, with realistic assumptions about occupiers/likely occupiers, use quantitative benchmarks, be vigilant about progress, review results regularly.
The design team	Don't turn means into ends, set expectation levels and be clear who owns which problems, seek to understand buildings and apply this understanding to future buildings, "*keep it simple and do it well"*.
Builders and Suppliers	Develop 'no surprises' industry standards, develop assured quality standards, provide after sales support.
Property Advisors and Agents	Learn from POE what adds genuine value to buildings so that this is reflected in the commercial value of space; use this to encourage owners to take sustainable measures, use benchmarks to make this easy.
Occupier Clients	Be clear about your ends, undertake occupant surveys and monitor energy use etc to diagnose problems, do not be reliant on professionals services - run your own building, set up arrangements for energy and facilities management, use the feedback
Facilities Mangers	Appreciate the importance of rapid response to occupant problems, set up and manage feedback streams, become involved in problem solving and brief making, represent the client more strongly in supply/client discussions.
Professional Institutions	Improve collaboration and data sharing, use common definitions, encourage POE, use information to target future practice, research and development and to guide policy and good industry practice, make POE part of education.
Government	Encourage measures that lead to all round improvements (triple bottom lines) not single issues, expand Egan agenda to cover post-handover and feedback, encourage transparency in benchmarking and reporting, consider open source databases.

Table 2. 5 PROBE recommendations for industry network action PROBE 5 (Bordass et al. 2001).

The diversity of responsibilities of different actors combined with the complexity of the process and interlinked nature of building energy consumption requires feedback to provide knowledge to a group of people with a range of expertise, motivations and interests. Bartlett and Howard talk about the need for a knowledgeable design team to achieve good quality buildings:

> *"in the vast majority of cases it is possible to design attractive, uncomplicated buildings that operate in a straightforward manner, achieve*

> *high standards of energy efficiency, and incur no additional cost. This ideal is seldom achieved without an appropriately knowledgeable consultant being involved at every stage of the design - particularly the early stages."* (Bartlett & Howard 2000).

Feedback must therefore be tailored to different actor groups. Existing POE methodologies are diverse and therefore so is the information collected. However, the purpose of POE is not often to inform designers. POE is often carried out to give researchers and practitioners a thorough understanding of building performance and users' preferences and perceived needs rather than increase the effectiveness of building design and management decisions. This provides little guidance for future design decisions and does not provide the insights discussed earlier (Vischer 2009). As Stern concluded, where the market is not providing the necessary change, this needs to be provoked through regulation, incentive or punitive measures (Stern 2007). The framework in which design, construction and management actors are operating needs to provide the supporting structure, within which decisions are made and justified.

2.6 Information Communication

The traditional focus of sustainability combines a 'triple bottom line' of economic, environmental and social sustainability (Edwards & Hyett 2005; Brundtland Commission 1987; Steemers & Manchanda 2010). This should be supplemented by a fourth element according to Steemers and Marcheda (2010) 'the project', thus creating a three dimensional 'sustainability pyramid' to help the design team communicate their priorities while being aware of the context of their decisions. Contextualising the aims of projects in this way could aid information communication.

The 'cognitive fit' model of information acquisition and dissemination aims to match information with appropriate decisions and decision-makers, cognitive fit puts forward the case for matching the way that a problem is presented, the task used to solve that problem to actors' perception or mental representation of the problem and the tasks and their individual skills in order to help generate a solution (p.67, Ibid.). This would necessitate understanding how the legislative framework makes actors think about the problem they are trying to solve: *"more effective and efficient problem solving results when the problem representation matches the task to be accomplished"* (p.64 Vessey 1991).

Bull et al (2012) have shown that in the case of DECs the representation of the problem does not match the task to be accomplished, they identified the kind of data needed to provide this insight. They do not suggest who needs this information beyond industry generally. Using a POE generated evidence base to provide data 'cognitive fit' requires tailoring of information to the ways that designers look at the world.

Evidence Based Design (EBD) is a movement to introduce scientifically robust data and scientific method into the design process to guide design decisions using empirical knowledge (Vischer 2009). In tailoring information to actors, a common language or set of indicators that is understood by disparate actors is required to communicate evidence. This has been touched upon by others; Dammann argues that *"Consensus on indicators is especially important across a set of non-mandatory users in a bottom up system"* (Dammann & Elle 2006). Damman suggests that performance indicators, or Environmental Indicators for Buildings (EIFOB), need to act as a common language between the actors in the design and construction and need to act in two spheres of research, the scientific sphere and the social sphere. A common language must speak to the lowest level of scientific knowledge, so that effective communication can take place between all actors involved in a project (Ibid.). This is apt for the construction industry and the range of actors' knowledge. Damman and Diaz, Moore and Geboy, Lutzenheiser, Vessey and Leaman et al and Beamish and Biggart all identify the need to communicate information to the disparate group of actors involved in the procurement and management of buildings. Friedman identified the difficulty of applying information to design practice in the nineteen-seventies which is still current today:

> *"There is too much separation between application and theory. Direct, physically orientated evaluations are often carried out by designers; theoretically orientated evaluations are carried out by social scientists. Yet, theory and application are synergistic. Every new design contains new and unique elements: a theory of what people need in their environment; what they can comprehend; what is beautiful to them; what makes them happy. These are critical questions for behavioural sciences, too. By better integrating theory and application, design evaluation can refine theory which, in turn, improves subsequent application."* (p.194 Friedmann et al. 1978).

Damman and Elle's model of knowledge-sharing relies upon increasing levels of scientific knowledge within the non-scientific community and vice-versa; Damman suggesting a range of changes required in education and industry to implement this, including architects learning more about environmental science and engineers learning more about social science. This should be reflected in tertiary and professional education. However, the scientific basis of indicators must be robust to ensure meaningful metrics that are flexible enough to evolve with knowledge. Importantly, indicators must provide a basis for communication but cannot replace good practice (Dammann & Elle 2006).

In the non-domestic sector, an effort to do just this and integrate information and good practice into the everyday running of the buildings has been described as 'intelligent buildings'. These have been defined by (So et al, 2001 cited in Cole & Brown 2009):

> *"intelligent buildings are not intelligent by themselves, but they can furnish the occupants with more intelligence and enable them to work more efficiently"* (Cole & Brown 2009).

There are a number of criteria defining intelligent buildings by the relationship between control intelligence, user comfort and automation. Intelligent buildings are designed to reduce energy consumption, through use of automated and controls and intelligent space management (Cole & Brown 2009). Intelligent buildings embody one of the common factors in all of these concepts which is a *"focus upon making better use of information to improve performance and increased value"* (Kell 2005) cited in (Cole & Brown 2009). Kell goes on to argue:

> *"the challenge of intelligent buildings is to make the best use of available information, with the understanding that which information, what performance, and how value is measured depend upon the viewpoint of the specific advocate"* (Cole & Brown 2009)

The recurrent theme in all of these feedback and design systems is that information needs to be available, tailored to specific users, must be understandable and frame specific problems properly. Information itself needs to be accessible to all and all need to be proactive in using it. Feedback can be used to reinforce decision-making, to provide a justification for designers' choices and to give design guidance. This will perhaps begin to bridge the gap between existing simplistic financially-based decision-making and apparently unjustifiable environment-based design decisions.

In the domestic sector, the availability of information is essential to affect change in energy consumption, and the information does not have to be complex to be successful – simple cost metrics can work (Darby 2008). If the type of information communicated about a building's energy consumption is the key to meaningful change, then perhaps the same could be said of the non-domestic sector. Leaman et al set out the needs of information feedback tools generally:

> *"Reports from building evaluations will go to people who will not necessarily understand, or be comfortable with, jargon or specialist language. On the other hand, over-simplification, especially with statistical*

> *graphics, may create even more problems by disguising or misleading. We advocate 'no unanswered questions', so everything that is included in the reports and graphics is carefully, but not long-windedly, explained. Visual images and diagrams that pinpoint a clear conclusion are vital. It is also usually better to split the findings into several sub-reports, with an overview report aimed at the wider, non-specialist audience. This also means that clients can choose which parts they wish to release to others."* (Leaman et al. 2010).

2.7 Crowd sourcing data

Crowd sourcing, in the terms of this thesis is a relatively new phenomenon, facilitated by internet based global communication. This chapter has shown a top down approach to the development of energy legislation to which individuals, or groups of individuals working on individual projects are required to respond. Crowd sourcing – gathering and interrogating the subsequent collective experience and expertise – could help solve the problem of the performance gap, decrease building energy consumption and advance a low energy built environment.

The term 'crowd sourcing', used in this case to describe a web based business model that uses a large network of individuals to develop creative solutions to a variety of problems, was defined by Jeff Howe in Wired magazine:

> *"…the act of a company or institution taking a function once performed by employees and outsourcing it to an undefined (and generally large) network of people in the form of an open call. This can take the form of peer-production (when the job is performed collaboratively), but is also often undertaken by sole individuals."*(Howe 2006).

The nature of the information gathering must be managed however, the success of crowd sourcing is dependent on '*aggregating talent [and] leveraging ingenuity' rather* than the averaging of all responses(Brabham 2008). John Surowieski explores this in the *Wisdom of Crowds*:

> *"…if you ask a hundred people to run a 100-metre race, and then average their times. The average time will not be better than the time of the fastest runners. It will be worse. It will be a mediocre time. But ask a hundred people to answer a question or solve a problem, and the average*

> *answer will often be at least as good as the answer of the smartest member. With most things, the average is mediocrity. With decision making, it's often excellence. You could say it's as if we've been programmed to be collectively smart." (Surowiecki 2005).*

Crowd sourcing can be applied to a range of industries to solve both mundane and highly complex problems. It is a strategic model used to *'attract an interested, motivated crowd of individuals capable of providing solutions superior in quality to those that even traditional forms of business can.'* (Brabham 2008). The crowd can out-perform industry and be *faster* and *cheaper* than even the top minds in the fields (Appadurai, 1996 in Brabham 2008).

Howe identifies *'the crucial prerequisite is the use of the open call format and the large network of potential labourers'* (Howe 2006), while Surowieski identifies four requirements to ensuring that crowd sourcing provides the best outcomes: diversity - a crowd comprised of a range of individuals with a range of expertise and experience; independence – self interested individuals developing independent solutions to problems to prevent the crowd sourced data becoming self-referential and mistakes being repeated; decentralisation of the crowd – a function of independence, rather than working from a top-down centralised starting point, a bottom-up approach to problems solving can produce a variety of intelligent solutions that can be aggregated; aggregation – combining the solutions of the crowd in a meaningful way to synthesise the best solution from all of the sourced material (Surowiecki 2005).

In addition to combined wisdom, the use of crowds by 'companies or institutions' to provide a problem solving capability offers a number of other advantages. Reductions in costs using a crowd to solve problems could allow more rapid development. Individuals are presented with an opportunity to contribute to wider development and learn new skills through the involvement in crowd sourcing (Lakhani et al 2007 cited in Brabham 2008). However, in certain industries, photography for example, crowd sourcing can destroy livelihoods and careers. The opportunity to source ideas or images more cheaply makes it more difficult for individuals to make a living. From a research point of view understanding what motivates a crowd to become involved and contribute to data collection will help to amalgamate information and make quicker advances in understanding various phenomena. In building energy consumption, rather than replacing industry professionals, feedback information aims to provide them with an evidence base for their work.

2.8 Data quality

The major issue to be overcome when using crowd sourced data in whatever field but in particular information based databases is how to validate the quality of the information submitted. Innocent mistakes and intentional falsehoods can reduce not only the quality of the information, but also people's confidence in it as a legitimate source of data (Mummidi and Krumm 2008 in Pawlowicz et al. 2011). When generating large data sets of labelled data the advantage of the low costs of crowd sourcing can be outweighed by this low quality and can render the information essentially worthless (Faridani et al. 2013). Therefore the main challenge in internet based crowd sourced data concern forming a robust quality assessment of the data (Brambilla et al. 2013).

Databases traditionally compiled by professional researchers under a rigorous scientific process and can apply similarly rigorous quality control measures; however they can also be time consuming to assemble. Crowd-sourcing can reduce costs and increase the scope of a study but can also significantly reduce the quality of the data collected (Pawlowicz et al. 2011). Data-quality issues need to be addressed and data collected by the public or lay industry must be validated whenever possible, so that crowd souring and 'citizen science' can become a widely accepted scientific practice (Dickinson et al. 2010).

Energy IQ – a fossil fuel location database - recognises the implications of poor data quality and has published guidance via the website to ensure the quality of the data in the system. *'Quality can be improved through the systematic application of rules to assess the data that has the highest value to the business'* (EnergyIQ n.d.) .The rules focus on three stages of data accumulation; data being loaded, edits on the data and data in place. Data being loaded into the system is assessed against a set of data quality rules upon which the decision of whether to load or reject the data is taken. Edits on the data are validated during the 'save' process to ensure that they do not violate any of the above rules. Data in place can be continually assessed against the rules using filters and comparisons with existing data (EnergyIQ n.d.).

Many types of data require a different approach to data quality assessment and many methods for validation exist from algorithmic 'active learning' assessment to calculate the likelihood of supplied data being accurate (Mozafari et al. 2012), a human-in-the-loop approach to monitoring the quality of data (using people to check data negating some of the labour savings), visualisation and statistical techniques (Faridani et al. 2013).

2.9 Other data bases

There are many examples of crowd-sourced data platforms performing many different functions. Specialist websites use 'citizen science' to gather data on many specialist subjects for research and commercial purposes (See et al. 2013). Examples of crowd sourced research projects include unravelling protein structures using internet based games (Khatib et al. 2011) and discovering new galaxies through use of volunteer crowds to push research capabilities beyond what was previously possible (Clery 2011). Other models of crowd-sourced enterprise include many creative and problem solving endeavours crowd sourcing ideas for various products including Threadless (a T-shirt design company, www.threadless.com), iStockphoto (a photographic archive, www.istockphoto.com), InnoCentive (to 'develop novel ideas and sole important problems', www.innocentive.com), the Goldcorp Challenge (locating subterranean gold deposits, www.ideaconnection.com), and user-generated advertising contests (Brabham 2008). However, those most comparable to energy data platforms aimed at a specific group of practitioners are perhaps environmental and medical databases because they require a general audience to provide information on which others can act.

2.9.1 Environmental databases

Examples of environmental crowd-sourcing websites include reporting of illegal logging and deforestation and waste dumping which have had an impact on local governance and policing (Nayer, 2009, Milcinski, 2001 both cited in See et al. 2013)

EcoInvent (www.ecoinvent.com) was set up by the Swiss Centre for Life Cycle Inventories to promote the use of data to inform the environmental and socio- economic life cycle impacts of decisions (Weidema et al. 2013). The inventory contains several different databases of information on agriculture, energy supply, transport, bio-fuels and materials, chemicals, construction materials, packaging materials, metals, metals processing, ICT and electronics and waste treatment. The data and associated services are aimed at industry, consultancies, public authorities and research institutions to help them improve the and enhance the environmental performance of their products, processes and services related to products, designs, management and product stewardship (www.ecoinvent.org n.d.).

The platform is independent and not for profit and relies on member organisations to submit data sets for others to learn from. The organisers have produced a rigorous and comprehensive guidance document aimed at ensuring the submitted data is of a sufficient depth to add value to the overall data base focusing on the level of detail, completeness, naming conventions, how to deal with uncertainty and validation and review.

The main purpose of the platform's guidance however is to attempt to ensure quality, validity and 'plausibility' of the data set (Weidema et al. 2013). The validity checks are based on both the relationship of the data to the rest of the information in the system and checks on the information prior to it being up loaded. The latter case includes such questions as checking the reference period of the data to be added (that it is greater than a year), the former can include checks for consistency with data already in the data base (for example that the production yield of a particular industry does not exceed the global maximum). The data quality assurance in this case is carried out both prior to uploading the data by those providing the information and during the upload by making cross references with other data in the system.

2.9.2 Health databases

Health databases are perhaps analogous to energy data in that the information in a health database is used to diagnose and resolve problems. There are a range of databases administered by NICE (National Institute for Health and Care Excellence) including the British Nursing Index, EMBASE (Excerpta Medica Database), HMIC, MEDLINE, PsycINFO (a database of Psychology and allied information and publications), and Health Business Elite (Healthcare administration information).

Health databases such as those above have traditionally been comprised of research and data compiled through clinical and other operational activity however, like other fields, internet based data collection provides an opportunity for a different kind of data collection. They represent the combination of ‘citizen science’, the development of the internet and related communication technologies and the involvement of individuals in their health care using web technologies (Swan 2012a). Sites can vary from those that allow patients to share their experience with a community of people with similar experiences while health providers can use this feedback for product development, quality improvement and policy change (Adams 2011). PatientsLikeMe is one such example that seeks to use patient experience and data to contribute to medical research (www.patientslikeme.com). The site collects information from patients with life changing conditions for commercial use through selling the information to researchers whilst giving those contributing data the opportunity to share experiences and receive support from a peer group with similar diagnoses to them (Wicks et al. 2010). Crowd sourced data relating to patients actual health effect can offer feedback that could personalise healthcare and generate preventative medicines (Swan 2012b).

Quality impacts of crowd-sourced health data related to both who is collecting the data but also what kind of data is being collected. Often the non-professionals (i.e. the patients) are not acting in the way that participants in other crowd-sourced databases are. Rather they are passive participants who provide the subject of the data (Swan 2012a). Where the patient is providing data directly, the issue of reliability and quality arises: Much of the available information is self-reported, and it cannot be verified whether the participant actually has the condition, is engaged in the intervention(s), and/or reported accurate outcome data. In addition, patients may not be sufficiently reliable to diagnose and report on their own conditions (Talan 2011).

The issue of data quality applies to all crowd sourced data: who is collecting it, how it is verified and what is going to be used for?

2.10 Energy databases

There is a number of existing web-hosted databases and data collation methods in existence that aim to address many of the issues raised in this review. The primary platform of interest to this thesis is CarbonBuzz.

CarbonBuzz

CarbonBuzz stores and displays detailed modelled and recorded building characteristics and energy end-use data according to user-defined comparison parameters. The platform highlights the discrepancy between design predicted and actual energy consumption and aims to feed back information to architects, engineers and facilities manager to inform future design work and existing building operation. The data structure of CarbonBuzz is based on the CIBSE TM22 framework and allows for the collection of building information in very general headline terms from the ‘top down’ (i.e. total electricity, gas or renewable consumption); or for users to build up very detailed illustrations of data use from individual energy loads from the ‘bottom up’ (i.e. by submitting disaggregated sub-metered end use consumption) table 2.6 describes the CarbonBuzz data structure (CIBSE 2006, www.carbonbuzz.org).

The CarbonBuzz database structure is dividing into two sections, ‘Project Details’ and ‘Energy Records’. Project details describe the characteristics of the building and are represented by a hierarchical structure broken down into details per project, per energy record and per building zone. Energy records describe the energy consumption associated with each building zone (or the complete building) and are split into Design and Actual data and electrical and non-electrical data. Each record has a hierarchical structure from a headline total consumption figure at the top, down to detailed disaggregated information.

CarbonBuzz stores data collected by others in a standard format. The CarbonBuzz platform is open to all: a simple registration procedure grants access to the database and the ability to create new records. This open access is the key characteristic of the platform, allowing any and all building industry actors to contribute; the implications of this are described in Chapter 6.

Project Details	Details
Project identifier	Building location Building use Number of zones Building ownership and tenancy Design/management teams
Energy record details	Data collection dates Benchmark targets/rating system used Which edition of building regulations applied Embodied energy Cost Any uploaded drawings or images
Building zone details	Servicing strategies (lighting, heating, A/C, Nat. Vent etc.) Low and zero carbon technologies employed Building fabric details (proportions of glazing, U-values etc.) Air tightness Building dimensions Separable or special energy uses Occupancy rates Facilities management strategies
Energy Record	Details
Source of data	Software if prediction Meter type/frequency if actual)
Total Electrical Energy use	Low and zero carbon uses/sources, Building loads (services, lighting) Occupational loads (small power, ICT, catering transport, special or separable functions)
Total Non-Electrical Energy use	Low and zero carbon uses/sources, Building loads (services, heating, DHW) Occupant loads (catering)

Table 2. 6 CarbonBuzz data structure: project details and energy records.

CarbonBuzz aims to help users overcome the financial risks associated with inaccurate energy consumption predictions that include higher utility bills, missed reduction obligations and lost income from unrealised value. This is delivered through three mechanisms: tracking carbon emissions through the development of a project, benchmarking against selected peer groups of buildings and analysing energy use trends, and storing and sharing data to ensure users are working with the best available data.

Information is captured using the DEC methodology for both design and actual recorded figures, this allows for a true comparison between total energy consumption, including unregulated energy. All energy figures are converted to carbon dioxide emissions using default or user defined conversion factors. The primary benchmarks used by CarbonBuzz are the TM46 figures, which, as discussed in this chapter and in chapter 3, do not reflect current building energy consumption in some building sectors (www.carbonbuzz.org). .

CarbonBuzz tackles issues of data quality through the information records. The site asks users to specify the source of their information (for example from meter readings or SBEM calculations) in order to allow users to compare like with like and to assign some risk factor to the data. CarbonBuzz is explored in more detail in chapter 6.

EnergyIQ

EnergyIQ has been developed by a partnership between the University of California, Berkeley, the State of California and the California Environmental Protection Group and collects recorded energy end-use data. EnergyIQ is *"an action-oriented benchmarking tool for non-residential buildings. Energy managers, building owners, architects and engineers use it to identify energy efficiency opportunities', save money and reduce carbon emissions"* using uploaded data. Users can benchmark buildings against a peer group of similar buildings by whole building energy, end-use or building system. The peer group is user defined by location, age, floor area and use type (http://energyiq.lbl.gov/EnergyIQ/index.jsp n.d.).

Like CarbonBuzz, the data in EnergyIQ is disaggregated to end-use level in order to provide insight beyond existing legislated feedback mechanisms (GreenStar in the United States of America). The site defines 'action oriented benchmarking' as that aimed at providing enough insight to provide justification for further investment in evaluation.

> *"Based on user inputs, the tool generates a list of opportunities and recommended actions. Users can then explore the "Decision Support" module for helpful information on how to refine action plans, create design-intent documentation, and implement improvements. This includes information on best practices, links to other energy analysis tools, and more."* (http://energyiq.lbl.gov/EnergyIQ/index.jsp n.d.)

The data structure is based on the CEUS (Commercial End Use Survey) database. The CEUS database is a recorded of a survey of over 2800 buildings recorded with supporting information in four frames: building type, utility district, climate zone and loads, over 100 physical and operational characteristics are recorded. The databases used (and subsequently the EnergyIQ benchmarks) were identified as providing suitable data for high level benchmarking to help identify opportunities and actions for further investigation. More in depth and wider comparisons (and better benchmarks) are reliant on the collection and collation of '*information rich databases'*, which in turn is reliant on implementation of sub-metering, collection of information and assurance of quality (Mathew et al. 2008).

iServ

iServ has been developed by Cardiff University with EU investment to highlight the benefits of an automatic monitoring and feedback systems in response to the recast EPBD and other future European legislation aimed at achieving energy efficient HVAC systems. The web platform focuses on and collates recorded sub-hourly data from heating, ventilation and air-conditioning (HVAC) systems in 1600 public buildings in EU member states. It is aimed at owners and operators of buildings, HVAC system manufacturers and policy makers who can act on monitored energy consumption, generate benchmarks and provide data to all stakeholders (http://www.iservcmb.info/ n.d.).

The structure of the information flow through iServ is to define the characteristics of the HVAC systems and the zones that they serve, collect and analyse sub-hourly data from the systems, generate benchmarks based on the system characteristics and served zones and report back to building managers with comparisons to benchmarks and suggestions on how the performance of the systems might be improved (Knight 2012a).

Data quality in iServ is handled through a 5 step data submission process and interaction with the database administrators. Step 1 is for prospective users of the site to complete a survey to ascertain if iServ fits their needs; step 2 involves potential users submitting sample data to iServ to ensure that data are in a compatible format; step 3 asks for a description of the relevant system, floor areas and building type; step 4 sets up user accounts and step 5 involves users submitting the data into the data base (http://www.iservcmb.info/ n.d.)

This data quality approach ensures that data entering the site matched the quality standards required to develop benchmarks and ensure that savings can be delivered. However, it is worth noting that unlike other crowd sourcing projects, iServ is in receipt of substantial EU funding to enable such intensive quality auditing of each data set (Knight 2012b)

Carbon Estates

Carbon Estates is a web-based energy efficiency, benchmarking and virtual simulation tool. The tool is aimed at organisations with large portfolios of buildings and tailors information to different audiences within an organisation. It is a management tool for recorded data that can be used for benchmarking, identifying potential reductions, CRC strategy assessment, retrofit scenario development and tracking and optimising expenditure. Insight is developed using algorithms and simulation software to suggest retrofit programmes and changes to operations (http://www.co2estates.com/ n.d.).

The platform uses a cloud based data storage system to compile data organised around building fabric systems (including walls, glazing, the floor construction, thermal performance and orientation) and building servicers systems and distribution (including heating, cooling, ventilation, lighting, hot water and controls). Operational energy consumption data is gathered from metered data and commercial real estate data is used to support the benchmarks, this includes tenant and lease information (http://www.co2estates.com/ n.d).

Information is presented through a series of dashboards aimed at stakeholders who wish to benchmarks their portfolios, those interested in retrofitting existing buildings and a simulation interface to help interrogate potential changes to buildings or management (http://www.co2estates.com/ n.d).. Carbon Estates uses crowd sourced data slightly differently to the other platforms discussed above in that the empirical data is used as a basis for simulation to improve performance. The quality of the underlying information is arguably less important as long as the simulation uses the same assumptions.

CarbonBuzz, Energy IQ, iServ and Carbon Estates are examples of crowd-sourced platforms that draw data from different sources for slightly different audiences. They are reliant on participants to provide robust, detailed data that can be filtered to a sufficient degree and communicated to industry. They aim to meet many of the aims of feedback but do not explicitly address the barriers to information collection. A number of data quality measures are used by each platform and can be summarised as:

- Pre submission checks on completeness and compatibility
- Relational checks in the data base
- Boundary checks of information

The next section summarises the literature review and defines the knowledge gap that this thesis aims to address.

2.11 Summary and knowledge gap

The energy gap is a result of a complex interplay of factors that mean energy consumption predictions do not often give an accurate depiction of how much energy will be consumed in a building. There are a range of reasons why the energy gap occurs, ranging from regulatory calculation methods to poor management. Post Occupancy Evaluation aims to understand and uncover anomalies in building performance, providing the data that can be analysed and utilised as feedback information to base decisions on and lower energy consumption. There are a number of reasons that POE is not carried out habitually in the construction industry that range from financial risk to lack of will. There is no obligation to collect data from buildings apart from headline information for mandated certification schemes in certain public buildings.

In order for feedback to be effective, it must contain detailed information backed up by case studies and contextualised within a comparable peer group of other buildings and rigorously checked for quality and integrity. Benchmarks aim to provide this contextualisation and are used by certification schemes. The elements of a building that can impact on energy consumption represent a complex network of physical, design and user interactions. POE must collect information on the most relevant. Designers must make decisions, often with competing motivations, about all aspects of a building. Energy may not be the prime motivator.

The actor network involved in the procurement and management of buildings is made up from an interaction between a diverse range of professionals with very different responsibilities. Whilst developing a common language of communication between them is crucial for the success of any information communication system, enabling information to be presented to different actors to suit their particular requirements is also vital. A number of tools and web platforms have been developed to communicate modelled and recorded energy data to users to overcome the risks associated with energy consumption, overcome the barriers to collecting data and help industry make better decisions.

The potential role for feedback is therefore varied and dependent on a range of factors: an actor’s responsibilities and interests, the aim of using feedback, how the information will be used, what kind of decision it is being applied to, who the audience for the information is (what is their role and why are they looking at the information), when it is being used, the desired outcome of its use and any barriers that are in place.

While the literature review has described a field in which much work has been done identifying the technical causes of poor building performance – defined by benchmarks - and the need to provide information to overcome these technical deficiencies, it also describes a complex industry based on interrelated professionals working within a changing landscape of incentives and legislation throughout the design process. Some effort has been made to collect and feed information back to industry to overcome the performance gap. However, despite efforts to reduce the performance gap, it still exists; this review has identified a gap in knowledge and seeks to understand the relationship between legislation, actors and the performance gap in order to define the future role of crowd sourced information feedback. Resulting in the following research questions that define the rest of the research:

1. What is the context for actor decision making in the UK design, construction and management industries?

2. How do the ‘contextual pressures’ influence the [lack of] interplay between design and construction practice and energy information?
3. What is the potential for crowd-sourced data platforms to fulfil the role of feedback mechanisms?
4. What does the relationship between the contextual pressures; building energy data and actors’ experience tell us about the future role of energy feedback?
5. What changes need to be made to the contextual pressures or actors’ behaviour to implement this future role of feedback?

In order to investigate these questions and develop a full methodology, question 1 is addressed in the following chapter.

3 What is the context for actor decision making in the UK design, construction and management industries?

Before a methodology was designed for this research, the context or contextual pressures needed to be understood. The literature review has described the issues surrounding feedback, building energy consumption and the cause of the energy gap. The research questions require an understanding of the context in which people are working in order to frame the subsequent methodology; therefore this chapter describes a methodology to synthesise the literature and a legislative review with some preliminary empirical research to define the contextual pressures within which the design, construction and management of buildings takes place.

Corbin and Strauss (1990) describe procedures and evaluative criteria for research aimed at developing theories of social phenomena such as the interplay between individuals within a system. Amongst other things they describe the importance of analysing the *'broader structural conditions'*, the setting that might impact on the central phenomenon being studied. This could be the political, economic or social context for the activity (Corbin & Strauss 1990). The structural conditions in this case are described as the 'contextual pressures' and are formed from the framework of literature-derived categories and from an initial phase of empirical data collection.

3.1 Methods

Two methodological strands were used to describe the contextual pressures, each independent of the other but carried out concurrently. These were a document analysis and two types of participant observation. Participant observation is a method of data collection often used as part of ethnographic studies and is a means of immersing a researcher in the culture, routines and activities of the subject population (Corbin et al. 2008; DeWalt & DeWalt 2010).The author had a role assisting in the early stage development of CarbonBuzz which afforded the opportunity to carry out participant observation, since the development was informed by a series of focus groups attended by an advisory panel of interested and expert consultants from industry.

The focus group was comprised of invited stakeholders from national scale developers, investment fund managers, local authority energy managers, architects, engineers and surveyors. The consultant meetings were formed of engineers, specialist building performance consultants and policy developers.

The author attended these meetings as a joint facilitator in the focus groups and as a contributing participant in the consultant meetings. This gave the opportunity to gather empirical data related to the social, professional and economic pressures that industry actors perceive themselves to be working under as well as the pragmatic issues facing industry when attempting to develop or manage low energy buildings and what role feedback can play.

The document analysis was comprised of a continuation of the literature review, extended to encompass all legislation and guidance aimed at reducing building energy consumption. The document analysis was combined with qualitative data collected during the participant observation to form the framework of contextual pressures.

3.2 The Contextual Pressures

Legislation and policy are often framed using a particular set of assumptions about the context and industry consensus – legislators often assume that actors' decision-making is driven by seeking optimal returns, ignoring or not appreciating the more complex and wider socially regulated framework that can have profound implications on decisions and innovation (Beamish and Biggart, 2010). This chapter seeks to define this regulatory environment as well as the wider socially regulated framework that forms the context for actor decision-making.

A number of schemes have been implemented to try and increase understanding of building energy use, improve the accuracy of energy predictions and reduce year-on-year consumption figures. The chapter is split into three sections; an underlying 'procedural framework' for the development, construction and management of buildings which describes the typical process for the procurement of a building; a 'formal framework' of pressures defined by legislation, regulation, guidance and other documented sources; and an 'informal framework' of pressures comprising perceived or actual social, economic, professional and other pressures. (See Figure 3.1).

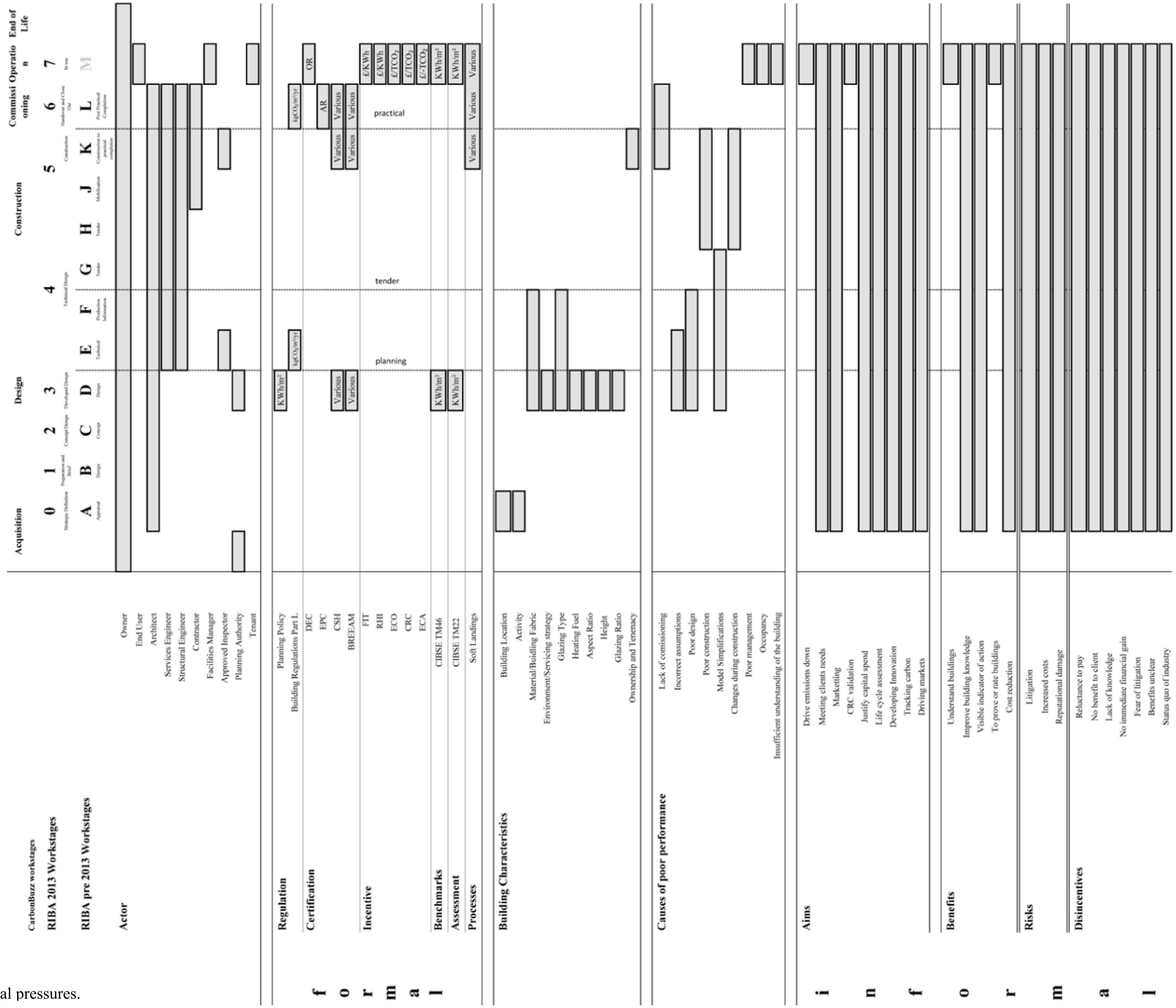


Figure 3.1 The contextual pressures.

3.3 Procedural Framework

The industry standard procurement process, defined by the RIBA plan of work, forms the backbone to the procedural framework shown in figure 3.1. In addition to the RIBA 2007 and 2013 work stages, the six-stage CarbonBuzz process has been overlaid. This extends the linear RIBA process to include site or building acquisition prior to the development of a design and the end of life of a building. Both of these stages are connected with the feasibility stage of the RIBA plan of work. The plan of work relates the typical contractual relationships inherent in the development process with the broader regulatory context and accordingly, the procedural framework also indicates four key and mandatory points in the process of building procurement. These are:

Planning Submission - The point at which a submission is made to a local authority planning department for permission to build the development is when key building characteristics such as form, orientation, window ratios, aspect ratio and floor area are defined following early design development. (Minor alterations are permitted through a revision process but substantial changes require a re-submission). This is also the stage at which any local authority energy requirements would be met.

Building regulations submission - A building regulations submission is made typically prior to tendering a project (but not always, depending on the contractual arrangement) and ensures that the proposals meet with regulatory standards. This stage therefore necessarily fixes the detailed elements of the building prior to construction like the fabric thermal performance, the environmental systems performance and requires calculations using the National Calculation Methodology, demonstrating predicted carbon dioxide emissions.

Construction - The construction phase often begins following a competitive tender process and is when the design is physically built on site. This is highlighted in the contextual pressures as a key period of information communication between the design team and the contractor. Depending on the type of contract used, the process can involve changes to the design that can impact on the resultant energy consumption of a building.

Practical Completion - ‘Practical Completion’ is a contractual term defining when a building is able to be occupied but not necessarily when all of the work has been carried out – just when the building is practically complete. As has been highlighted in the literature review, this point is crucial to commissioning systems, setting up occupancy and building management practices and beginning the defects liability period (Joint Contracts Tribunal 2009).

The decisions points defined by the procedural framework are the reference points for the formal and informal frameworks. The role that feedback can play in this process is explored throughout later chapters.

3.4 Formal Framework

The formal framework is comprised of directives, regulations, policy, guidance and other formalised mechanisms aimed at reducing building energy consumption and associated carbon emissions.

Directives, Legislation and Regulation

The Energy Performance of Buildings Directive's (EPBD) principal objective is to *'promote the improvement of the energy performance of buildings within the EU through cost-effective measures'*. The measures stipulated in the directive are first, to establish a calculation methodology for predicting energy consumption. In the UK this has resulted in the National Calculation Methodology (NCM). This calculation method is used to demonstrate compliance with minimum energy performance requirements, the second requirement of the directive. The Building Regulations ensure compliance with this in the UK. The third measure is the implementation of performance certificates: this has resulted in the introduction of Display Energy Certificates and Energy Performance Certificates in the UK. The final measure is the implementation of regular maintenance and inspections of boilers and air-conditioning systems to ensure efficiency of service (Anderson 2006).

The EPBD has created the context for the development of individual national strategies for the reduction of building energy consumption. In the UK, the CCA defines a nationwide aspiration; in this context of sector-specific statutory and voluntary policies, benchmarks and guidance documents are developed.

The energy balance of a building is a complex interaction of physical processes and user influence. The relationship between these factors is regulated across England and Wales through Part L of the building regulations 'Conservation of Fuel and Power'. Part L is split into Parts L1A for new dwellings, L1B for changes to existing dwellings, L2A for new buildings other than dwellings and L2B for changes to buildings other than dwellings. Part L focuses on the building fabric, the insulation levels and glazing ratios, and the fixed building services; heating, cooling, lighting, lifts and escalators (Department for Communities and Local Government 2012). Compliance is measured as per the National Calculation Methodology (NCM) for buildings other than dwellings, and the Standard Assessment Procedure (SAP) for dwellings. The CO_2 emissions of a proposed non-domestic building are calculated as $kgCO_2/m^2$ which is called the proposed Building Emission Rate (BER). The BER must be better than a Target Emission Rate (TER), calculated as the emissions from a notional building geometrically identical to the proposed building but using default specifications from the 2002 edition of Part L, by a standard improvement factor.

A delayed update of Part L of the building regulations was announced at the end of July 2013. Originally announced to come into force in October 2013, this will now be applicable from April 2014. The changes represent a reduction to the carbon targets of 6% for residential buildings and 9% for non-domestic buildings. The original consultation proposed more ambitious reductions of 8 and 20% respectively (Department for Communities and Local Government 2012; Department for Communities and Local Government 2013). The building regulations define the key design-stage energy consumption targets through the use of the National Calculation Method (NCM) and various licensed software programs. While the regulations are the primary means of regulating energy at the building design stage, the limited calculation method used are also one of the sources of the energy gap.

Calculation Methods

The NCM (National Calculation Method) was developed by the Department for Communities and Local Government (DCLG). It sets out the methodology for calculating the anticipated annual energy use of proposed buildings for building regulation compliance and Energy Performance Certificates . The NCM allows the calculation to be carried out using approved software or the Simplified Building Energy Model (SBEM) developed by the Building Research Establishment (BRE). The calculation takes into account only the energy uses that are regulated through Part L of the building regulations. These include the location of the project to make weather corrections, the proposed use of the building, U-values of walls, roofs, floors, doors and glazing and the relationship the construction has with adjacent space, geometrical information about the buildings area (m^2), zones sizes, number of storeys and orientation, the air permeability and thermal bridges in the fabric, building services, general metering strategies and main fuel types and air conditioning inspection regimes, specific information of about individual HVAC systems, solar energy systems, wind generators, lighting systems and controls, and display lighting. This calculation methodology does not include plug loads or occupancy variables and therefore does not account for some of the main drivers of energy consumption (Building Research Establishment 2013a).

The Standard Assessment Procedure (SAP) is the domestic equivalent of SBEM. The calculations take into account building characteristics but also consider environmental factors such as solar gain. The factors included in a SAP calculation are the materials used for construction of the dwelling, the thermal insulation of the building fabric, the ventilation characteristics of the dwelling and ventilation equipment, the efficiency and control of the heating system(s), any solar gains through openings in the fabric, the fuel used to provide space and water heating, ventilation and lighting, energy used for space cooling (if applicable) and any renewable energy technologies. An ‘energy balance’ calculation is used to assess how much fossil and electrical fuel will be required to run a household which is then set against a sliding scale of 1-100+, 100 being zero emissions – a figure above this indicates a predicted surplus of energy. Whilst the above list seems comprehensive, like SBEM, no account is taken of plug loads or occupancy rates (BRE 2010).

In both cases the DCLG guidance acknowledges that buildings with more complex, or slightly more unusual approaches to building services will require some approximations and assumptions. Strategies such as natural ventilation, use of thermal mass, occupant controlled ventilation (adaptive measures) automatic blind controls, variable speed pumps and internal light transfer fall into this category (Building Research Establishment 2009). The calculation methods and compliance procedures used by the building regulations can therefore make it difficult to utilise innovative strategies. However, there is scope to contextualise energy consumption regardless of design and service strategies through the use of benchmarks and certification, another stipulation of the EPBD.

Benchmarks and Certification

One of the stated purposes of the CIBSE TM46 benchmarks is to provide designers and managers with yardsticks against which designs and records can be measured: it is *“all about tracking performance and identifying opportunities for improvement”* (CIBSE 2008). Current benchmarks as described by CIBSE TM 46 provide total electricity and fossil fuel consumption figures categorised by building use type and are based on data used to establish early office building benchmarks in ECON 19 (BRESCU 2003). This data was supplemented with data for other building use types and with some amendments to provide better support to DECs prior to their introduction (CIBSE 2008) . They are based on a data set that, apart from the 2008 update, has not changed to reflect developments in other aspects of the legislative framework that impacts on building energy consumption.

Energy Performance Certificates (EPCs) and Display Energy Certificates (DECs) form the only mandated feedback mechanism in place in the UK today. They provide feedback on building energy consumption (of public buildings greater than 500m^2 in floor area) in the case of DECs and building energy efficiency in the case of EPCs. They have been shown to be an effective catalyst for engaging building users with energy reduction but not enough detail to drive down consumption. To deliver significant reduction they need to be part of a wider strategy complete with more detailed energy-based case studies (Bull et al. 2012; Godoy-Shimizu et al. 2011).

Display Energy Certificates (DECs) are based on a building's actual energy performance. The DEC displays this as an 'Operational Rating' alongside the EPC Asset Rating (see below) if available. The operational rating is based on a numerical scale (0-150 and beyond) compared to the building category's average CO_2 emission rate (Department for Communities and Local Government 2008). Both the DEC and the EPC are supplied with advisory reports suggesting economical ways of improving a building's energy performance with short pay-back periods. However, these recommendations themselves are limited by the data contained in the DEC.

In contrast, EPCs attempt to create an industry-wide standard for assessing the physical merits of new buildings and any permanent services in an easily understood graphic format. Using the same national calculation methodology as Part L, a proposed building design is compared to a notional building geometrically identical to the proposals but with Building Regulations Part L 2002 edition specifications. EPCs differ from Part L in that a benchmark is created by the improvement (or not) on this notional building and converted to an Asset Rating on a scale of 0-100 (the lower the number the lower the potential emissions). A similar limited range of building characteristics is taken into account: the construction of the building; whether parts (zones) of the building are used for different purposes; the heating, cooling, ventilation and hot water systems and the lighting systems used. The resultant benchmark is given a rating from A-G (converted from the 0-100 scale). The Asset Rating is based on the way the building is designed rather than used and as such describes the 'potential performance' (Department for Communities and Local Government 2009). This is intended to help prospective tenants or occupiers make informed decisions about the buildings before they decide to move in, but as the calculation is as limited as others, it is of limited use.

Certification schemes attempt to provide a reputational incentive to reduce building energy consumption; however as discussed in Chapter 2, the information provided through the scheme falls short of that required to base management and design decisions on.

Planning Policy

Planning policy is by nature a set of localised requirements, particular to Local Authorities (LAs) and covers everything from buildings to infrastructure. LAs themselves have in place separate instruments to reduce carbon emissions. In the UK, the Department for Energy and Climate Change (DECC) produces the 'Carbon Dioxide Emission within the Scope of Influence of Local Authorities' data set (Previously known as NI 186) that estimates carbon emissions generated within the boundaries of LAs. This includes only those emissions that the authority has some influence over and they can use this data to track their emissions and set internal targets. This is then reflected in local policy (DECC 2010).

So while regulations are national standards, actors must reconcile these with local pressures. The most prominent example of Local Authority policy relating directly to building energy consumption (as opposed to other factors like massing, scale etc that also influence energy but are driven by other concerns) in the recent past is the 'Merton Rule'. This policy was developed in Merton, South London and similar schemes were adopted across the country. The rule stipulated that developments equal to or larger than 10 dwellings or 1000m² of non-domestic space are required to generate at least 10% of the required energy on-site through renewable sources (Merton Council 2013). This was adapted in the London Plan, the Greater London Authority's (GLA) overall strategic plan for London, setting out *'a fully integrated economic, environmental, transport and social framework'* for development in London. Local authorities in Greater London's own development policies need to be in 'general conformity' with this plan, just as the London plan needs to be in general conformity with national targets (Clause 4A.7 Greater London Authority 2011). The difficulty with the Merton rule is that high-density urban environments are sometimes not the most appropriate places for renewable energy generation and therefore it can encourage a low prediction. While local energy targets require coordination with national aims, local authorities often utilise other nationwide certification schemes, such as BREEAM, to ensure broader sustainability issues are considered.

Building Research Establishment's Environmental Assessment Method and Non-Domestic Buildings (BREEAM)

BREEAM is a system designed to set standards for best practice in sustainable building design addressing a wide range of environmental and sustainability issues. The scheme aims to help developers and designers to prove the environmental credentials of their buildings through market recognition for buildings with low environmental impact, assurance that best environmental practice is incorporated into a building, encouraging innovative solutions that minimize the environmental impact of buildings. It provides a benchmark that is better than regulation, a tool to help reduce running costs, improved working and living environments, and a standard that demonstrates progress towards a corporate and organisations' environmental goals (Building Research Establishment 2013b).

BREEAM offers specific use-type building assessments including offices, industrial units, retail, schools, further education, higher education, healthcare, multi-residential, prisons, courts and other building types. Projects are assessed on nine different areas of potential environmental impact. These are: building management, health and wellbeing, energy, transport, water, materials, waste, land use and ecology and pollution. Assessments are made depending on decisions made in each of these categories relating to the perceived environmental impact. A rating is assigned to a given project based on points ‘scored’ in each of the various categories. Designers can offset poor performance in some categories with better performance in others depending on the situation of a building and the site (Building Research Establishment 2013b). There are a number of international equivalent and competing schemes to BREEAM.

LEED (Leadership in Energy and Environmental Design) is the North American equivalent and like BREEAM it utilises a similar points-based system and rating scale to demonstrate degrees of environmental responsibility (https://new.usgbc.org/leed/certification/ n.d.). Green Star was developed by and specifically for the Australian commercial property market to realise the value of environmentally considerate buildings. It aims to set measurable standards, recognise and reward integrated design and life-cycle impact reductions (http://www.gbca.org.au/green-star/green-star-overview/ n.d.). NABERS (National Australian Built Environment Rating System**)** is another Australian voluntary certification scheme which assesses the energy efficiency, water consumption, waste production and management and the quality of the indoor environment of a building or tenancy and its impact on the wider environment (www.nabers.gov.au/public/WebPages/Home.aspx n.d.). Finally, Estidama is the Abu Dhabi Urban Planning Council’s guidance for the promotion of a *‘sustainable way of life for the Arab world’* (the word translates as ‘sustainability’). It is perhaps unique in this suite of certification schemes in that the criteria that projects are assessed on economic, social and cultural issues as well as environmental (http://www.estidama.org/ n.d.).

Some sectors and client types require the use of specific rating systems such as the Defence Related Environmental Assessment Method (DREAM) for Ministry of Defence work, the Royal Institute of Chartered Surveyors sKa Rating for office buildings and the Carbon Trust Standard aimed specifically at carbon emissions (www.dreamassess.com n.d.); (http://www.rics.org/uk/knowledge/more-services/professional-services/ska-rating-/about-ska-rating/ n.d.); (www.carbontruststandard.com n.d.). While these schemes take a broad and multi-faceted interpretation of sustainability, none obliges actors to check that buildings are built as specified or function as expected.

Code for Sustainable Homes and Domestic Buildings

The CSH is a variant of the BREEAM assessment system specifically for residential buildings. It has been tied to a progressive reduction in CO_2 emissions associated with domestic buildings. It uses the same nine criteria as BREEAM, allocating points to each depending on the perceived impact. The ‘level’ awarded (from 1 to 6, 6 being the lowest environmental impact) is determined by the number of credits achieved. There are three un-credited mandatory categories; the environmental impact of materials, management of surface water run-off and storage of non-recyclable and recyclable household waste. If these are met, there are four further mandatory issues in which points are awarded: fabric energy efficiency, Lifetime Homes (a design standard aimed at adaptable dwellings to suit residents throughout their lives), dwelling emission rates and indoor water use. Dwelling emission rates and indoor water use are progressively more onerous as the rating achieved improves. For example to achieve CSH level 3 a dwelling’s emission rate must merely comply with Part L 2010, but to achieve level 4 it must achieve a 25% improvement on this regulatory standard.

There are similar international domestic standards, of which the most prominent is Passivhaus, a German scheme that has become a European standard for a fabric-based approach to low energy building. Unlike other certification approaches, Passivhaus focuses on energy and certifies on a pass or fail basis. The approach is relatively simple. Passivhaus buildings are designed with a very well-insulated and very airtight fabric. Mechanical ventilation with heat recovery is then used to control the internal conditions. Accreditation is based on achieving an energy consumption of 15kWh/m^2/year (www.passivhaus.org.uk/standard.jsp?id=122 n.d.).

The UK contextual pressures are therefore not unique in using this kind of assessment method for non-domestic buildings; taking into account environmental issues and energy in the design process is a necessary part of practice. However, while the BRE is a commercial organisation and the assessment method is theoretically voluntary, local authority planning departments often use a certain certification level as a condition of planning approval. This can also be combined with provision of public funding being dependent on a commitment to delivering a BREEAM or CSH-rated building. BREEAM and the CSH occupy a position in the contextual pressures where they are voluntary but are frequently, if not most often, carried out as an obligation at design stage as part of statutory approval, and only need actors to demonstrate intent rather than approval.

Financial Incentives

The predominant mechanisms of the contextual pressures at design stage are mandated and quasi-voluntary; for occupied buildings the preferred approach is via financial incentives, ranging from tax exemptions for low-energy equipment to payments for renewably generated energy.

The Carbon Reduction Commitment (CRC) scheme is designed to target buildings and organisations that do not already fall under CO_2 emissions legislation covered in the Climate Change Act and the EU Emissions Trading Scheme. It uses tax rebates to encourage management-driven year-on-year carbon reductions until they were removed in late 2012. CRCs are aimed at large scale commercial and public organisations and aim to encourage the development of better energy management to achieve consumption reductions. They are based on a year-on-year reduction for commercial operations and allow trading in emissions rights between participants. The scheme features an annual league table of performance as an added incentive (Department for Energy and Climate Change 2012b). CRCs encourage monitoring, data collection and managerial engagement with energy consumption through the taxation system.

Enhanced Capital Allowance (ECA) also uses the tax system. ECAs are an 'enhanced tax relief' for the purchase of efficient servicing equipment including energy-saving plant and machinery, low carbon dioxide emission cars and natural gas and hydrogen refuelling infrastructure and water conservation plant and machinery. The allowable products are published on the 'Energy Technology List' and both purchasers of equipment and suppliers and manufacturers stand to gain from installation and development of low energy plant (Department for Energy and Climate Change 2012c).

While CRCs and ECAs target commercial organisations, the Feed in Tariff (FIT) encourages electricity generation from renewable sources on small to medium scale installations in commercial or domestic settings. There is a double incentive; users benefit from low or zero cost electricity for use on-site and can sell excess power directly to the grid. The sale price has a guaranteed lowest figure, to reduce the risk in investment and offsetting capital costs against the savings in bills, reducing the pay-back period on the technology employed (Department for Energy and Climate Change 2013b). The Renewable Heat Incentive (RHI) is equivalent to FIT but for heat generation. There is no means of exporting generated heat to a central grid in the same way as electricity but heat generated through renewable measures is subsidised through payment of the equivalent moneys required to generate that heat through non-green means. The incentive is aimed at the domestic market and will be introduced in spring 2014. In the meantime, there is the Renewable Heat Premium Payment scheme which is designed to support households until the RHI proper comes into force (Department for Energy and Climate Change 2013d).

The FIT and RHI aim to increase the use of renewable sources of energy and therefore reduce carbon emissions using direct payment as an incentive. The Green Deal, in contrast, encourages householders to invest in their property through savings in energy bills. The scheme operates by an assessor visiting a property, making recommendations for energy saving measures based on the costs being offset by reductions in energy bills. This ‘golden rule’ says that an intervention will only go ahead if this rule is met, however, there is no guarantee for the golden rule to be actually met during the building’s use (Department for Energy and Climate Change 2013c). Since the Green Deal has been introduced uptake has been reported to be very low (Vaughan & Harvey 2013).

The domestic building stock is also targeted by the Carbon Emission Reduction Target (CERT) and its replacement the Energy Company Obligation (ECO). CERT placed the onus on domestic energy suppliers to reduce the carbon emissions associated with their customers. The manifestation of this policy was for energy suppliers to provide professionally installed insulation measures and low energy light bulbs to customers, with a particular emphasis on low-income or vulnerable households CERT obliged suppliers to achieve 68% of reduction targets through home insulation measures (Department for Energy and Climate Change 2012a). Supplier Obligations (SO), like CERT, place the onus on energy suppliers and have evolved since 1994 into one of the most important carbon reduction policies in UK housing: the Energy Company Obligation (ECO) replaced CERT in January 2013 and continues the principle of corporate responsibility for carbon reductions with additional emphasis on customers in low income households and measures that cannot be met through other policies (such as the Green Deal) (Rosenow 2012). The details of the funding mechanism for ECO were altered in the government’s 2013 Autumn Statement but still aim to prioritise the poorest households(Office for Budget Responsibility 2013). The financial incentive components of the contextual pressures target different audiences in different ways but do not take into account the potentially diverse range of motivations within the actor network.

POE and other assessment methods

To enable actors to access these incentives and assist with monitoring activity to understand buildings, the contextual pressures also include a range of data collection and building evaluation techniques. The Building User Survey (BUS) was developed by ARUP and the Usable Buildings Trust (UBT) and is a qualitative assessment of building users’ opinion of their facilities. The survey takes into account levels of user satisfaction through rating aspects of the design such as air quality, lighting, noise, overall comfort, design, needs, perceived health, image to visitors and perceived productivity, and benchmarks this against similar buildings (Leaman 2009). This information when combined with quantitative data about energy performance can be fed back to building management and design teams to effect change through identification of the root cause of dissatisfaction (Leaman & Bordass 2004).

CIBSE TM22 Energy Assessment and Reporting Methodology sets out a means of assessing a building's energy use. It has three aims; to identify poorly performing buildings and systems, to indicate the cause(s) of poor performance and to benchmark operating procedures, and can be used to assess building designs or occupied buildings in use. The parameters cover building characteristics like floor area, building use type, fabric specifications and occupancy patterns (CIBSE 2006).

There are three levels of assessment that can be carried out using TM22. The first stage is used to establish if there is a problem with a building's energy use by comparing simple benchmarks with building energy use. The second stage can be used to further understand where the energy discrepancy is occurring by use of data from individually metered areas or appliances; the third stage can be used to identify at a system level the root cause of energy discrepancy and therefore suggest methods of improvement. The software allows for users to record energy consumption from the 'top-down' or from the 'bottom-up' (CIBSE 2006).

BUS and TM22 methodologies aim to assess buildings when they are occupied. The Soft Landings framework was developed by an industry task group led by the Building Services Research and Information Association (BSRIA) and is designed to be a 'golden thread' running through a project, linking the procurement process with initial and long term occupation. It aims to address all aspects of a building design, not just energy performance. The work is carried out by a lead member of the design team who moves into a building with the first occupants and is on hand to witness the way people use a building, answer questions and assess how the building is working. This is a way of directly feeding back information to the design team whilst simultaneously improving a building's performance (BSRIA 2009).

These formalised POE methods, together with the informal methods listed in the literature can be effective but are not obligatory.

3.4.1 Summary of the Formal Framework

The formal framework is a hierarchy of European, national and local regulations and policy. These set out how energy consumption is predicted at design stage and how other general sustainability measures are incorporated into a building design. The contextual pressures also describe how building performance is defined and how buildings are certified. This provides a direction for the project and design teams' work.

A series of levers have been developed, aiming at different actors in the procurement process. Financial incentives use the tax system to encourage commercial organisations to bring about energy reductions while householders are targeted through direct payment and reduced bills. There is no direct financial incentive aimed at design and procurement teams.

Only one component of the pressures, Soft Landings, seeks to link the design team actively with a finished building. TM22 and other POE assessment methods encourage building assessment but not necessarily by the original designer.

The formal framework assumes and requires diligent and engaged actors to overcome its weaknesses. However, there is an informal framework of perceptions and motivations that can obfuscate the aims of these legislative and voluntary mechanisms.

3.5 Informal Framework

The informal framework is comprised of literature and participant observation-derived pressures on industrial actors. These perceived pressures include barriers, aims and benefits to collecting and analysing energy data and using a crowd-sourced feedback platform.

The literature review-derived barriers include practical, financial and cultural reasons why actors do not collect data. This includes a lack of engagement with building occupiers, difficulty of access to buildings on the part of design and construction teams and a lack of knowledge about how to carry out evaluations. There is a perceived risk of additional work or liability, a perceived lack of value in the information and unclear financial benefits to the evaluation process itself (Way & Bordass 2005; Bordass & Leaman 2005; Jaunzens et al. 2003; Andreu & Oreszczyn 2004; Vischer 2009).

Just as the formal framework comprises a set of components that aim to engage different actors with different mechanisms, the informal framework applies to different people at different points in the process of designing, building and operating buildings. Empirical data collected through participant observation at steering groups and CarbonBuzz project development meetings was used to understand these variances.

The steering group was comprised of those identified as key stakeholders; actors from local authorities, QUANGOs (Quasi-Governmental Organisations), developers, institutional investors, architects, professional bodies and local authorities. The project development meetings were made up of those involved in the development of CarbonBuzz. The discussions centred around what people would like to be able to do with a feedback platform, what information would be required to do this and how a platform could deliver it. The discussion has been categorised as being concerned with aims, risks, benefits, barriers and performance measurement.

Aims

Stakeholders identified a number of aims in line with the formal directives. They wanted to *'drive emissions down'* using feedback to *'track carbon emissions throughout the* *development and life of a project'*. They felt that a feedback platform could *'Raise awareness of carbon*' generally and 'r*aise the profile of embodied carbon'* specifically. Carbon emissions were important to those with a financial interest in buildings such as developers. This was coupled by a desire to *'drive markets';* a market that acknowledges the value inherent in low carbon or low energy buildings was seen as a necessary goal of a feedback platform to help reduce overall building emissions.

Those stakeholders traditionally associated with the design team like architects suggested that a role for a feedback platform could be *'helping meet targets'*, to '*meet energy briefing targets' and 'meet energy legislation targets'*. The source of these briefing targets was not clear but could be part of the formal framework or could derive from company, project or personal aims. Participants also felt that a feedback platform should help people strategise their design; this was universally acknowledged as a goal.

Stakeholders identified the need to *'prove or rate buildings'* as a function of feedback. The motivation for proving or rating buildings came from national certification schemes and other drivers like reputation and CRC validation. Stakeholders also identified a publicity element to the use of feedback. The need to *'market successful buildings and management strategies'* was deemed an important use of data. The aims of the participants are broadly in line with the formal pressures; however the fact that these aims are seen as something that a feedback platform could or needs to deliver suggests that the current formal framework is not doing this effectively.

Risks

Participants in both groups also identified a range of risks or challenges to be overcome through the use of feedback including to *'expose the credibility gap'*. Awareness about the differences between design predictions and actual energy records, this was seen as a credibility issue rather than an energy or carbon issue. This introduces perceived actor professionalism into the pressures.

Benefits

The empirical data gathered during participant observation showed a range of benefits that stakeholders thought could be realised through the use of a feedback platform. These included helping to *'increase knowledge'* [of effective design and management techniques] and disseminate this knowledge through more effective '*interdisciplinary work'* and *'enhanced connections across industry'*. This also led to stakeholders expressing the need for a feedback platform to *'aid interdisciplinary work and knowledge transfer'*. The idea of interdisciplinary working is arguably inherent in the formal pressures, since measures like BREEAM and Part L are aimed at a design team and therefore require input from those with different expertise. However, the need for a feedback platform to aid this communication suggests that the network of actors is not operating as well as it might. This may be inherent in other aspects of project set-ups.

Feedback has a key role to play in '*cost reduction'*, '*justifying capital spend relative to energy use'* in the building sector and for helping to *'reduce building running costs'*. This shows a need to identify both design stage savings and to reduce costs of buildings in use. A 'life cycle assessment' was highlighted as a potentially useful cost function of feedback. '*Marketing'* was identified as a desirable outcome of energy feedback. Using feedback to assess building energy consumption also provided a *'visible indicator of action'* that could be used as a signifier for an organisation's approach to the environment.

General benefits identified by the steering group included the desire to *'increase understanding of what makes a good building',* to *'develop innovation'* and to *'develop innovative techniques to reduce energy consumption'.* The interest in innovation and development is counter to some of the calculation and validation methods discussed in the formal pressures.

Barriers

Practical and technical issues pertaining to the potential effectiveness of the CarbonBuzz platform were discussed exclusively in **t**he developmental meetings. These discussions centred on the best methods of capturing the information required for use as effective feedback, particularly on how performance should be measured, how to capture and store meter readings or other energy data, how best to represent building characteristics such as U-values and service types, the complications inherent in recording occupancy rates and management strategies, and how this information should be organised to reflect any zonal arrangements in building services.

3.5.1 Summary of the informal framework

The informal framework mirrors the formal framework to a degree in that many of the aims of stakeholders are similar to the general aims of the legislative and market mechanisms. However, the informal framework highlights a series of weaknesses and inconsistencies in the formal framework.

The barriers in the informal framework show perceived difficulties in direct contradiction to the aims of the formal framework. The barriers were mostly felt by designers and other members of the pre-occupation project team. They included practical difficulties in accessing buildings and a perceived lack of value in the collected data which makes it difficult to begin the evaluation process. Stakeholders with financial interests in building through ownership seemed to have fewer practical barriers, as they have access to their buildings.

Aims of using feedback included factors that the formal framework already attempts to address and some it does not. Stakeholders want to create or drive a market in low energy buildings through a feedback platform, suggesting that the reputational and certification mechanisms currently in place are not effective. Stakeholders wish to be able to effectively prove and market the performance of buildings, meaning that the existing certification schemes are not effectively doing this, or at least perhaps not maximising the potential benefits.

Potential benefits of overcoming these barriers identified by stake holders include the potential to increase understanding and knowledge of low energy buildings and the opportunity to improve interdisciplinary work. The desire for improved interdisciplinary working suggests that existing project team set-ups are not generating effective communication channels.

Finally, and perhaps most debilitating, there is a series of risks in industry that prevent engagement with building performance and seem to be generated by the culture and set-up of industry. The main risks apply to designers and other project team members and centre on the possibility of uncovering designs that do not work as intended. The potential for additional and costly work discourage designers from investigating buildings.

3.6 Contextual Pressures Summary

The literature review has shown that a range of measures have been implemented in an attempt to reduce building energy consumption. These have been combined with preliminary empirical data to define the contextual pressures. These include regulatory measures, guidance and incentives, social pressures, professional responsibilities and aspirations as well as attempts to generate a downward trend in carbon emissions. However due to the complexities inherent in the building procurement process and the often conflicting aims of individuals involved, the suite of measures does not rely wholly on a market-based approach.

The design and construction industry operates within an inter-connected framework of pressures. These can be legislative, market-based, social, legal, environmental, reputational, economic, personal or organisational. They may be perceived or actual pressures affecting decisions and actions that can affect resultant energy consumption. Information, inputs and metrics relating to each of these pressures can be very different. For example the building regulations use the quantifiable energy consumption metric of kilowatt hours consumed per metre squared of serviced floor space per annum (kWh/m^2/year) converted to CO_2 emissions (kg CO_2/m^2/year), whereas social pressures on practitioners may exist only in opinion, communicated through media, peer review or conversation.

The contextual pressures show a changing landscape of influences and metrics that vary depending on the stage that a project or development is at. There is a divide in both the formal and informal frameworks in that the pressures are different between those actors working on the procurement of buildings and those for whom buildings are procured.

The metrics at design stage are generally energy or carbon-related and use mandate or obligation to ensure that they are considered, whereas financial incentives are used for completed and occupied buildings. There are contradictions in each framework; in the informal framework, a barrier to a designer, for example the 'risk' of finding out something is wrong with a building, can be an incentive to an owner. The formal framework involves contradictions in that the Part L aims to generate a realistic prediction of the energy consumed by fixed building services, while the Merton Rule could encourage design teams to produce the lowest prediction possible in order to minimise the outlay on renewables.

The following chapter describes a methodology aimed at exploring the impact that these pressures have on industry actors.

Data collection and analysis must allow for insights into how actors' soft responses to this framework of hard legislative inputs and outputs throughout the process of designing, building, operating and occupying buildings affect design proposals, management strategies and energy consumption.

4 Methodology

Before describing a specific methodology for this thesis, this chapter will describe the theoretical context and research process, outlining how various methods of collecting, analysing and interpreting data will be integrated to answer the research questions. The structure of this chapter is loosely based on these criteria and is made up of the following sections:

4.1. Knowledge gap
4.2. The research boundaries and theoretical perspective;
4.3. Methodology design;
4.4. Survey method
4.5. Energy data method
4.6. Interviews method

4.1 The knowledge gap

The research questions based on the knowledge gap identified in the literature review have interconnected subjects (industry actors, energy consumption, and the contextual pressures), a range of possible variables (energy consumption data, opinion, building characteristics) and a range of data types. The potential role for feedback is therefore varied and dependent on a range of factors: an actor's responsibilities and interests, the aim of using feedback, how the information will be used, what kind of decision it is being applied to, who the audience for the information is (what is their role and why are they looking at the information), when it is being used, the desired outcome of its use and any barriers that are in place. This chapter describes a methodology aimed at exploring the potential role of feedback as a device to respond to and where necessary overcome the existing contextual pressures. Each of the four research questions are answered using a specific method prior to the conclusion drawing.

4.2 Research Boundaries and Theoretical Perspective

All actors are working within the contextual pressures but may have different relationships to the pressures depending on their role, worldview, responsibilities, clients, personal ambitions and more. In this regard the contextual pressures may vary from actor to actor. There are pieces of legislation and guidance that require fixed inputs and have quantifiable outputs; however these are wrapped up in a host of perceived inputs and outputs constructed by professional and social influences. This range suggests a mixed methodology study. This methodology is designed to assess these complexities and explore where feedback can contribute to this process and improve outcomes. The boundaries for this work are therefore actors and their interactions with each other, legislation, data and building design or management protocols. Analysis will describe actor interactions within the contextual pressures and energy consumption data in order to define a theory for the future role of feedback.

The types of data and operations that are being studied are both quantitative and qualitative therefore a mixed methods study is appropriate (Tashakkori & Teddlie 2003; Leech & Onwuegbuzie 2007b) but the range of data required to answer the research questions could fall within a number of traditional research paradigms which raises potential analytical complexities, however, the strengths of mixed methods centre on offsetting the weaknesses of opposing paradigms that typically use only single methods and data types.

In a mixed methods study, qualitative words and narrative can be used to add meaning to numbers, and similarly quantitative data can be used to add precision to qualitative narrative thus providing the strengths associated with both qualitative and quantitative work. The methodology design can be adapted to provide the best way of approaching a problem using sequential or concurrent phases; these can be adjusted during the research process. This kind of pragmatic approach to research using the strengths of one method to counter weaknesses in another can provide different insights that may otherwise be missed and can therefore create more rounded knowledge. (Tashakkori & Teddlie 1998; Mertens 2012; Johnson & Onwuegbuzie 2004).

A pragmatic approach to research can be viewed as an ‘anti-paradigm’ (Howe, 1988, Reichardt & Rallis 1994 cited in Tashakkori & Teddlie 1998) or as the third research paradigm despite the wide range of methods that are employed (Christ, 2009; Greene, 2008; Harrits, 2011; Morgan, 2007 in Torrance 2012a). A pragmatic research approach is described by Tashakorri and Teddlie as the adoption of *‘whatever philosophical or methodological approach works for the particular research problem under study’* (Tashakkori & Teddlie 1998) and supports the use of mixed methods on the premise that there is no single set of appropriate methods, and that the criteria for choosing methods should largely be driven by what fits with the research question without over simplifying the research questions (Mertens 2012).

Pierce uses an analogy of a cable as opposed to a chain to describe pragmatic enquiry and the ‘strength’ of the resultant knowledge; a chain being no stronger than its weakest link, a cable being made of numerous fibres all of which can be very slender. The strength comes from the intimate connections between them (Pierce, 1868 cited in p 5- 6 Peirce & Menand 1997). A pragmatic study must therefore embrace eclecticism, pluralism and a multi-method approach to the development of theory (Johnson & Onwuegbuzie 2004).

This methodology aims to integrate quantitative and qualitative work into a single study where the weaknesses of each phase of the methodology are compensated for by the strengths of others. A pragmatic approach means that no one overriding position is used throughout the research and that the sub-strands of the work will be approached in different ways prior to integration.

4.3 Methodology Design

There are six methodological approaches used in this thesis, split into three phases.

Phase 1 consists of the definition of the contextual pressures that will form the framework for the rest of the work and have been described in chapter 3.

Phase 2 consists of three partially concurrent strands. An internet survey; the analysis of the CarbonBuzz data; and a series of qualitative interviews. The survey aimed at beginning to answer research question 2 *'How do the contextual pressures influence the [lack of] interplay between design and construction practice and energy information?'* A further aim was to understand how different actors in industry respond to this framework.

Analysis of the data in the CarbonBuzz database identified particular characteristics of the energy consumption figures and answered research question 3 *'Does building energy consumption reflect actors' experience of working within the contextual pressures?'*

The series of semi-structured interviews aimed at developing the research themes and filling the gaps in the survey and energy data. The interviews use research question 4 as a starting point *'What does the relationship between the contextual pressures, building energy data and actors' experience tell us about the future role of energy feedback?'*

Phase 3 comprises the triangulation and integration of the results and the development of an overarching theory. It is presented as a synthesis chapter which answers the final research question: *'What changes need to be made to the contextual pressures or actors' behaviour to implement the future role of feedback?'*

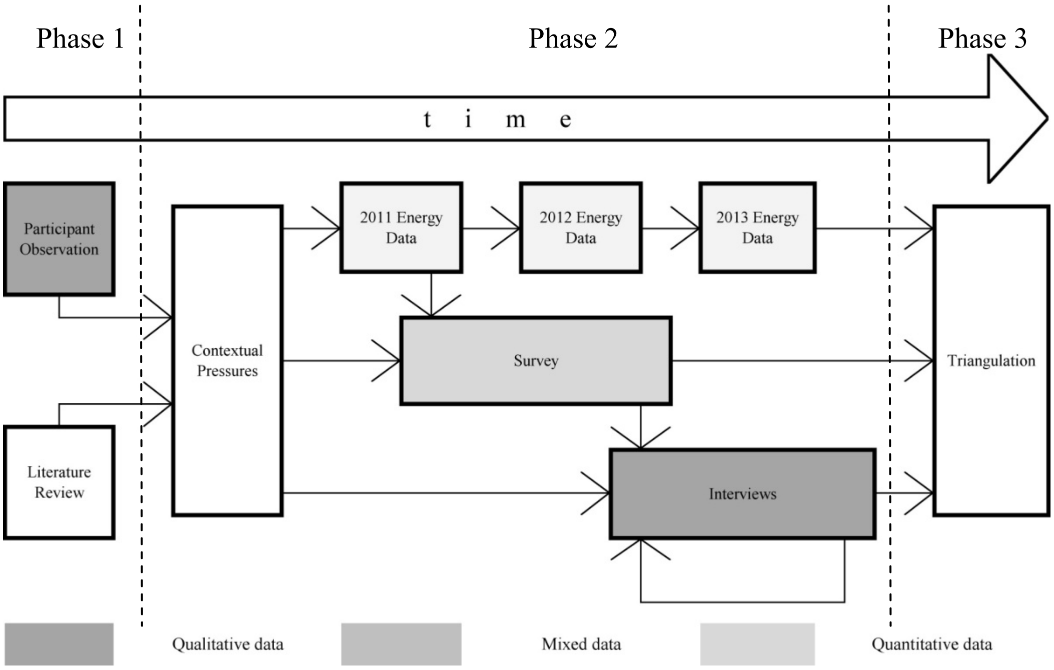


Figure 4. 1 Diagram of the research process.

Figure 4.1 illustrates the methodology and shows how the contextual pressures are used. Quantitative and qualitative data was collected simultaneously or as close to simultaneously as was practical and was then be analysed separately and the data only mixed at interpretation stage. Equal weight or status was given to both quantitative and qualitative data, each used to validate the other (Leech & Onwuegbuzie 2007b).

Target Population

The target population of this study was the UK building design, construction and management industries, in particular those actors whose decisions impact on energy consumption; architects, engineers, managers and builders. The Construction Industry Council, a quasi-non-governmental organisation (QUANGO) that researches, represents and provides educational services to the UK construction industry regularly surveys construction professions.

Service	No. of Industry Actors	%
Engineering	74,682	28
Architecture	63,261	23
Management	33,426	12
Surveying	60,912	23
Facilities management & others	17,442	6
Planning	20,277	8
Total	270,000	100

Table 4. 1 Construction Industry Council (CIC) survey of industry, 2005 (Construction Industry Council 2005).

Table 4.2 shows the numbers of professionals working in the UK construction industry in 2005 (the latest data collected by the CIC). The largest group in industry are Engineers, who account for 28%. The next largest groups are Architects and those working in Surveying. The smallest group are Facilities Managers with 6% of industry and Management and Planning which represent 12 and 8% respectively. This sample does not include contractors or policy makers and is therefore not representative of a typical project team.

4.4 Survey

The broad aim of the survey is to answer research question 2 'How do the contextual pressures influence the [lack of] interplay between design and construction practice and energy information?' through understanding how the various pressures impact on practice and to understand how information is currently used or not by various actors in the industry.

Question Design and Data Collection Methods

To carry out a cross-sectional study targeting a geographically diverse and numerically large population required a method that allowed for mass communication and low-cost data collection. An interactive web survey was deemed the most efficient approach. Using an internet survey provides a ready language for the development of questions; 'rules' for interaction are already established and understood which include multiple choice, grid, Likert scale and free text questions. Radio buttons were used for multiple choice, grid and Likert scale answer options, with one or more answer choices possible depending on the question.

A small number of stand-alone open-ended questions were included to allow respondents to add further comment and increase the 'richness' of the data and used as a basis for identifying potential interview candidates. Bosnak has shown that that these questions are often answered by those with strong opinions, therefore those answering them may be suitable interview candidates (Bosnjak, 2001, cited in Leeuw et al. 2008).

The survey questions were developed in four steps. Initially, a draft was prepared for industry comment covering technical aspects relating to legislation, platform specification and issues of question clarity based on the themes of the contextual pressures.

Secondly, a refined question set was sent to academic specialists in social research and building performance evaluation for comment on clarity of meaning, the tone of the questions and technical issues relating to the question content, with regards to building performance or methodological issues. At this stage Question Base (http://questionbase.50megs.com/) was utilised where possible, to word questions and answers in standard questionnaire format so as to try and ensure a minimum of bias in the responses through leading wording.

The third step in the process was a series of ‘cognitive interviews’. The process of cognitive interviewing is intended to identify potential sources of response error through misunderstanding in questionnaires through intense sessions with a small number of people to carry out ‘think aloud verbal profiling’ (Powers 2000). Four people, two from architectural, one each from sustainability consulting and engineering backgrounds took part individually in this process.

The final stage in the development process was to use the initial version of the survey to carry out a pilot study, the pilot was sent out to around 50 of the target population. This allowed the author to check the functionality of the web-based survey software, the data collection, storage, analysis and retrieval processes. The following sections describe the question set, breaking it down into seven categories. Refer to Appendix 1 in the Appendices volume for the full questions.

1 Profile of actor: These questions were aimed at characterising respondents by role, organisation type, organisation size, actor experience and the kind and location of work that they have been doing. Data were also captured to characterise respondents by the more subjective perception of the importance of certain design and management factors to their organisation. The categories for both the respondent role and the building sector type were aligned with the CarbonBuzz platform categories allowing for a cross-reference between survey responses and the CarbonBuzz energy data.

2 Energy Targets: the respondents were asked what factors are important when setting project targets.

3 Energy Analysis: these questions relate to the performance gap, aiming to understand how respondents make energy consumption predictions, what energy end-uses they take into account, and how they monitor the impacts of the decisions they make.

4 Post Occupancy Evaluation: this set of questions established the number of participants who are actively collecting energy data from finished buildings. Answers to this question determined the remaining question set that respondents answered; if they did no data collection, respondents were directed to category 6 questions, only those that collect data answered category 5 questions.

5 Information Flow Paths: these questions were answered by those respondents who did collect energy data and aimed to capture the methods used to communicate information. This category contained question 17 (see Appendix 1) which explicitly asked respondents whether they use Carbonbuzz or any other data sharing platforms.

6 Disincentives: the final set of questions was framed to establish the main disincentives to data collection facing respondents.

7 Free text question: Finally, a free text question was included. This question was not connected to any other multiple-choice question and was aimed at those potential interview candidates.

Data Cleaning

The internet survey data collection method meant that minimal cleaning of the analysis data set was required. Non-responses were left in; the number of responses declined throughout the question set as is to be expected. The number of respondents in each case is indicated in the results chapter. Some answers were normalised for analysis; this is explicitly stated in the analysis chapter. The assumption was made that no one would answer the survey twice; therefore duplicate IP addresses were left in, as many pieces of equipment can lie under one router.

Sampling Strategy

The required response rate was defined by using Cochran's formula for determining sample size. The required sample is based on three criteria: the level of precision, the level of confidence and the degree of variability in the population (Field 2013). The level of precision can also be expressed as the sampling error; a sampling error of 5% is typical. The confidence level is based on the number of respondents within two standard deviations of the true population value. 95% is often a standard used. The degree of variability is determined by the by the homogeneity of the target population (i.e. the proportion who are likely to share the same characteristics or views): the less variable, the smaller the required sample size Cochran's formula is as follows:

$$n_0 = \frac{Z^2pq}{e^2}$$

Where n_0 equals the required sample size, Z is the confidence level, e is the desired level of precision, p is the estimated variability in the sample and q is p-1. For this study a maximum variability was assumed of 50% so p=0.5. A 95% confidence level was desired so Z=1.96 and precision level of ±5%, so e =0.05.

$$n_0 = \frac{(1.96)^2(.5)(-.5)}{(.05)^2} = 385$$

The total target population would require a sample of 385 respondents. For small population sizes, an adjustment can be made to reduce the required sample size. However, with a large target population such as the construction industry (with 270,000 people), this adjustment reduces the required respondent number by a fraction of one (see Appendix 2 in the Appendices volume for the calculation) therefore the figure of 385 was used as a target for the number of responses to this survey.

To ensure that a sample size of 385 was achieved, likely response rates were taken into account when defining a sample frame. Expected response rates to emailed surveys have been reported as high as 70% and as low as 19% (Yun & Trumbo 2000). Using a 19% response rate a sample frame would need to consist of a minimum of 2019 people.

In order to approach a sufficient range of industry actors, overcome the difficulty of obtaining contact details and avoid the inherent bias in the methods, two sampling strategies were used: a geographical area frame and a list frame. This results in a non-probability convenience sample as the survey was sent to all addresses in two sample frames rather than a random sample from across industry.

The London Area Frame (LAF) consisted of all organisations registered with the RIBA, CIBSE and British Institute of Facilities Mangers (BIFM) in London and listed on their respective membership web-sites. London was chosen as the geographical definition of the area frame for two reasons: first, the scale of the city and the number of organisations represented, and second for practical reasons: it was hoped to use the survey respondents as a basis for identifying interviewees, since interviews were to be carried out face-to-face, therefore identifying participants within close proximity to the author would make the next phase of data collection easier.

The list frame used the CIBSE School Design Group (CSDG) membership list. The CSDG is an industry group who aim:

> *"to improve the design, operation, and environmental quality of educational buildings." (http://www.cibse-sdg.org/ n.d.).*

Access to this group was granted through the group administrator. Table 4.3 shows the sample frames used.

Area Frame	London Area Frame	CSDG List Frame	Total Sample Frame
RIBA	1061		
CIBSE	288		
RICS	63		
Total	1412	5715	7127

Table 4. 2 Survey sample frame populations.

A total number of 7127 contacts were made. In order to achieve the required sample size, the response rate could be 5%. Two emails were sent to all email addresses, (See Appendix 3 in the Appendices volume for the invitation process and email text.)

The invitation email contained contact information offered to respondents and encouragement to get in touch for clarification, complaints, questions or other reasons as a means of engendering trust and encouraging responses (Eichman, cited in Leeuw et al. 2008). Assurances were given regarding the anonymity of responses and the safety of the data to create trust and encourage responses.

Response Rate

	Total Contacts	Number of Responses	Response Rate
London Area Frame (LAF)	1412	109	7.7%
CSDG List Frame	5715	394	6.8%
Total	7127	503	7.1%

Table 4. 3 Survey response rates.

Table 4.4 shows the number of the responses from each sample frame. The response rates are low according to target rates (Dillman 2007). As the list frame was to individual addresses rather than company addresses, it might have been expected that the response rate for this would be much higher than the area list, but they are very similar. This could be explained by the fact that although there were 1412 addresses on the LAF list, the actual response rate is not known because the introductory email requested that the survey link be forwarded to the rest of the recipient organisation. The actual response rate is therefore likely to be lower. The overall (known) response rate of 7% could be explained by the restrictions placed on how many emails could be delivered to the CSDG list. However, the target sample of 385 was achieved.

Table 4.5 shows the respondent roles and the actual breakdown of industry professionals according to the CIC survey of industry. Together with differences in the proportions of the sample and a Chi-square goodness of fit test. The survey responses have been grouped in the CIC categories, however this leaves 21 percent of respondent in ‘Other’ categories and not included in the comparison. Of the 104 respondents registering as ‘Other’, 72 could be classified in CIC categories and 32 could not.

Respondent Role	CIC Total	CIC %	Survey Responses Category Specified	‘Other’ Responses Categorised	Survey Total	Survey %	Differences	Chi-squared p-value
Engineering	74682	27.7	211	9	220	43.7	16.1	
Architecture	63261	23.4	91	14	105	20.9	-2.6	
Management	33426	12.4	11	28	39	7.8	-4.6	
Surveying	60912	22.6		17	17	3.4	-19.2	
Facilities management	17442	6.5	11	3	14	2.8	-3.7	
Planning	20277	7.5	1	1	2	0.4	-7.1	
Other	0	0	0	32	32	6.3	N/A	
Sustainability Consultants	0	0	74	0	74	14.7	N/A	
Total	270000	100	399	104	503	100	0.0	0.00000076

Table 4. 4 Response breakdown.

The chi-squared test shows a statistically significant difference between the sample and the industry survey; however there are reasons for this. As well as variance in the target population, the sample frame can be a source of error including erroneous exclusions, where the target population is not fully represented by the sample frame; no list contains the full target population. The nature of a mixed method study allows for some compensation to be made through other sampling strategies in other phases of the research.

4.4.1 Data Analysis

The survey collected a range of qualitative and quantitative data, typically using a Likert scale. The data is mostly categorical or ordinal with some nominal characteristic data, continuous figures and some free text boxes. (See Appendix 1 in the Appendices volume for details of variable types collected). The statistical options for assessing such data are limited; nevertheless this section describes the procedures followed.

First, a descriptive analysis was carried out on the responses, using ranked mean scores to define the most important factors in each question category. The mean score is used to rank the responses and is calculated by assigning a value to ordinal response options; for example 1 for ‘not at all important’, 2 for ‘slightly important and so on, up to 5 for ‘extremely important’. This value is multiplied by the number of responses in the corresponding category and the mean score for each response option calculated. The data is then tabulated and displayed graphically.

Second, a series of contingency tables is described from single or multiple questions to develop uni- and multivariate analyses. In questions with ordinal data, and where response rates allow, Chi squared tests are used to test the null hypothesis of each question. Where the distribution of responses shows that some response categories have a figure lower than 5, a, Fisher’s exact test is used. The overall survey data set aims for a 95% confidence interval; a Chi or Fisher’s test value below 0.05 indicates a significant difference in the responses between two categories.

Where values are distributed so as not to make a Fisher’s exact test possible, categories are collapsed to look at specific groups of respondents: ‘Architects’, ‘Services Engineers’, ‘Designers’ (Architects and Services Engineers) and ‘Others’ (all other respondents). Other groups are defined by previous responses to questions, inferential questions or related variables described in the analysis chapter. Finally, the results are discussed in the context of the mixed research study and are used to inform the following data collection and analysis phases.

4.5 CarbonBuzz data

This section describes the analysis of the data contained in the CarbonBuzz database. The aims of the energy analysis are to answer research question 3 ‘*What is the potential for crowd-sourced data platforms to fulfil the role of feedback mechanisms?’* This is done through a description of the sources of data in CarbonBuzz, analysis of the energy and building data, and the identification of issues surrounding the quality, usability and comparability of data.

Quality Assurance and Data Cleaning

There are a number of quality assurance procedures built in to the platform interface, for example users are asked to stipulate the source of their data, be it from an SBEM calculation or a sub-meter. However, the nature of the database means that the quality is dependent on users correctly entering information. For the present analysis, minimal data cleaning was carried out. As the database is reliant on data entry by users, and part of this study aims to investigate the efficacy of crowd-sourced feedback platforms as much data as possible was left in the data set. However, the following steps were taken:

1. All projects that were marked as ‘test’ or similar were removed from the analysis database; as a relatively new platform, CarbonBuzz has a number of users who have entered trial data.
2. A manual check of categories was made to remove contradictory information. For example a project can be entered as ‘Education’ in the CarbonBuzz categorisation but in, say ‘Covered Car Park’ in the CIBSE TM46 categories.
3. Energy consumption outliers – low and high were left in as there is no way of knowing that they are not valid or genuine energy consumption figures.
4. CarbonBuzz does not correct for weather conditions for heating consumption figures. In order to make a fair comparison with the TM46 benchmarks, which are based on a heating requirement of 2,012 degree days per annum, the space heating consumption figures in the Education subset were adjusted using monthly average heating and cooling degree days from the Central Information Point (Landmark Information Group 2013). Totals were adjusted using the methodology illustrated in CIBSE TM47 to account for the variation in heating demand due to regional and seasonal differences in climate (CIBSE 2009). One adjustment from the TM47 methodology was made: 80%, rather than 55%, of the fossil-thermal energy use was assumed to be used for space heating and adjusted to 2,021 heating degree days, based on Hong et al’s analysis of the DEC database (Hong et al. 2013).

These procedures are described in detail throughout Chapter 6.

Sample and Analysis Procedures

The nature of the platform raises a number of issues: the data represent a self-selected sample of industry actors who are interested in this topic as there is no mandate to provide information for the platform. The robustness relies on enough actors providing accurate information.

There are over 700 registered organisations in CarbonBuzz which could be considered a representative sample of industry by the criteria applied to the survey data; however, the statistical power is dependent on the sample size. The sample size in a crowd-sourced platform is determined by not only the number of registered organisations but the filtering criteria applied to examine the data. This analysis uses a range of subsets and techniques to examine the relationship between design prediction and actual records and the contextual pressures. The sample sizes are small – in the single figures for detailed data – and therefore are used as part of the broader mixed-method study to discuss the likely impacts of the contextual pressures.

The analysis runs from high-level comparative statistics to detailed analysis of variances in end-use energy consumption using five subsets of the data:

> *Subset A*: Consists of all projects with any headline energy data (design or actual heat consumption or electricity use). 'Heat consumption' refers to any energy used for heating, electrical or fossil fuel.
>
> *Subset B*: All projects with headline design and actual electricity use data.
>
> Subset C: All projects with design and actual heat consumption data.
>
> Subset D: All projects with headline design and actual electricity use data and design and actual electricity use data.
>
> Subset E - All projects with headline design and actual electricity use data and design and actual electricity use data and design and actual equipment and appliance data (an unregulated end-use).
>
> Subset F - All Education projects with headline design and actual electricity use data and design and actual electricity use data and design and actual equipment and appliance data, with weather-corrected space heating figures.

Subsets A, B and C are used to perform a descriptive and longitudinal analysis of the data to understand the characteristics of the users, the available data and how this has developed over the three years of the platform's existence.

Subset D is used to carry out a series of comparative high-level performance studies to examine the relationship between design predictions and actual recorded energy figures. These are explored through distribution graphs of headline energy consumption, shown relative to mean values and benchmarks where possible, and by simple scatter plots of design versus actual data, illustrated relative to benchmarks, mean values and change ratios. The relationship between design and actual values is tested using Pearson's correlations (see Appendix 4).

Subset E is used to look at the relationships of targets, the type of building, the available characteristics and the underlying energy data. Projects with detailed disaggregated energy data are used to explore the differences in the energy gap using 'energy bars' - the industry convention and CarbonBuzz's main visualisation method - and box plots of disaggregated energy use.

Subset F is used to explore the relationship between crowd-sourced data in CarbonBuzz and TM46 Education benchmarks used as part of the contextual pressures and examine the role that crowd-sourced reporting could play in providing insight into energy consumption and dynamic energy benchmarks.

4.6 Interviews

The series of interviews used the themes from the contextual pressures as the starting point for the generation of a semi-structure of conversation prompts. Using the literature and contextual pressures as initial themes in this way also gives a starting point for development of a theory 'grounded' in the data (Charmaz, 2006). This study has followed Corbin and Straus by using the contextual pressures as starting point for the contextual conditions. Using Corbin and Straus's version of grounded theory, a researcher enters the field with a broad understanding of who he or she want to talk to and why (Corbin et al. 2008). Sampling is aimed toward theory construction, not for population representativeness.

Interview Sampling Strategy

The interview sampling strategy was determined by two considerations, one practical and opportunistic and the second purposeful. The practical consideration was that access was required to the participants for face-to-face interviews; the opportunistic approach took advantage of existing networks of contacts and used prior stages in the research to identify potential participants. The purposeful consideration was initially the selection of appropriate actors and then to identify further participants to develop and expand on the theory (Furniss et al. 2011). 23 interviews were carried out over an 18 month period, four interviewees had responded to the internet survey. Table 4.8 outlines the interviewee roles and the dates that the interviews were carried out.

Data collection procedures

Semi-structured interviews were chosen as a method as opposed to structured interviews since a 'directed conversation' can provide greater insight than a series of fixed questions. A loose structure of themes allows scope for the researcher to direct the conversation and for the interviewees to express their views, tell their stories and reflect on their work on their own terms (Charmaz, 2006). The eighteen-month interview period allowed for an evolving interview structure. The aim of the interviews was to get detailed and in-depth information about the interviewees' experiences and decision-making processes when working within the contextual pressures (see Appendix 5 for the semi-structure).

Interview Number	Date	Interviewee Role
01	07/12/2011	Architect
02	17/01/12	Engineer
03	20/01/12	Architect
04	26/01/12	Architect
05	27/01/12	Architect
06	03/05/12	Engineer
07	22/05/12	Architect/University Tutor
08	11/06/12	Architect
09	01/08/12	Contractor
10	21/08/12	Developer
11	19/09/12	Building Performance consultant
12	19/09/12	Local Authority Policy Maker
13	25/09/12	Central Government Policy Maker
14	10/10/12	Plant Equipment Manufacturer
15	16/10/12	Local Authority Energy Officer
16	17/10/12	Sustainability Consultant
17	23/10/12	Engineer
18	24/10/12	Facilities Manager - Developer
19	24/10/12	Facilities Manager – Local Authority
20	18/11/12	Architect
21	21/11/12	Consultant Policy Advisor
22	19/12/12	Energy Consultant
23	13/08/13	Surveyor

Table 4. 5 Interview participants' roles and dates of interviews.

The opening question themes and sub themes were used to guide the conversations, but were not rigidly adhered to, the decision making process, the use of feedback, the use (or not) of post occupancy evaluation derived data and data sharing (through crowd sourced platforms or otherwise) were the main discussion points. The themes were designed to generate a series of ad-libbed questions that create a data set rich in detail and depth. In order to achieve this it is necessary to combine main questions, follow-up questions and probes. Main questions were derived directly from the main headings in the themes and were largely prepared in advance; however they were not all necessarily asked of every interviewee. Follow-up questions and probes were ad-libbed to ensure depth, clarity, to get examples and to develop themes and concepts (Seidman 2006).

With face-to-face interviews; the challenge for the researcher is to develop a rapport with an interviewee in a short amount of time and create an atmosphere conducive to free and open speech as well as negotiating a rich and meaningful conversation that is going to forward the aims of the research project. In order to do this a researcher must remain alert to 'leads' and be aware that many participants may speak with implicit meaning, rather than explicit words, and must be constantly reflexive about questions and responses, how they work and how they potentially affect the data. A researcher must, as in any social or professional situation, be aware of dynamics surrounding gender, race, age and self image and respect the participant and express appreciation for participating (p. 32 Charmaz 2006).

All interviews were recorded and transcribed verbatim using 'Express-Scribe' transcription management software and Microsoft Word. Transcripts were sent to participants for comment, correction and clarification. Torrance (2012) has identified this 'respondent validation' as a means of checking for accuracy, encouraging participants to reflect on what they have said and indeed alter their contribution following further thought and reflection on the conversation (Seidman 2006).. All twenty-three transcripts were sent to respondents for validation; four returned clarifications or additional contributions. Respondent validation has a further role in the interview process: arguably there is an ontological issue with participants' knowledge that what they are saying may be quoted and published.

Data analysis

There are three phases to the processing of qualitative data that have been employed in this thesis, as outlined by Miles and Huberman (1994). These were:

Data reduction; This stage involves the selection and sometimes abstraction of data through transcribing and coding. Coding was carried out using nVivo 10 qualitative analysis software. This was used in the coding of transcripts to develop the existing themes and identify new themes, sub-themes and categorisation of responses to interviews.

Data transformation and display; Involving the use of matrices, networks, charts and graphs to make the data more readily readable. This was used purely as an exploratory method.

Conclusion drawing and verification. This process builds through the analysis from tentative theories and ideas to fully formed theory informed by patterns, regularities and configurations found in the data. All of these techniques have been used alongside representative quotes to generate a narrative discussion.

4.7 Discussion

The final phase of this research aims to answer the final research question 'What changes need to be made to the contextual pressures or actors' behaviour to implement this future role of feedback?' This is organised into two main sections and draws on all three strands of empirical data gathering and analysis along with the contextual pressures. The discussion chapter (8) is written as a narrative, converting quantitative results into qualitative discussion. This data transformation of 'qualitizing' quantitative data is a standard mixed-method technique (Tashakkori & Teddlie 1998).

The discussion chapter is organised around the four research question topics:

- How do the ‘contextual pressures’ influence the [lack of] interplay between design and construction practice and energy information?
- What is the potential for crowd-sourced data platforms to fulfil the role of feedback mechanisms?
- What does the relationship between the contextual pressures; building energy data and actors’ experience tell us about the future role of energy feedback?
- 8What changes need to be made to the contextual pressures or actors’ behaviour to implement this future role of feedback?
- Further work

4.1 Summary

This methodology has described 3 phase multi-strand sequential design with a concurrent portion. Equivalent status is given to each data type. The process of analytical triangulation aims to give a full and informative picture, more rounded and nuanced than produced by a single method and compensating for any bias in the sample. The different data sources generate discrepant accounts; this helps define areas for further investigation discussed in the final chapter (Torrance 2012b).

5 How do the ‘contextual pressures’ influence the [lack of] interplay between design and construction practice and energy information?

This question is answered using data gathered through the internet survey. The analysis focuses on survey respondents’ role related to building energy and how the contextual pressures influence their work. The chapter is organised in seven sections, the first six presenting statistical analysis of the survey responses and the final section, 5.7, synthesises these results into a discussion answering the title question of the chapter. The sections are described below:

5.1 describes the profile of the respondents through a simple statistical analysis of categorical characteristic information.

5.2 develops the factors that respondent feel influence their decision making.

5.3 explores how respondents define energy targets on their projects.

5.4 describes how respondents analyse if energy targets have been met.

5.5 looks at how many respondents evaluate buildings and which techniques they use to do so.

5.6 examines the disincentives that respondents feel hamper their efforts to carry out POE.

5.7 is a discussion section drawing on the main findings from the previous six sections.

5.1 Actor Profile

Table 5.1 shows the number of respondents ordered by the type of organisation they work for, disaggregated from the data in table 4.4. Those working for 'Services Engineers' are the largest group in the sample, making up nearly 30% of respondents. People working for 'Architectural Practices' form the next largest group, 21% of the sample.

Organisation Type	List Frame	Area Frame	Number of Respondents	% of Sample
Services Engineer	146	3	149	30
Architectural Practice	23	84	107	21
Multi-Disciplinary Practice	75	5	80	16
Other	64	7	71	14
Sustainability Consultant	33	1	34	7
Contractor	32	0	32	6
Facilities Manager	11	0	11	2
Building Surveyor	4	6	10	2
Developer	4	1	5	1
Structural Engineer	2	0	2	<1
Planning Authority	0	2	2	<1
Total	394	109	503	100

Table 5. 1 Number of survey respondents by organisation type.

74% of respondents indicated that they had been doing work based in the UK and therefore within the UK contextual pressures. 9% had been working in the wider EU and so under the European Performance of Buildings Directive. 3% had worked in other European countries and 14% in other parts of the world.

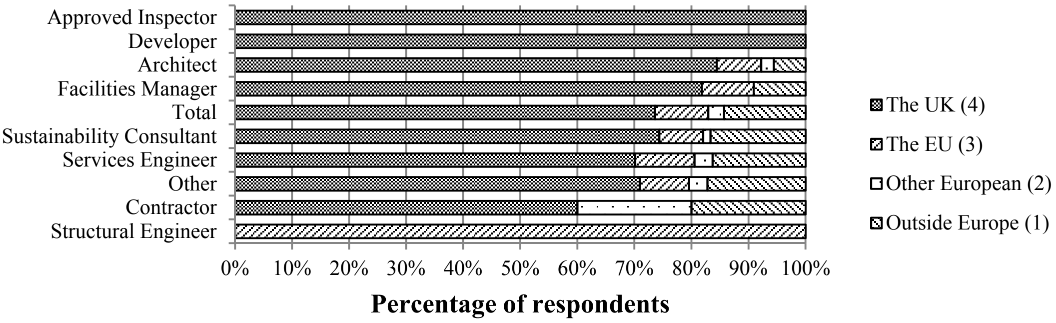


Figure 5. 1 Location of survey respondents' work.

Figure 5.1 shows the breakdown of project location by respondent role. It illustrates that the small numbers of approved inspectors and developers (1 and 3 respondents respectively) did all of their work in the UK. Architects had the next highest proportion of projects in the UK.

The sample contained respondents with roles across the eight category options defined in the survey and 104 people with ‘Other’ roles. The scope of respondents’ duties may vary depending on the size of their organisation. Approximately half (75 out of 149) of respondents working for services engineering organisations work for companies with fewer than 50 people, while the majority of architectural practices (68 out of 107) that respondents work for are smaller than 20 people. In contrast most (59 out of 80) respondents who work for multi-disciplinary practices work for organisations employing more than 100 people, and nearly half (36 out of 80) work for organisations larger than 100 people. (The data is shown in Appendix 6 in the Appendices volume).

Within these company categories, individual roles varied. The largest group of respondents was Services Engineers, 41% of the sample. 20% of the sample perform roles that were not defined by the answer options; the third largest group of respondents were Architects, who made up 18% of respondents. The smallest groups of respondents were Contractors, Developers, Structural Engineers and Approved Inspectors; respondent numbers were in the single figures for each of these categories, the proportion of respondents is shown in Appendix 7 in the Appendices volume. The majority of respondents (64%) have more than 20 years experience in their current role. Appendix 8 in The Appendices volume shows a table of respondents’ experience. The sample is a broad and experienced range of industry professionals.

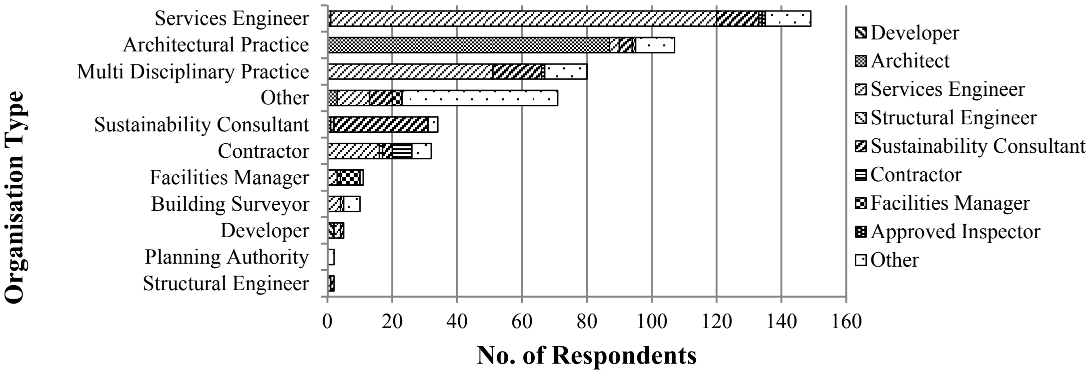


Figure 5. 2 Survey respondents sorted by organisation type and respondent role.

Figure 5.2 illustrates that respondents' roles were not necessarily defined by the organisation that they work for, for example 12 percentage points more Services Engineers responded than worked for service engineering organisations. 18% of respondents identified their role as 'Architects', 3 percentage points less than worked in Architectural Practices.

Services Engineers are represented in most other organisation types apart from architectural practices where almost exclusively Architects work. This traditional industrial arrangement could have implications for energy figures; the contextual pressures have illustrated the need and desire for increased interdisciplinary working. Architects' apparent professional isolation, despite their key role at the heart of the design process, is notable.

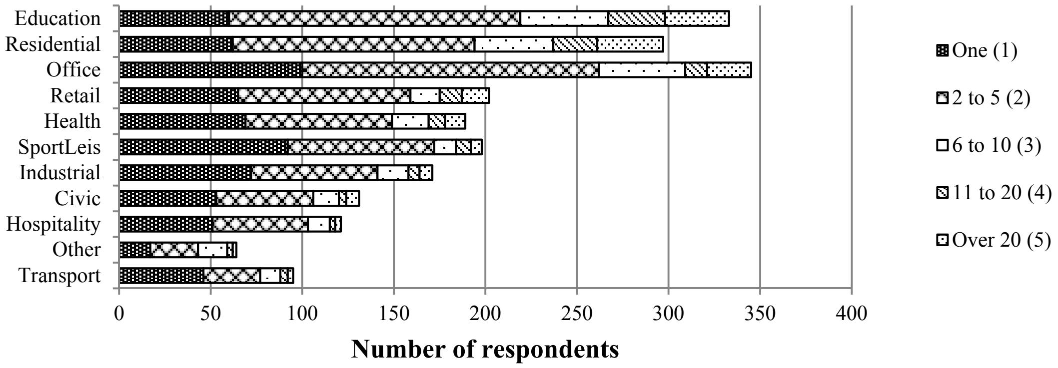


Figure 5. 3 The number of buildings worked on by survey respondents, sorted by sector.

Figure 5.3 illustrates the number and type of projects that respondents have been working on in the last year. The majority of respondents have worked on 2-5 projects, mostly in the residential, education and office sectors. 75% of respondents have worked on at least one education project in the last year. Over 20% of respondents stated that they worked on other categories of building outside of the nine categories offered. The largest 'Other' categories are defence and MOD (Ministry of Defence) projects, religious buildings made up of 'Churches', 'Mosques' or unspecified 'Religious' and 'Community'. The range of building types suggests a range of public and private sector work (assuming that most Education work is publicly funded and most office and retail is privately funded) with associated energy obligations as outlined in chapter 4.

5.2 Influencing decision making

Table 5.2 shows the number of responses to the Likert rated response options in question 5, 'Rate the importance of the following to your organisation'. The table illustrates that 'Organisation Reputation' is the most important factor to the respondents. This scored a mean value of 4.66 whereas 'Architectural Design' had a mean score of 3.82.

Factor	Mean Score	Ranking	Total Responses	Missing
Organisation Reputation	4.66	1	456	47
Occupant Satisfaction	4.39	2	458	45
Energy Consumption	4.24	3	456	47
Sustainability	4.14	4	458	45
Carbon Emissions	3.99	5	454	49
Building Running Costs	3.99	6	457	46
Building Capital Costs	3.91	7	453	50
Architectural Design	3.82	8	455	48
Other Factors	2.36	9	77	426

Table 5. 2 Survey respondents' ranked mean scores for factors' importance to their organisations.

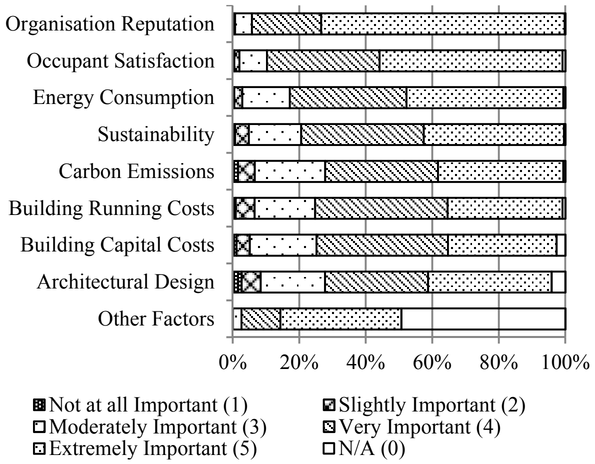


Figure 5. 4 Survey responses to 'importance of certain factors to your organisation.'

Figure 5.4 shows that approximately 70% of respondents answered that 'Organisation Reputation' was 'Extremely Important'. Approximately 55% considered 'Occupant Satisfaction' 'Extremely Important'; this is arguably connected to reputation. Architectural Design was 'Extremely Important' to the fewest respondents and also scored the lowest mean rank. Energy consumption was considered of some importance to all respondents and 'Extremely Important' by around 50% while carbon emissions were considered 'Extremely Important' by 40%.

Over fifty percent of respondents identified other factors as having some importance to their organisation. Over 25% of those respondents identifying other factors cited *'Client Satisfaction'* or related subjects, such as *'Occupant Comfort'* or *'Ease of Use'*. *'Maintenance'* and *'Lifespan of building'* were also mentioned along with '*Fuel poverty'* and *'Whole life costs'*.

Given the focus of the contextual pressures, it may be expected that 'Carbon Emissions' would be considered more important to actors. DECs and EPCs are the only published record of building performance and neither directly reflects the contributions of individual organisations or managers and therefore do not directly attribute reputation gains (or damage) from building performance. The difference in the perceived importance of

‘Energy Consumption’ and ‘Carbon Emissions’ is counter to the design stage metrics of the contextual pressures where carbon is the driving metric. The low score for ‘Architectural Design’ suggests a contradiction in the design team or overall aims of a project. The isolation of the Architect in the organisational set-up could therefore be of some significance.

Over 78% of responding Services Engineers (155 out of 198) considered ‘Organisation Reputation’ to be extremely important while 64% of Architects (53 out of 82) considered the same. Only one respondent, a Sustainability Consultant, considered organisation reputation not at all important.

Table 5.3 shows the ranked mean scores for respondent subsets’ consideration of Organisation Reputation. While all respondents consider this of high importance, Architects and Contractors consider this to be less important than other respondent groups; arguably because they are the most responsible for the overall functioning of a building but perhaps are less associated with finished buildings. Developers are high on the table; they have a direct profit motive associated with a building and their reputation is arguably dependant on the quality of the architecture.

Figure 5.5 illustrates the above data in a stacked column chart normalised to percentages of respondent roles. This shows the cumulative percentages of responses in each category (the maximum value for any category therefore being 900) ‘Extremely Important’ comprises a range of all respondent types whereas organisation reputation is considered ‘Slightly Important’ by only Contractors and Approved Inspectors. The existing mechanisms within the contextual pressures for leveraging reputation such as a BREEAM rating or DECs focus on the building itself rather than the designers or managers.

Factor	Mean Score	Ranking	Total Responses	Missing
Approved Inspector	5.00	1	1	0
Services Engineer	4.71	2	198	11
Developer	4.67	3	3	0
Sustainability Consultant	4.66	4	67	7
Facilities Manager	4.64	5	11	0
Other	4.64	6	88	16
Architect	4.60	7	82	9
Structural Engineer	4.50	8	2	0
Contractor	4.00	9	4	4

Table 5. 3 Survey respondents' ranked mean scores for importance of organisation reputation.

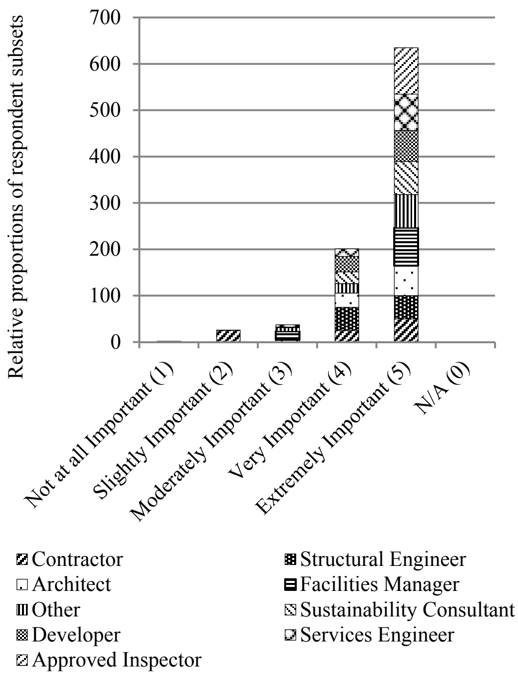


Figure 5. 5 Survey responses to importance of organisation reputation sorted by role.

A Fisher's exact test has been used to test the association between the importance of organisation reputation to different respondents. The sample has been collapsed into 'Designers' (Architects and Services Engineers – 300 respondents) and 'Others' (all other respondents - 203 respondents).

Significance of the difference in the importance of organisation reputation between Architects and Services Engineers								
Respondent Role	Missing	Not at all Important	Slightly Important	Moderately Important	Very Important	Extremely Important	N/A	Fishers p value
Architect	9	0	0	4	25	53	0	
Services Engineer	11	0	1	9	32	155	1	
Total	20	0	1	13	57	208	1	0.05

Significance of the difference in the importance of organisation reputation between Designers and Others								
Collapsed Respondent Roles	Missing	Not at all Important	Slightly Important	Moderately Important	Very Important	Extremely Important	N/A	Fishers p value
Other Role	27	1	1	10	38	126	0	
Designers	20	0	1	13	57	208	1	
Total	47	1	2	23	95	334	1	0.8

Table 5. 4 Survey respondents' contingency table of designers' importance of organisation reputation.

The contingency Table 5.4 uses the two ‘Designer’ respondent roles, Architects and Services Engineers and Designers as compared to the rest of the Sample. The first test shows Architects and Services Engineers’ responses to the importance of organisation reputation are significantly different, but only just so. While most of both respondent subsets find organisation reputation ‘Extremely Important’ a significantly greater proportion of Services Engineers than Architects do. However, there is no significant difference between Designers as a group and Other Respondents. This suggests different motivations within the design team but not necessarily between the design team and the wider project participants.

Considering the traditional services represented by the respondent groups, it could be expected that different building characteristics would be of different importance to respondents. Table 5.5 shows the ranked scores by respondent role for the importance of ‘Architectural Design’. As could be expected Architects have the highest mean score, however Developers also rate this factor highly, perhaps relating architectural design to financial value. The range of mean scores in this table is greater than in table 5.3 and is reflective of how little importance some respondents ascribe to architectural design.

Factor	Mean Score	Ranking	Total Responses	Missing
Architect	4.66	1	85	6
Developer	4.00	2	3	0
Approved Inspector	4.00	3	1	0
Services Engineer	3.70	4	195	14
Other	3.60	5	87	17
Sustainability Consultant	3.58	6	66	8
Facilities Manager	3.27	7	11	0
Contractor	2.60	8	5	3
Structural Engineer	2.50	9	2	0

Table 5. 5 Survey respondents’ ranked mean scores for the importance of architectural design.

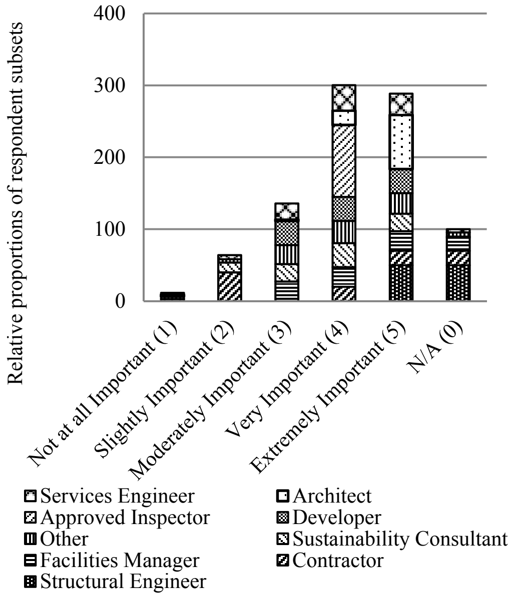


Figure 5. 6 Survey responses to the importance of architectural design by respondent role.

Figure 5.6 illustrates the data in a stacked column plot (similar to figure 5.5) showing the overall distribution of responses normalised as a percentage of each role. In contrast to Figure 5.5 there is a greater spread of responses across the range of answers. Most respondent roles show a fairly even distribution between ‘Moderately’ and ‘Extremely’ important, apart from Architects, the largest proportion of whom considers Architectural Design 'Extremely Important'.

Table 5.5 shows the p values for each test subset (Designers and Others) against the importance of architectural design. Both show a p value well below 0.05 indicating significantly different attitudes to Architectural Design both within the design team and between the design team and other actors. This emphasises the isolated position of architects in the project team and raises questions about the value placed on their contribution.

Architects and Service Engineers importance of architectural design Fisher's Exact Test	
p	0.0

Designers and others importance of architectural design Fisher's Exact Test	
p	0.0025

Table 5. 6 Survey responses: Designers Fisher's exact tests for the importance of architectural design.

The range of opinion on the importance of architectural design to respondents' organisations is greater than for Organisation Reputation and is significantly different between Architects and Services Engineers and between Designers and Others. The contribution that 'architecture' – the shape, orientation, layout etc of buildings - makes to energy consumption has been outlined in the literature review. The lack of importance attributed to this by other members of the project team could be important. Architectural design arguably impacts upon all of the factors that respondents view as important like occupant satisfaction. This discrepancy is significant for the way that actors relate to the contextual pressures as a team and may have an impact on decision-making and resultant energy consumption.

Table 5.7 shows the ranked scores for the importance of energy consumption to respondents. The Approved Inspector is the highest ranked response followed by Facilities Managers and Services Engineers. This is perhaps reflective of the respective responsibilities of each, Facilities Managers being responsible for the day-to-day running of buildings and Service Engineers responsible for energy based compliance calculations.

Figure 5.7 shows a stacked column plot of the responses to the importance of energy consumption to respondents, normalised as percentages of the respondent subsets. It illustrates that all respondent subsets are represented in the 'Extremely Important' category with a significant proportion of respondents, particularly Contractors and Structural Engineers and Architects considering energy consumption 'Moderately Important'.

Respondent Role	Mean Score	Ranking	Total Responses	Missing
Approved Inspector	5.00	1	1	0
Facilities Manager	4.55	2	11	0
Services Engineer	4.36	3	198	11
Developer	4.33	4	3	0
Other	4.30	5	88	16
Sustainability Consultant	4.25	6	69	5
Structural Engineer	4.00	7	2	0
Architect	3.85	8	79	12
Contractor	3.80	9	5	3

Table 5. 7 Survey respondents ranked mean score for importance of energy consumption.

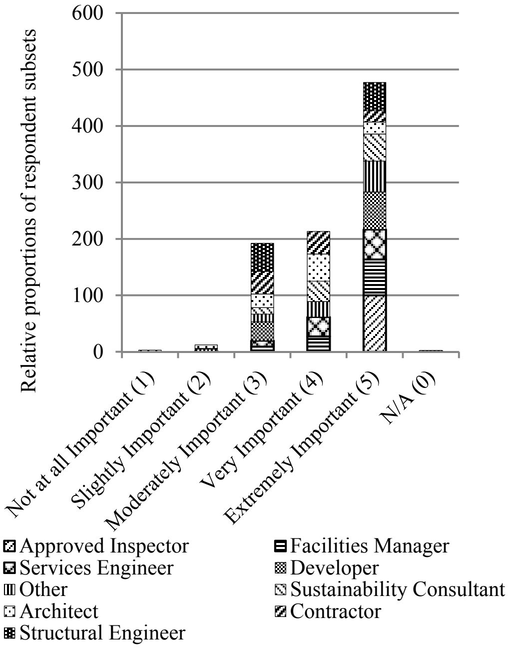


Figure 5. 7 Survey responses for the importance of energy consumption by respondent role.

Table 5.8 shows p values for Architects and Engineers and Designers and Others for the importance of energy consumption. Again there is a significant difference between Architects and Services Engineers. In this case Architects consider energy consumption significantly less important than Engineers. There is no significant difference between Designers as a group and Other respondents.

Architects and Service Engineers: Importance of energy consumption Fisher's Exact Test	
p	0.00

Designers and Others: importance of energy consumption Fisher's Exact Test	
p	0.24

Table 5. 8 Survey responses: Designers Fisher's exact tests of the importance of energy consumption.

The ranked scores show that actors have different opinions about the importance of energy consumption that reflect their responsibilities in the procurement and management of buildings. The discrepancy between the importance of energy consumption to Services Engineers and the lack of importance of Architectural Design and vice versa for Architects may indicate a lack of integrated thinking about energy in the design team. When taken in the context of the importance of Architectural Design, the results could suggest that actors are working to a narrow band of responsibility with less interest in other actors' work.

Carbon is the main metric used at design stage in the contextual pressures. Table 5.9 shows the ranked scores for the importance of carbon emissions to respondents. The order of respondents is similar to that for energy consumption, although Facilities Managers and Services Engineers have changed places in the ranking. It is notable that the range of mean scores is greater than with Energy Consumption. The lowest mean score for Carbon Emissions is 2.5; it was 3.8 for Energy Consumption, suggesting a lower overall regard for Carbon Emissions. The discrepancy between the importance of energy and carbon could stem from the fact that energy has a tangible outcome, whereas with the exception of CRCs, carbon does not.

Factor	Mean Score	Ranking	Total Responses	Missing
Approved Inspector	5.00	1	1	0
Services Engineer	4.16	2	198	11
Facilities Manager	4.09	3	11	0
Sustainability Consultant	4.09	4	69	5
Developer	4.00	5	3	0
Other	3.92	6	87	17
Architect	3.59	7	79	12
Contractor	3.50	8	4	4
Structural Engineer	2.50	9	2	0

Table 5. 9 Survey respondents' ranked mean scores for the importance of carbon emissions by respondent role.

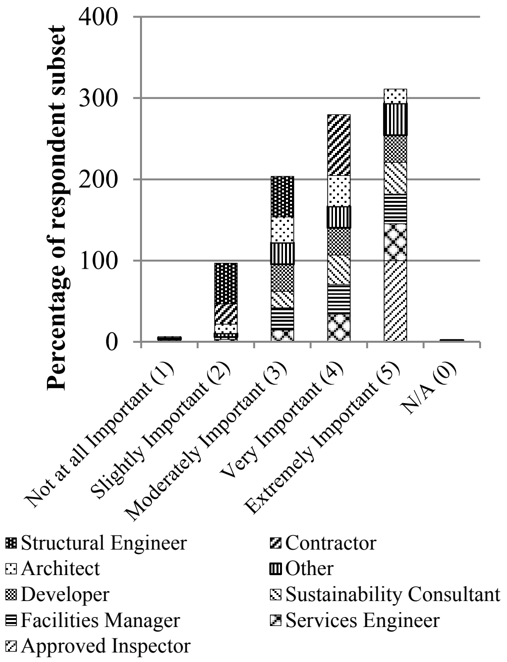


Figure 5. 8 Survey responses to the importance of carbon emissions sorted by respondent role.

Figure 5.8 shows a stacked area plot of responses to the importance of carbon emissions normalised to percentages of respondent subsets and total respondents. 'Extremely Important' has the greater spread of responses reflected in individual actor sub-groups and interests. Table 5. 10 shows that there is a significant difference between the responses of Architects and Services Engineers, but not between Designers and Others.

Architects and Service Engineers: Importance of carbon emissions Fisher's Exact Test	
P	0.00

Designers and others: Importance of carbon emissions Fisher's Exact Test	
P	0.90

Table 5. 10 Survey respondents: Designers Fisher's exact tests for carbon emissions.

Carbon emissions, like energy consumption, are reflective of individual actor groups' responsibilities however the range of mean scores is greater, the lower mean values reflecting the lower consideration of the importance of carbon emissions by the sample as a whole. The need to engage industry with carbon or with a metric that can function as a proxy for carbon is vital for the UK's CCA commitments.

The relative importance of Architectural Design and Energy Consumption showed a significant variance between actor groups: this suggests a lack of cohesiveness in project teams and in industry generally. The contrary attitudes and priorities between actors, particularly about energy consumption and architectural design, questions how decisions about building design and management are made. The contextual pressures are aimed at the predicted or actual performance of building designs and management, rather than the individual responsibilities of the design team. A lack of understanding of the interconnected importance of each others' work may impact on resultant energy consumption.

5.3 Defining Energy Targets

Given the disparate aspirations across project teams, this section looks at what influences respondents' project or organisation energy targets and how they are determined. 28% of respondents are required to meet a particular energy target on every building that they work on, while 9% are never required to meet an energy target. The largest group of respondents are those who are required to meet an energy target on 'Most Buildings'. The fact that this is not all respondents reflects the varying responsibilities across industry and the disjointed nature of the contextual pressures.

Table 5.11 shows the respondents sorted by role and ranked by the frequency with which they need to meet some energy target when working on a project. Sustainability Consultants, despite being ranked sixth in the importance of energy consumption are the top-ranked respondent type, indicating that they most often have to meet an energy target. Facilities Managers, who were second highest, ranked for the importance of energy consumption, are ranked fifth for the frequency with which they have to meet energy targets. Perhaps other metrics are more frequently used for targets.

Actor	Mean Score	Ranking	Total Responses
Sustainability Consultant	4.01	1	68
Approved Inspector	4.00	2	1
Developer	3.67	3	3
Services Engineer	3.65	4	199
Facilities Manager	3.64	5	11
Other	3.45	6	88
Architect	3.15	7	85
Structural Engineer	3.00	equal 9	2
Contractor	3.00	equal 9	5
Total			462

Table 5. 11 Survey respondents' ranked mean scores for individual actors' frequency of working to an energy target.

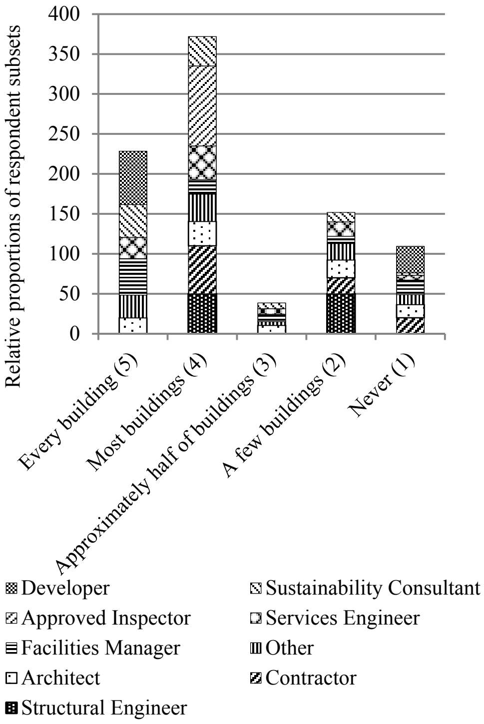


Figure 5. 9 Survey responses to frequency of working to energy targets by respondent type.

Figure 5.9 shows a stacked column chart of the frequency with which respondents are required to work to an energy target by respondent role normalised to percentages of role subsets. The chart shows a split distribution with more respondents represented at 'a few' and 'most'. This is perhaps a symptom of the question's wording and answer format but illustrates two peaks at 'most buildings' and 'a few buildings'.

Table 5.12 shows the p-values for Architects and Services Engineers and Designers and Others. Again there is a significant difference in the design team between Architects and Services Engineers but not between Designers as a group and the Other respondents.

The difference in the way the design team operates compared to the other respondents is reflective of the different mechanisms applied by the contextual pressures and could have repercussions for energy consumption. If some of the project team are working to an energy target and others are not, the communication of the implications of others decisions needs to be tailored to their intentions. Similarly if some are working to an energy target and others to a carbon target, the kind of decisions that are made could be quite different. Again communication between the team members is key.

Architects and Service Engineers: How often working to an energy target Fisher's Exact Test	
p	0.02

Designers and Others: How often working to an energy target Fisher's Exact Test	
p	0.28

Table 5. 12 Survey respondents: Designers Fisher's exact tests for the frequency of respondents aiming to meet an energy target.

The difference in the use of targets is possibly attributable to the contextual pressures as some actors are not subject to energy targets as part of their typical project responsibilities. Table 5.13 shows the ranked mean scores for factors important in determining project energy targets. It shows that ‘Mandatory Targets’ are the most important factors to respondents when determining energy targets for their projects. ‘Client Goals’ are the second most important factor followed by ‘Planning Requirements’. The lowest ranked factors are ‘Other Factors’, ‘CIBSE benchmarks’ and ‘Personal Goals’ and ‘Organisation Goals’.

Factor	Mean Score	Ranking	Total Responses	Missing
Mandatory Targets	4.47	1	369	134
Client Goals	4.27	2	372	131
Planning Requirements	4.19	3	365	138
Familiarity with Targets	3.95	4	371	132
Other Targets	3.93	5	369	134
Organisations Goals	3.81	6	371	132
Personal Goals	3.48	7	368	135
CIBSE Benchmarks	3.29	8	367	136
Other Factors	1.60	9	91	412

Table 5. 13 Survey respondents’ ranked mean responses for factors’ importance in determining energy targets.

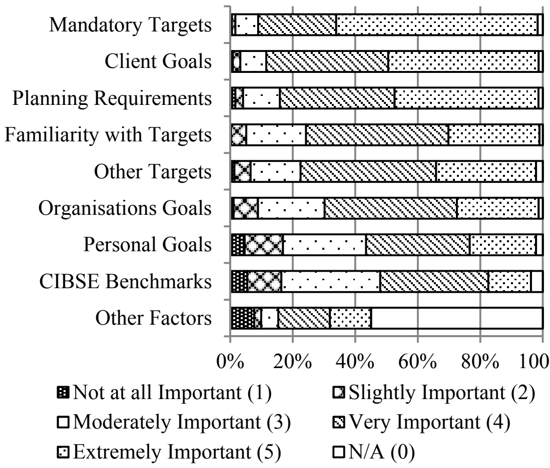


Figure 5. 10 Survey responses for factors’ importance in determining energy targets.

Table 5.10 illustrates the above data and shows in the breakdown of responses that over 5% of respondents do not consider CIBSE benchmarks or Personal Goals at all important and some 10% find each factor slightly important. Other specified factors important to respondents when deciding on energy targets include budget and cost restrictions or aims and other statutory standards, such as Section 6 in Scotland and site specific factors like fuel availability.

These factors do not describe an industry bristling with ambition; rather, a professional group adhering to minimum standards. If a ‘new professionalism’ is to be instigated, it must recognise that professionals are, for a variety of reasons, unwilling or unable to engage. However, while figure 5.10 showed that respondents mainly use mandated figures to determine their project energy targets, Figure 5.11 shows that to those for whom Energy Consumption is most important, this becomes the driving force in determining their energy targets. Of the 185 respondents who claimed that Energy Consumption is Extremely Important to their organisation, more than 40% also claim that their Organisation’s Goals are extremely important to setting targets. The development and leveraging of this interest in energy in the project team is crucial for the UK’s climate obligations and building energy performance.

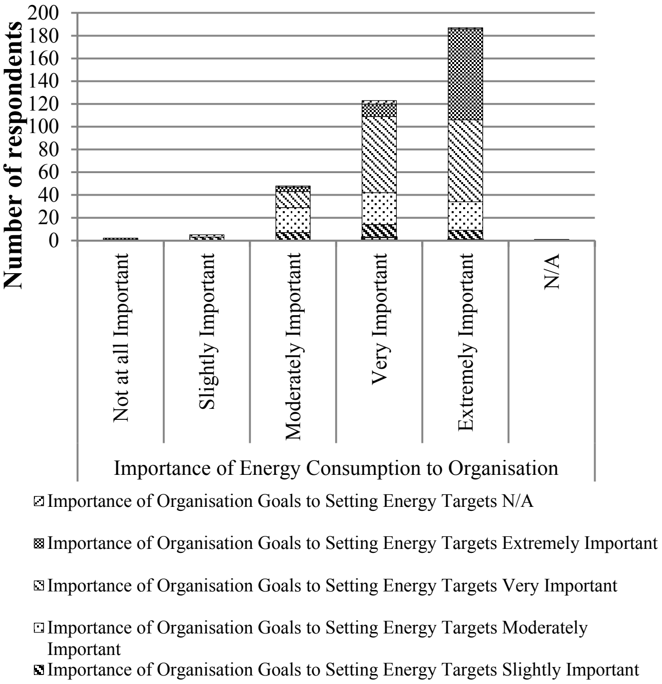


Figure 5. 11 Survey respondents’ importance of energy consumption to their organisation versus the importance of organisation goals to setting energy targets.

While mandate creates a need to engage with energy in predictions, the predictions have limitations and there is no obligation to confirm whether these targets have been met in actuality. The contextual pressures seem to encourage a lack of engagement, almost as if the professionalism of actors means that they do not engage, they simply carry out their contractual and statutory obligations. The relationship between actors' attitudes and their energy targets is an important one. The contextual pressures must do more to properly engage industry with energy targeting.

5.4 How Targets Are Met

Given the apparent deference to mandate, this section explores how respondents make energy predictions and rate existing buildings' energy performance. Table 5.14 shows the ranked scores for the frequency with which respondents use particular methods of assessing either design predicted or actual energy consumption. Part L design calculations are used more often than any other assessment method; they are used by 87% of respondents. They are used on 'Most' or 'Every' building by 59% of respondents. This is to be expected as Part L is mandated for development and major refurbishment. The figure is not 100% as not all respondents are involved in this kind of work. Around 60% of the sample are designers (Architects and Engineers) who could be expected to use Part L. Others, like Facilities Managers will not necessarily use Part L but may use meter readings or bills as a source of data. This reflects the data in Table 5.13 data that suggested mandate was the most important way of determining energy targets.

Factor	Mean Score	Ranking	Total Responses	Missing
Part L Design Calculations	3.37	1	393	110
EPCs	2.92	2	383	120
Energy Modelling Software	2.90	3	391	112
Meter Reading	2.70	4	388	115
Bills	2.36	5	382	121
DECs	2.25	6	377	126
Own Assessment Method	2.15	7	360	143
CIBSE TM22	2.03	8	375	128
Other Assessment Method	1.09	9	99	404

Table 5. 14 Survey respondents' ranked mean scores for use of assessment methods

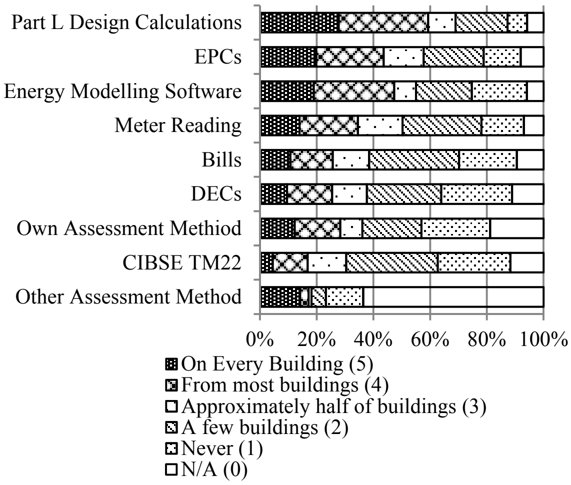


Figure 5. 12 Survey responses; frequency of use of assessment methods.

The least used industry-wide assessment method is CIBSE TM22. It is used by 62% of respondents, on half or less of all projects by 45% of respondents and 'Never' by 26% of respondents. The type of assessment method used has an impact on the resultant energy consumption prediction or diagnostic capability. Energy Modelling software which gives users the opportunity to assess and predict building energy use fully (i.e. beyond the limitations of SBEM), is used by 74% of respondents; by 18% of respondents 'On every building' and 'Never' by 19% of respondents. 'Bills' which by nature include full energy consumption but do not include a detailed breakdown of end-uses are used by 13% of those responding to the option.

Figures 5.13 and 5.14 show the numbers of respondents who use Part L design calculations (such as SBEM) as an assessment method and the frequency with which they do so. The same figures are shown for Energy Modelling Software. These calculation methods are selected for further analysis because they represent one of the causes of and a potential solution to the energy gap.

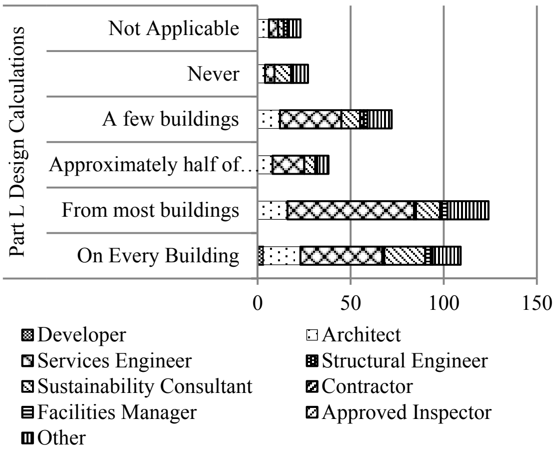


Figure 5. 13 Survey respondents' frequency of Part L calculation use, by respondent role.

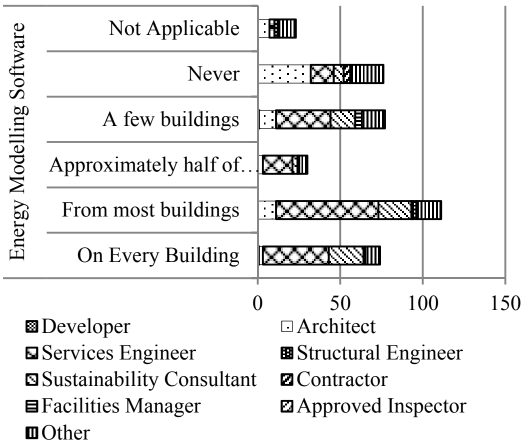


Figure 5. 14 Survey respondents' frequency of Energy Modelling Software use, by respondent role.

Approximately 240 respondents, mostly Services Engineers, use Part L calculation on most buildings or every building they work on. Approximately 25 respondents, mostly Contractors, never use SBEM. Approximately 180 respondents use Energy Modelling Software on most or every building, again mostly Services Engineers; the proportion of

Architects doing so is smaller. Of the respondents who never use Energy Modelling Software, Architects are the largest group.

Frequency of Part L as an assessment method. Architects and Services Engineers. Fisher's Exact Test	
P	0.09

Frequency energy modelling as an assessment method. Architects and Services Engineers. Fisher's Exact Test	
P	0.00

Table 5. 15 Survey respondents: Designers Fisher's exact test for the frequency of Part L and Energy Modelling Software as an assessment method.

Table 5.15 shows the p-values for the difference between Architects' and Engineers' use of Part L assessment methods and Energy Modelling Software. It shows there is no significant difference between the uses of Part L but there is a significant difference in the use of Energy Modelling Software. Architects' reliance on other members of the project team is highlighted by this table.

Frequency of Part L as an assessment method. Designers and Others	
P	0.023

Frequency energy modelling as an assessment method. Designers and Others	
P	0.284

Table 5. 16 Survey respondents Designers and Others: Fisher's exact test for the frequency of Part L and Energy Modelling Software as assessment methods.

Table 5.16 shows the p-values for the differences between Designers and Others. Contrary to the differences between Architects and Services Engineers, there is a significant difference in the use of Part L assessment methods but not in Energy Modelling Software. The difference between the Designers and Others highlights the discrepancy in the contextual pressures between prediction methods and actual records. One role of feedback is to create a meaningful link between the two, with continuous assessment throughout design and through to building use.

Table 5.17 shows the ranked mean scores for the frequency with which respondents include certain factors in energy assessments. Building Fabric Measures are the highest ranked followed by Occupancy Levels, Operating Hours and Regulated Energy, all of which are included in the national calculation methodology. Those factors not included in the NCM are in the lower half of the ranked list; Equipment Loads, Management Strategies, IT loads and Special Functions. This is consistent with the fact that Part L was the most commonly used assessment method but also highlights the need for detailed feedback analysis to be better integrated in the design and management processes. The limitations of the NCM are followed in the assessments.

Factor	Mean Score	Ranking	Total Responses	Missing
Building Fabric Measures	3.80	1	398	105
Occupancy Levels	3.69	2	391	112
Operating Hours	3.61	3	392	111
Regulated Energy	3.61	4	388	115
Equipment Loads	3.31	5	391	112
Management Strategies	3.27	6	388	115
IT Loads	3.21	7	383	120
Special Functions	2.56	8	375	128
Other	1.08	9	93	410

Table 5. 17 Survey respondents ranked mean scores for factors included in energy assessments.

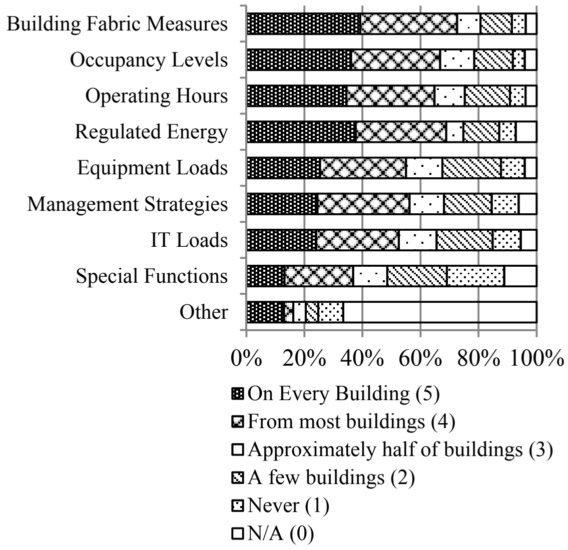


Figure 5. 15 Survey responses, factors included in energy assessments.

Figure 5.15 shows the detailed responses to the factors included by respondents when making energy assessments. ‘Building Fabric Measures’ are included on every building by the greatest proportion of respondents, nearly 40%. ‘Occupancy levels’, Operating Hours’ and ‘Regulated Energy’ are included by just fewer than 40% of respondents. ‘IT Loads’ and ‘Equipment Loads’ are included ‘On every building’ by approximately 25% of respondents. ‘IT Loads’ are ‘Never’ included by approximately 10% of respondents. This highlights the inherent weaknesses in the contextual pressures: without consideration of these unregulated loads a realistic energy consumption prediction is impossible.

Over 20% of respondents stated that they take into account ‘Other’ factors when making an assessment of the energy consumption of a project. When specified, these factors included ‘Cold bridging calculations’ and the ‘Impact of LZC’s’ [Low and Zero Carbon Technologies]. The ‘Diversity and Seasonal variation’ was also a factor for one respondent as was ‘Everything that consumes energy’ for another. The contrast between actors doing the minimum and those with an interest in energy is marked.

The list of factors taken into account in making energy assessments confirms that estimates frequently do not include all of the energy end-uses. This is consistent with the prevalence of Part L as the main assessment method (as it only accounts for fixed building services) and the lack of leadership shown by respondents in determining energy targets.

How actors use these assessment, particularly incomplete assessments, to inform their decision making can help frame a feedback tool. Table 5.18 shows how respondents monitor the impact of their decisions. The responses are ranked using an arbitrary scoring system; a value of 2 is assigned to options that involve collecting any data from finished buildings (‘Collect Feedback’, ‘Monitor Consumption’ and ‘Monitor Parts of Building’), a value of 1 is assigned to design stage analysis and iteration (‘Compare Iterations’ and ‘Other’) and a value of 0 is assigned to ‘No monitoring of impact’. This scale is designed to rank respondents by those that use the most techniques to collect actual data records.

The highest-ranked respondents are Structural Engineers followed by Facilities Managers and Developers. The lowest-ranked are Architects and Services Engineers. This is contrary to Table 5.7 that showed that Services Engineers were ranked highest for importance of energy consumption, but reflects the fact that those with access to buildings or a financial interest are most engaged with actual building data.

	Mean Score	Ranking	Total Responses	Missing
Structural Engineer	2.00	1	2	0
Facilities Manager	1.57	2	23	-12
Developer	1.50	3	4	-1
Approved Inspector	1.50	4	2	-1
Sustainability Consultant	1.46	5	108	-34
Contractor	1.43	6	7	1
Services Engineer	1.38	7	270	-61
Other	1.29	8	111	-7
Architect	1.08	9	84	7

Table 5. 18 Survey respondents ranked mean scores of techniques used to assess the efficacy of decisions.

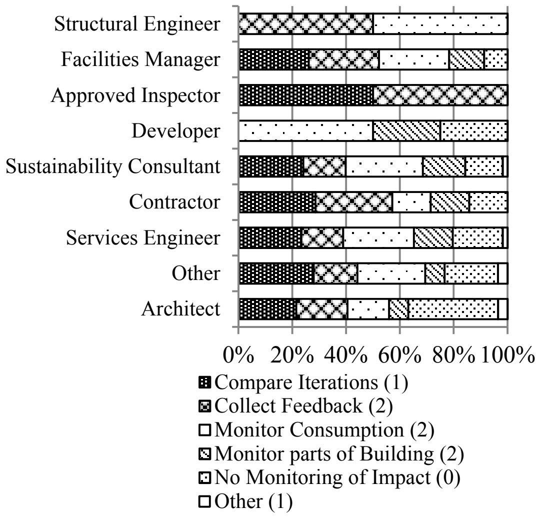


Figure 5. 16 Survey responses for techniques used to assess the efficacy of decisions.

Figure 5.16 illustrates that over 30% of architects do ‘No monitoring of impact’ although just less than 20% ‘Collect Feedback’. How respondents rated the importance of energy consumption to their organisation has a relationship with how they measure the impact of their decisions. Figures 5.17 and 5.18 illustrate the importance of Energy Consumption and Carbon Emissions respectively to respondents together with the action they take to assess their decisions. There is a clear difference between those who consider both Energy Consumption and Carbon Emissions to be extremely important and those who do ‘No Monitoring’ of the impact of their decisions.

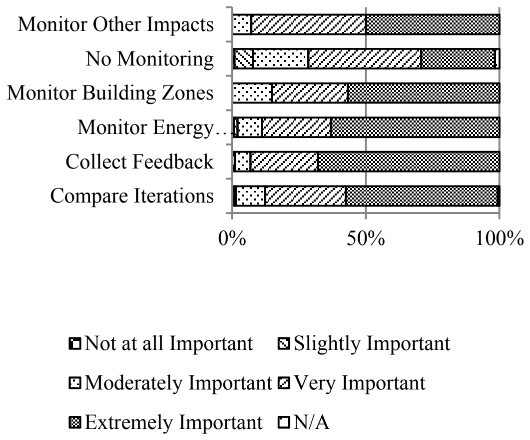


Figure 5. 17 Survey respondents’ importance of energy consumption versus the measures taken to assess the impact of their decisions.

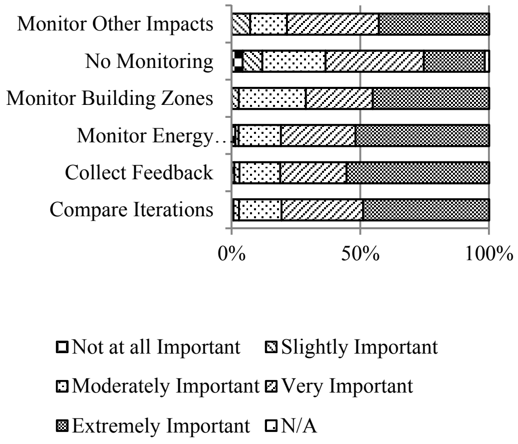


Figure 5. 18 Survey respondents’ importance of carbon emissions versus the measures taken to assess the impact of their decisions.

Actors’ willingness to engage with energy and information feedback depends on their attitude to energy or the perceived importance of energy consumption. The connection between the importance of energy and carbon and POE activities is explored further in the following section.

5.5 Collecting Data and Evaluating buildings

This section looks at those people who collect data and why they do so. Table 5.19 shows the frequency with which respondents themselves collect, or have collected on their behalf (by monitoring agencies for example), energy data about their completed buildings. 19% of respondents never collect data and 40% collect data from ‘A few buildings’. 10% collect data from ‘Every building’ and nearly 18% from ‘Most buildings’. Feedback is not habitually used in industry, despite efforts to engage actors with the practice.

Frequency of data collection	Frequency	Percent
Every building	40	10
Most buildings	71	18
Approximately half of buildings	53	13

A few buildings	159	40
Never	75	19

Table 5. 19 Survey respondents' frequency with which data is collected by, or on behalf of, respondents.

Table 5.20 shows ranked mean scores for the frequency of data collection. Approved Inspectors are the highest ranked respondent subset followed by Developers, Structural Engineers and Facilities Mangers. Architects are the lowest ranked group below Contractors, other and Services Engineers. Again, this follows the pattern that those actors with access to or having a financial interest in buildings are those most likely to collect energy data.

Actor	Mean Score	Ranking	Total Responses	Missing
Approved Inspector	5.00	1	1	0
Developer	4.33	2	3	0
Structural Engineer	4.00	3	2	0
Facilities Manager	4.00	4	10	1
Sustainability Consultant	2.80	5	65	9
Services Engineer	2.65	6	175	34
Other	2.53	7	73	31
Contractor	2.50	8	4	4
Architect	2.00	9	65	26

Table 5. 20 Survey respondents' frequency of data collection by respondent role.

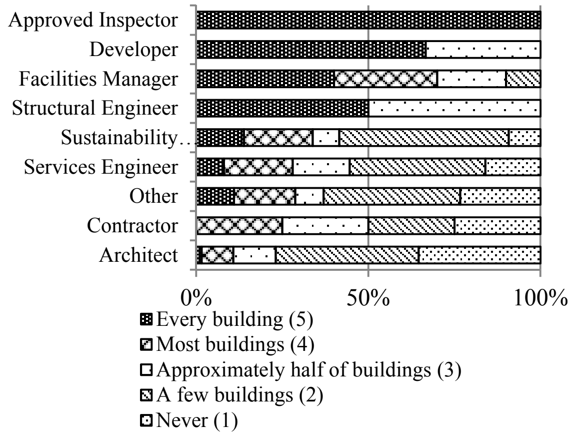


Figure 5. 19 Survey responses to the frequency of data collection by respondent role.

Collection of data is perhaps dependent on respondents' responsibilities and interests. However Architects, who make many of the strategic decisions that can impact on the energy consumption of a building, collect the least amount of data. Figure 5.19 shows over 35% of Architects never collect data from buildings. The literature review and contextual pressures have shown the pivotal position that Architects have in the procurement process.

While the respondent role has an impact on the frequency with which data is collected, others ratios may be more influential. Figures 5.20 to 5.27 illustrate the relationships between the frequency with which respondents collect data from finished buildings and the importance of various factors. Data is collected more often by respondents whose organisations think Energy Consumption, Carbon Emissions, Building Capital Costs and Building Running Costs are more important. Those respondents who find other factors important are less likely to collect data. The contextual pressures may therefore be creating this ‘importance’. Whether it is through formal or informal levers is unclear; it may be that the formal framework creates the informal pressures.

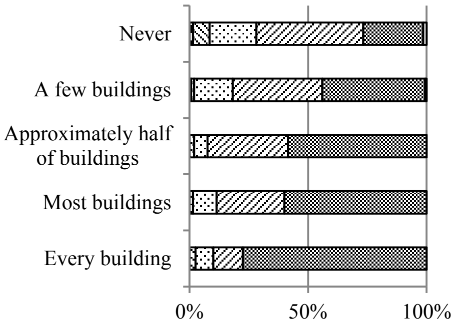


Figure 5. 20 Survey respondents’ importance of energy consumption versus the frequency of data collection

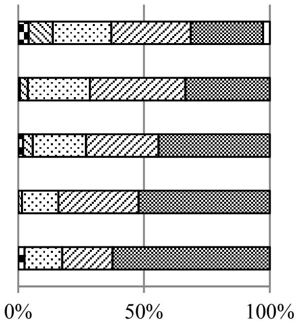


Figure 5. 21 Survey respondents’ importance of carbon emissions versus the frequency of data collection

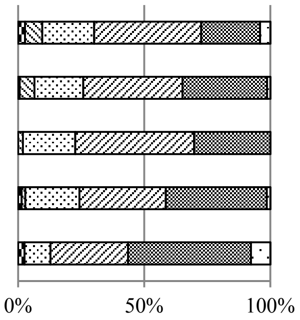


Figure 5. 22 Survey respondents’ importance of building capital costs versus the frequency of data collection.

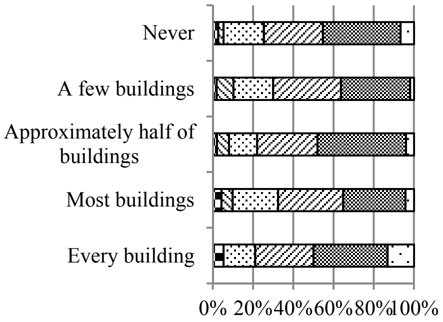


Figure 5. 23 Survey respondents’ importance of architectural design versus the frequency of data collection.

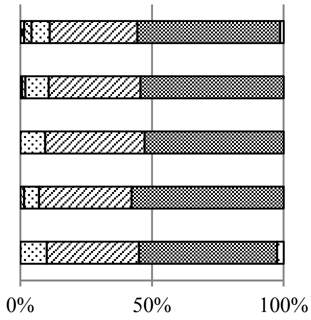


Figure 5. 24 Survey respondents’ importance of occupant satisfaction versus the frequency of data collection.

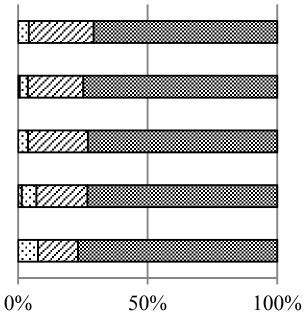


Figure 5. 25 Survey respondents’ importance of organisation reputation versus the frequency of data collection.

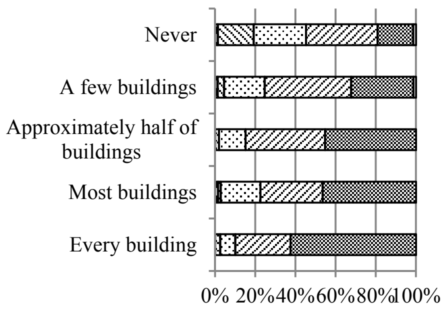


Figure 5. 26 Survey respondents' importance of building running costs versus the frequency of data collection.

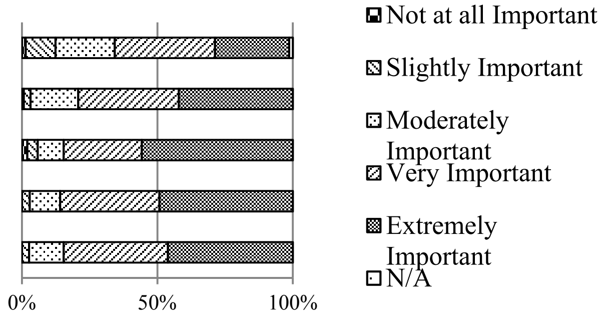


Figure 5. 27 Survey respondents' importance of sustainability versus the frequency of data collection.

The following responses were gathered from the 324 respondents who indicated that they collect data from at least 'A few' buildings i.e. those that collect any data at all. Table 5.21 shows that of those who regularly collect data from at least a few buildings, they most often collect 'total kWh of electricity' consumption followed by data on 'Occupant Satisfaction'. The lowest ranked data collected were 'Other Data', 'Individual Zones', 'Individual Systems Consumption' and 'Physical Information'.

Factor	Mean Score	Ranking	Total Responses	Missing
Total kWh Electricity	3.27	1	286	217
Occupant Satisfaction	3.24	2	284	219
Operating Hours	3.06	3	284	219
Total kWh Gas	3.03	4	282	221
Occupancy Data	2.90	5	283	220
Internal Conditions	2.85	6	281	222
Total kg CO_2	2.52	7	262	241
kWh for individual systems	2.43	8	276	227
kWh for individual zones	2.22	9	268	235
Physical information	1.56	10	458	45
Other Data	0.88	11	67	436

Table 5. 21 Survey respondents' ranked mean scores for the kind of data typically collected.

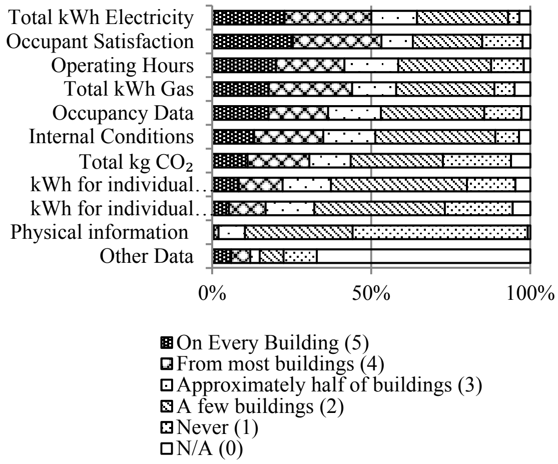


Figure 5. 28 Survey responses to the kind of data typically collected.

Figure 5.28 shows that Physical Information about a building is never collected by more than 50% of respondents; however most, if not all respondents must have information on the size and physical nature of the buildings they work on. The difference between electricity and gas consumption collection may be explained by larger numbers of electrically-heated buildings. CO_2 data is collected on every building by only 10% of respondents despite being the primary metric for the contextual pressures. 25% of respondents indicated that they collect other kinds of data from at least a few buildings including '*kgCO$_2$/person year*', '*humidity*' and '*data to compare to other standards, e.g. PassisHaus*' and *'person years worked'*.

The more detailed the information - building zones energy consumption for example - the less often it is collected. This has implication for the usefulness of the data in a diagnostic and decision-support platform – without collection of detailed information, 'effective feedback' will never be delivered. The lack of mandate for data collection means that detailed information is not collected. However, those who collect data obviously act outside of legislative obligations. Understanding what prevents others collecting information will help define the role of feedback and reshape the contextual pressures.

Table 5.23 shows detailed responses as well as ranked mean scores for reasons for collecting energy data. To 'Improve Future Projects' is the highest ranked reason followed by to 'Meet Legislation' and to 'Meet Briefing Targets'. The lowest ranked reasons are 'Knowledge Transfer', to 'Track Carbon Emissions' and 'Other Reasons'.

Factor	Mean Score	Ranking	Total Responses	Missing
Improve Future Projects	3.89	1	282	221
Meet Legislation	3.85	2	285	218
Meet Briefing Targets	3.78	3	282	221
Reduce Running Costs	3.75	4	290	213
Reduce Carbon Emissions	3.69	5	286	217
Marketing	3.48	6	283	220
Justify Capital Costs	3.46	7	280	223
Knowledge Transfer	3.25	8	283	220
Track Carbon Emissions	3.01	9	281	222
Other Reasons	1.14	10	63	440

Table 5. 22 Survey responses on the importance of different reasons for collecting data.

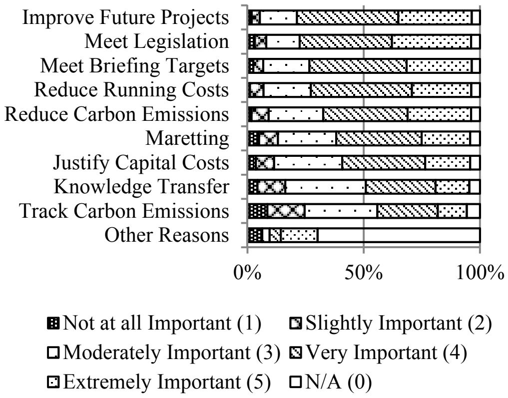


Figure 5. 29 Survey responses on the importance of different reasons for collecting data

Figure 5.29 illustrates the same data and shows that while a small proportion of respondents find each reason not at all important, apart from to 'Track Carbon Emissions', each reason is considered at least very important by more than 50% of respondents. Carbon is the primary metric for the contextual pressures. The importance of 'Improving Future Projects' contrasts with the relative lack of importance ascribed to 'Knowledge Transfer' which is in contrast to earlier results but does also confirm some of the barriers identified in the contextual pressures about realisation of benefits. The idea that feedback can be used for advocacy or diagnosis is not supported by other responses. The importance of 'Meet Legislation' and 'Meet Briefing Targets' reinforces the importance to the respondents of mandate and client goals and regulations.

20 respondents gave reasons under the 'Other' category for collecting energy data. These reasons included: *'to track progress against target savings and to help identify further projects that could be implemented to save energy'* suggesting an active role in POE and exploratory data collection. A reason for not collecting any information was given; *'clients expect energy efficiency knowledge but do not expect to pay extra for it, and certainly not to have it monitored afterward'* suggesting an interest and willingness to engage with building energy data but a difficulty in persuading Clients to follow.

Three respondents identified contractual requirements as reasons for collecting data, with one elaborating that this was *'to help avoid consumption penalties imposed by contract'* Two others cited funding application requirements and grant application procedures and one identified the practicalities of sizing equipment during renovations as a reason for collecting information. The use of contracted energy targets is not currently part of the contextual pressures but could be an independent way of ensuring that greater consideration is made of energy at design stage and holding designers responsible for the results of their decisions.

The reasons that respondents collect data supports their reliance on mandate to set energy targets and their desire to enhance their reputation through improved building quality. There is less interest in sharing or in carbon emissions, a key metric of CarbonBuzz, as well as the contextual pressures.

The contextual pressures have shown that the manner in which data is communicated is important to actors. Table 5.23 shows detailed responses and ranked mean scores for techniques used to collect data. The list of techniques is derived from Bordass and Leaman's *'Making Feedback and Post Occupancy Evaluation Routine'* (Bordass & Leaman 2005). The top ranked method is 'Technical Discussions'. These involve the project team in a post-project meeting to discuss how the project went and any lessons that can be learned. The next most widely used techniques are 'Walk Through Surveys' and 'Energy Surveys'.

The least used techniques are ‘Focus Groups’, respondents’ ‘Own Data Capture Techniques’ and ‘Occupant Surveys’ – the latter contradicting the importance of ‘Occupant Satisfaction’ to the respondents and the most frequently collected data.

Factor	Mean Score	Ranking	Total Responses	Missing
Technical Discussions	2.93	1	282	221
Walk Through Surveys	2.88	2	281	222
Energy Surveys	2.78	3	288	215
Post Implementation Reviews	2.67	4	281	222
Post Project Reviews	2.64	5	281	222
Occupant Surveys	2.38	6	285	218
Your Own Data Capture Techniques	2.25	7	201	302
Focus Groups	2.23	8	277	226

Table 5. 23 Survey respondents’ data collection techniques typically used.

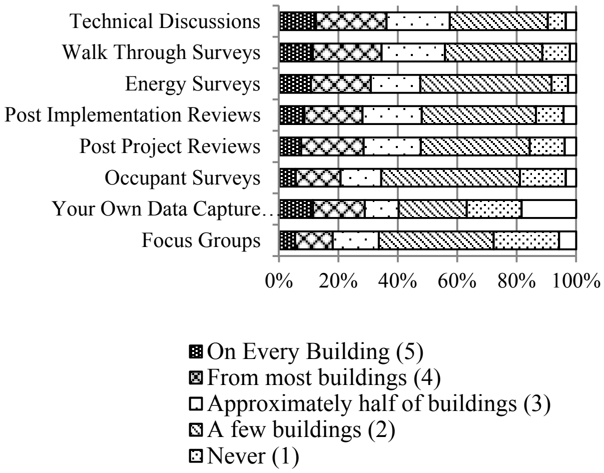


Figure 5. 30 Survey responses to data collection techniques typically used.

Figure 5.30 shows the assessment methods that respondents use when determining the outcome of their work. There appears to be a relationship between the difficulty or complexity of a survey technique and the frequency of use. ‘Focus Groups’ and ‘Occupant Surveys’ are arguably the most onerous to arrange, while ‘Technical Discussions’ and ‘Walk Through Surveys’ are perhaps the simplest. However, the mean scores in table 5.23 indicate that the most used technique is used on less than half of all buildings and even the easier techniques are not often used.

Table 5.24 shows the difference between Designers and Others use of Energy Surveys and the difference between Architects and Services Engineers. This difference is not necessarily a negative: each actor group does have its distinct responsibilities. The p values indicate that there is a significant difference in both cases.

Fisher's Exact Test Energy Survey between Designers and Others	
Pr <= P	0.0017

Fisher's Exact Test Energy Survey between Architects and Services Engineers	
Pr <= P	0.002

Table 5. 24 Survey respondents: Fisher's test for use of Energy Surveys.

'*Your own data capture techniques'* are used on at least a few buildings by more than 60 per cent of respondents. Where details were given on respondents' own assessment techniques in the free text box, there was a variety of methods mentioned.

The majority of those who specified their own techniques described a suite of methods used to carry out energy assessments depending on the building and circumstances. For example, one respondent said *'It's a combination of above collection methods and is tailored to each project depending on the outcome.*' The dependence of the technique on the building type or focus is echoed by another respondent who said techniques were *'specifically designed and tailored energy action plans, in-house designed utility data capture and reporting.'*

Other responses described the combination of monitoring, data collection and collation techniques; *'data is constantly being gathered about occupancy via a helpdesk/satisfaction surveys/contract monitoring etc. It is the basic building block of FM.'* Another described the practicalities; *'Installation of mobile data-loggers in all apartments / offices of a building for one year, for collection of actual information, recorded on part l chart and downloadable electronic data.'* One respondent described the often temporary and outcome specific nature of monitoring a; *'In situ temporary monitoring for areas of particular interest'*.

More permanent techniques include information from BMS (Building Management Systems) but these too are often used as part of a wider suite of techniques:

> *'Using BMS meter readings if reliable but usually utility meters as base and then breakdown as far as possible. This data is logged monthly for a comparison with the same months from previous years - gas is checked against degree days to obtain a view of weather influences.'*

The above quote also emphasises the time commitment required to properly collect and analyse data. Finally one respondent reflected on the inherent tension between the desire to capture data and the cost implications of doing so:

> *'Mainly gleaned from bills. The problem is that we do not always get all of them. An analysis of Kw consumed per square foot is quite a good analysis tool, and can be useful when advising clients as to whether meaningful energy savings are worth investigating and implementing. Every exercise has a monetary implication, and money is tight.'*

This statement reinforces the discrepancies between the type of data respondents are collecting (or are able to collect) with regularity, the reasons that are important to their organisations' and the detail required in data. In order to *'Improve future projects'*, detailed data about buildings is required to diagnose problems and understand successful strategies; however this is not collected as often as headline data. The actors who most often carry out Energy Surveys are not those who make the decisions about the forms of buildings and the services systems installed. The communication of this information is therefore critical; however, the respondents' relative lack of interest in 'Knowledge Sharing' suggests a breakdown in the information loop.

When information is shared it is communicated in a variety of ways. Table 5.25 shows that the most common way of communicating energy data is through written reports, followed by graphs and charts and informal written communications. The least common ways of sharing data is via press releases and lectures.

Factor	Mean Score	Ranking	Total Responses	Missing
Written Reports	3.19	1	289	214
Graphs and Charts	3.04	2	286	217
Informal Written	2.92	3	283	220
Verbally Informally	2.65	4	277	226
Scientific Papers	1.75	5	271	232
Lectures	1.74	6	274	229
Press Releases	1.72	7	272	231
We do not share our data	1.17	8	245	258
Other methods	1.10	9	244	259

Table 5. 25 Survey respondents' frequency of use of communication techniques.

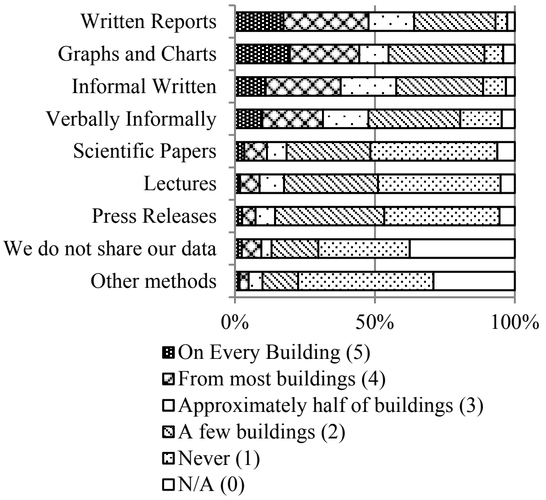


Figure 5. 31 Survey responses to frequency of use of communication techniques.

Figure 5.31 shows more than 30% of respondents use 'Informal Written' and 'Verbally informal' communication techniques on more than half of their projects. 'Written reports' and 'Graphs and Charts' are used on more than half of all projects by approximately 40% of respondents. The use of written reports suggests industry is most comfortable communicating in this way; a feedback platform and the contextual pressures must tap into this. Written reports are static and take time to compile, while a platform or model could be both more relevant and immediate.

Other communication methods identified by respondents included their organisation's *'own corporate platform'* and other company-specific internal seminars, discussion groups and *'Annual desktop reviews of HH and billing data, exception reporting on bills with direct email to building manager, customised monthly online reports*.' Others identified various web-based platforms such as '*iMeasure.org.uk', 'STARK', 'systemslink'* and *'SMeasure.com'*. One respondent's organisation uses their own website as a data communication page. Actors' use of their own methodologies and platforms independent of the contextual pressures is indicative of the framework's failure to provide sufficient assessment methods.

A free text box was used to ask respondents for suggestions on how to improve existing data communications. Suggestions centred on costs and particularly the development of a mechanism to cover the costs for collecting and communicating data. Actors also suggested that standards and legislation have a role to play in ensuring that barriers are overcome; the use of further mandate would create a level playing field for this work and ensure that investment was even across industry. The importance of education of clients, building users and professionals was raised as a means of increasing knowledge across industry of the issues surrounding building energy consumption to encourage better engagement and communication. Better benchmarks were thought to be required along with a standardised communication method or system. The final requirement for effective communication was 'more data', accessible, detailed and comparable for Actors to use when making decisions.

5.6 Disincentives

While these suggestions aim to improve the communication of data, most disincentives discourage any data collection at all. Table 5.26 shows detailed and ranked mean scores for these disincentives in the contextual pressures. The strongest disincentive is the cost to respondents' organisations, followed by the cost to their clients. Persuading clients of the benefits is next greatest disincentive. Each of these is linked as the costs are directly linked to the perceived benefits. Respondents' own organisations not seeing the benefit was the least powerful disincentive after inexperience in POE and concerns over liability. This ordering of the disincentives suggests that it is not through a lack of desire on the part of the respondents that the rate of post occupancy evaluation is not higher; rather the barriers are in the procurement and legislative framework and the contextual pressures.

Factor	Mean Score	Ranking	Total Responses	Missing
Cost to Organisation	3.19	1	341	162
Cost to Clients	3.12	2	337	166
Client cannot see the benefit	3.09	3	333	170
Difficulty accessing buildings	2.74	4	330	173
Concern over liability	2.54	5	328	175
Inexperience in POE	2.41	6	319	184
Organisation cannot see the benefit	2.21	7	326	177
Other	1.53	8	240	263

Table 5. 26 Survey respondents' ranked mean values for the influence of disincentives.

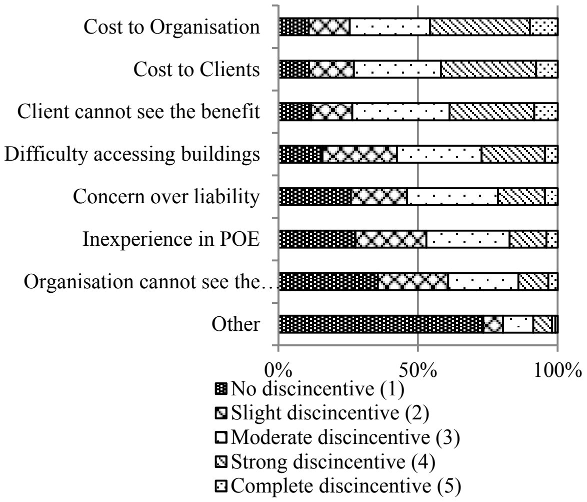


Figure 5. 32 Survey responses to the influence of disincentives.

Figure 5.32 shows a detailed breakdown of responses to question 3. 50% of respondents consider 'Concern over liability' only a slight disincentive, whereas the costs, benefits and practicalities of accessing buildings are moderate to complete disincentives for 25% of respondents. 'Organisation cannot see the benefit' is *'No disincentive'* to nearly 40% of respondents. 'Other' disincentives identified by respondents included the type of buildings that respondents were working on; for example *'Nuclear buildings - energy not primary concern'*. Also Clients lack of engagement came up as a factor again; *'most clients do not seem to care so long as everything works well'*. Finally, frustration was expressed at the inability of one respondent to generate income from data collection, get support from their professional body and convince Clients of the values of the work; *'unpredictable workload, lack of support on techniques and equipment from professional bodies (RIBA), ignorance of owners and clients.'*

5.7 Summary

The second research question asked 'How do the contextual pressures influence the [lack of] interplay between design and construction practice and energy information?' This chapter has shown that while the contextual pressures represent a suite of influences that inform actor behaviour, there are significant differences in the way that actors across industry respond to the pressures. A designer has different relationship with building energy consumption to those who own and manage buildings. The split in the pressures between incentive and mandate means this different response is in-part enforced but the survey has shown that it is also a function of actors' different interests and responsibilities.

The factors that respondents' considered influential to their activity and decision making were largely those that are not directly addressed by the contextual pressures; organisation reputations for example. While there are mandatory feedback mechanisms such as DECs and EPCs in the pressures in-part aimed at 'shaming' organisations into action, these do not have equal influence over all actors. Facilities managers' reputations are more likely to be adversely affected by a poor DEC rating than the contractor or architect involved in designing or building the building. The contextual pressures also do not make the connection between reputation and occupant satisfaction that many respondents find important.

Section 5.2 also showed a significant difference between the importance of energy and carbon to actors. Despite being the primary metric of the contextual pressures, carbon is of relatively low importance to actors. Energy is of greater importance to most and while a simple conversion factor can be applied to convert one value to the other, the fact that Part L of the building regulations' compliance metric is a Target (carbon) Emission Rate suggests that this legislation is not creating the professional focus it might.

Section 5.3 showed mandate to be the most common way of determining targets. This does not describe an industry bristling with ambition to determine new building performance standards but rather an industry doing the minimum required to operate. While arguably mandate is therefore performing its function and ensuring that energy is a consideration at all, the calculation methods that form part of the design stage contextual pressures mean that energy performance predictions do not often include all of the energy uses found in occupied buildings. Industry must recognise this and push beyond legislation.

Section 5.4 illustrated that actors' willingness to engage with energy and information feedback depends on actors' attitude to energy and broader sustainability issues more than the contextual pressures or their professional responsibilities: enthusiasm can overcome barriers. While section 5.4 showed that actors would like to use information collection as a way of improving future projects and make connections across industry, this is not facilitated by the contextual pressures; rather the fear of liability hinders this. Actors' relationship with the contextual pressures and energy varies depending on their role in the design or management process and the perceived benefits they stand to gain from engaging. For example, those with responsibility for building running costs were more likely to engage with and act on information than those working in design and construction and they did carry out evaluations rather than any single mechanism.

The differences in engagement with POE are predictably affected by those with access to buildings but also by those with a financial interest in building operation. Facilities managers and building owners are more likely to carry out POE while designers are the least. This shows the ineffectiveness of DECs and EPCs as a feedback mechanism capable of adversely affecting project team reputations.

Actors' relationship with energy also varies with their interest in the subject, and is not necessarily connected with their professional responsibilities. Those with an interest in energy consumption see the need for greater education throughout industry to engage others; this education should stretch to the client side of industry as well as the project teams. However, it is notable that while education is raised as an important way of engaging industry, one of the least used ways of communicating data by those who collect it is lectures. This suggests that perhaps the links between industry and academia are not functioning as well as they might.

Section 5.6 showed that feedback is not habitually used in design, construction and management practice to highlight the performance gap or inform decisions. Where information is used, it is more frequently used by facilities managers and building owners; architects collect the least. The reasons that information is not collected is costs to both actors and clients, access to building and persuading clients that it is of benefit to them, not because industry cannot see the benefit or necessarily because of a fear of liability. So while the scale of industry ambition is low when it comes to setting energy targets, perhaps there is greater appetite for building evaluation work. Those actors who do carry out post occupancy evaluation described using a suite of assessment methods to gather and analyse data.

The contextual pressures influence the interplay between design and construction practice and energy information in different ways. The variance in project actors' attitudes that suggest discordance in design teams and often between designers and the rest of industry could be driven by their different responsibilities within the pressures. Architects in particular have a different outlook to other actors at odds with their central role in the design process. Architects' organisational isolation is problematic given their role in making so many of the decisions that impact on energy consumption. The differences in attitudes are perhaps exacerbated by actors' reliance on others to verify work and the different mechanisms employed by the contextual pressures. The contextual pressures and traditional project set-ups have not adapted sufficiently to accommodate the need for more collaborative working across industry.

There is a tension between actors' individual professional responsibilities, their organisational or personal interests, their obligations under the contextual pressures and their clients' goals. Aligning the contextual pressures more closely with actor interests and motivations could help to engage more of industry with post occupancy evaluation and using data to inform decisions.

6 What is the potential for crowd-sourced data platforms to fulfil the role of feedback mechanisms?

This chapter presents the data in CarbonBuzz up to June 2013 in order to assess the capability of the existing database to provide 'effective feedback' and the potential for crowd-sourced data generally. Following a brief description of the contents of the database, the chapter is organised in five sections focusing on statistical analysis of different aspects of the data followed by a sixth discussion section synthesising the findings. The sections are:

6.1 focuses on the completeness of records in the database and the ability to generate 'effective feedback' from the crowd sourced data.

6.2 describes the typical energy characteristics by sector of the projects in the database.

6.3 looks at distribution curves of the energy records relative to industry benchmarks.

6.4 uses scatter plots to compare design predicted performance and actual records.

6.5 examines the available disaggregated end-use data to determine potential end-use benchmarks and decision support.

6.6 draws together the discussion points from the previous section to answer the chapter title research question.

The number of organisations registered with CarbonBuzz has increased year-on-year since the platform's launch in 2010. There were 406 registered organisations at the end of the first year of operation in 2011, a total increase of 42% between 2011 and 2012 and a further increase of 29% to 743 in June 2013. The largest group of users is Architects and the second largest is Universities; there was a 54% increase in this latter category in the year to 2013, although it is not always clear if these users are institutional facilities managers, individual researchers or students. The third and fourth largest categories are Engineers and 'Consultants'. Other notable increases in user numbers are in Surveyors, Environmental and Media, albeit from low starting points. A new category was added in 2013, 'Renewables', representing suppliers and installers of renewable energy generation equipment. (See Appendix 9 in the Appendices volume for details).

Whilst there are 743 registered organisations, indicating an engagement with the issue of carbon across industry, less than 50% of these contribute energy data. Architects have contributed the highest number of energy records – in June 2013 there were 172 projects with any energy data submitted by architects in the database. There have been proportionally more contributions from University, Local Government and Engineers' organisations from 2012 - 2013. There are three new categories of users contributing energy data, the most notable being Property Organisations which contributed 35 projects. (See Appendix 10 in the Appendices volume for details).

The number of projects in the database with both design and actual data is significantly lower than those with any energy data. The overall number of projects with design *and* actual data increased from 2012 to 2013 by 47% to a total of 86. Architects contribute the most projects with any design and actual data.

Company Categories	Number of Projects 2011	Number of Projects 2012	Percentage Change	Number of Projects 2013	Percentage Change
Architects	25	16	-36	45	64
Engineers	6	6	0	12	50
Business Management	4	7	75	5	-40
Unknown	0	1	100	1	0
University	0	1	100	3	67
Quasi-governmental	8	15	88	11	-36
Property	2	0	-100	6	100
Consultants	0	0	0	3	100
Total	43	46	7	86	47

Table 6. 1 CarbonBuzz: Organisations contributing projects with design and actual data 2012 and 2013.

Table 6.1 shows that architects contribute the largest number of projects with design and actual data. In the last year there has been an increase in 'Property' organisations contributing data; this is a result of a marketing campaign by the CarbonBuzz organisation and significantly increases the amount of data from occupied buildings. Figure 6.1 compares the proportions of registered organisations with those contributing data. Over 50% of projects with energy data are entered by architects, whereas only 20% of the registered organisations are architects.

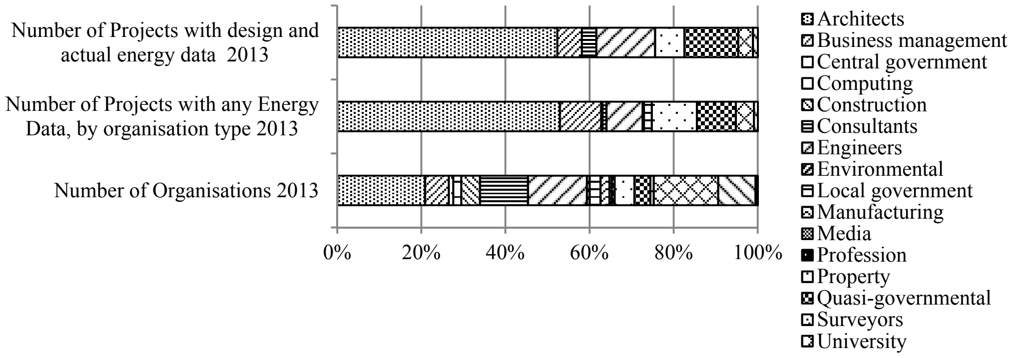


Figure 6. 1 CarbonBuzz: Comparison of the number of registered organisations and the number of projects with any energy data.

The registered organisations represent a diverse range of industry actors; however Architects dominate those contributing data. This discrepancy may be because Architects have a central role in the development of buildings and maintain a relationship with owners and occupiers in the early stages of occupation and use. Architects' strong representation in the CarbonBuzz database is contrary to the survey responses which showed that architects were least likely to collect post occupancy evaluation data.

Sector	Total Number of Projects 2011	Total Number of Projects 2012	Total Number of Projects 2013
Sport & Leisure	10	20	24
Retail	15	21	22
Residential	30	37	81
Other	0	5	5
Office	101	110	122
Industrial	4	4	5
Hospitality	4	6	6
Health	9	16	21
Education	126	151	189
Civic & Community	4	11	11
Total	299	381	486

Table 6. 2 CarbonBuzz: Projects by CarbonBuzz sector.

While there were 743 organisations registered to use CarbonBuzz, there are a total of 486 individual projects in the database. Projects are registered in eleven sector types. These are a rationalisation of the 29 CIBSE TM46 benchmark categories. The categories are 'Civic and Community', 'Office', 'Education', 'Health', 'Residential', 'Retail', 'Sport and Leisure', 'Hospitality', 'Industrial' and 'Other'. Figure 6.2 shows the number of projects by sector, together with figures with all test projects removed. The number of non-test projects in the database has increased from 319 in 2012 to 423 in 2013, a 33% increase. Education is and always has been the largest category although Residential has had the largest increase in numbers of projects by 154% in the last 12 months.

The Education sector's strong representation in the database is illustrative of the public sector's lead in the engagement with post occupancy evaluation through various state-funded research programmes. The necessity of public buildings to undergo DEC certification has generated interest in building energy consumption, however a project's presence in the database does not mean it necessarily carries any energy data.

The majority of projects in the CarbonBuzz database are in urban locations (73%, 354 of the 486 projects); of those just over half are in London. There is only one region with no projects represented in the database; rural Northern Ireland. The dominance of buildings in London may have an impact on energy consumption figures through urban heat island effects on heating and cooling. (Appendix 11 in the Appendices volume shows the data).

The steady growth in numbers of participants has resulted in a diverse range of registered organisations in the CarbonBuzz database. Those that fall under the CIC survey of industry are broadly representative of industry. There are also a range of users from outside the traditional construction industry, such as academia. Despite the broad range of registered users, the proportion of those contributing design and actual data is small.

6.1 Completeness of records

While the number of records with energy data is low, this section assesses the completeness of the supporting information, first at projects with basic entries in the 'Project Details' section based on the list of factors that contribute to energy consumption identified in table 2.1; then the completeness of the Energy Records, from top-down headline information to disaggregated detailed information. The data assessed for completeness are therefore:

Building Factors: these data describe the number of zones in a building, cost of the building, floor area, service type designed and installed, low and zero carbon technology (LZCT) used, other carbon factors and floor-to-floor height.

Occupant factors: supporting information on occupancy figures (how many people use the building, the number per unit area) and the operating hours of the building.

Other Carbon Factors: other data captured by CarbonBuzz relating to other generators of carbon emissions other then energy consumption.

Electricity: headline information including total design predicted electricity use and total actual electricity use.

Heat Consumption: how many projects contain information on total design heat consumption and total actual heat consumption.

Occupant Energy Factors: this sub-section assesses the records for information on occupant dependent energy end uses.

Table 6.3 illustrates this data.

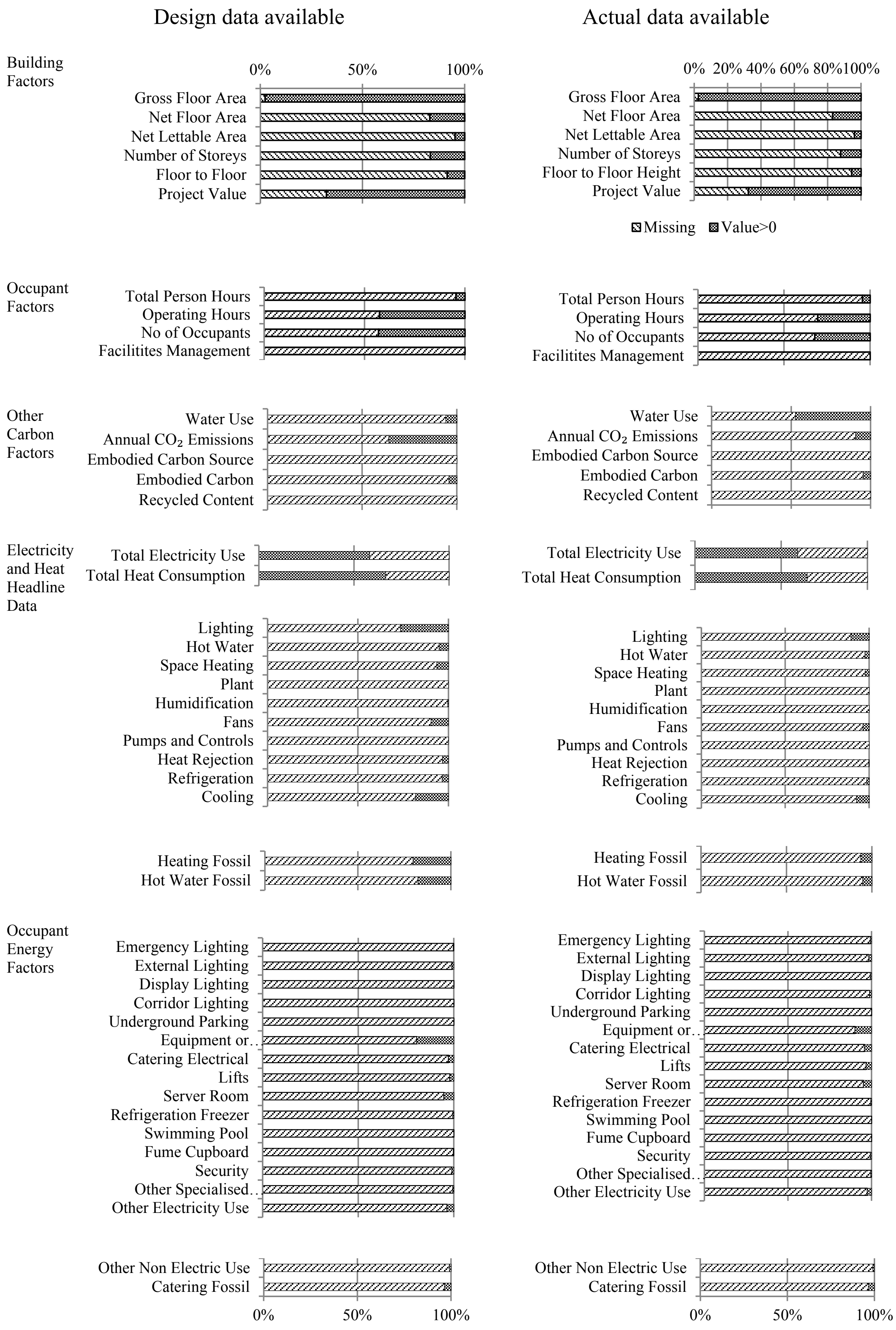


Table 6. 3 Completeness of CarbonBuzz records.

Building Factors

Table 6.3 shows that the majority of projects have some cost and area data; 'Project Value' and 'Gross Floor Area' – which are supposed to be compulsory data fields – are included in most records; however other basic dimensional metrics such as Floor-to-Floor Height, Net Lettable Area, Number of Storeys and Net Floor Area are missing from around 90% of projects. (See Appendix 12 and 13 in the Appendices volume for tabulated data). A higher proportion of design stage records have this information than actual, perhaps because this data can more easily be retrieved from design drawings, whereas actually measuring complete buildings is more onerous.

There is a decrease in the inclusion of data from design to actual records across all building factors. Small numbers of projects have no change in the amount of data from design to actual. Of the largest project groups – Education and Office – less than 20% have information on the number of storeys, and less than 10% have information about the floor-to-floor height. Determining aspect ratios, fabric areas and other metrics that influence energy consumption from this data is therefore impossible.

The 'ventilation strategy' field defines how a project is heated and ventilated using four categories: 'heating and natural ventilation', 'heating and mechanical ventilation', 'mixed mode with natural ventilation' or 'air-conditioned'. For meaningful comparisons across the database, design versus actual data is required in each sector. Service strategy information is more often present in the database. However, in actual records, less than 50% of projects have any information. This is slightly higher in 'Retail' projects. (Appendix 14 in the Appendices volume illustrates this data). As the servicing strategy is part of the NCM, there is no reason why this data should be omitted at design stage – it should be available to all those entering information to the database. That it is not identifies a further weakness in the contextual pressures, or in the platform itself. Incentivising actors to provide this data is important.

The proportion of projects with specified low and zero carbon technology is also low, less than 10% of actual Education records for example; however LZCT is not necessarily present in all buildings. Nevertheless, given the contextual pressures' planning stage requirements for on-site renewables in London, and the fact that more than 50% of the projects are in London, it could be expected that these figures would be higher. (Appendix 15 in the Appendices volume illustrates this data).

The basic level of information unavailable in the CarbonBuzz database suggests that the barriers to data collection are not only practical, financial or to do with the risk of litigation. These reasons would not prevent those collecting or entering data providing information regarding the number of storeys in a building. The lack of information on these subjects suggests other barriers to the use of a crowd-sourced data-sharing platform that will be explored in further chapters.

Occupant factors

Occupancy factors, such as how a building is used, are among the determinants of building energy consumption identified in the chapter 3. Less than half of all projects have Occupancy and Operating Hours data at design stage. Virtually no projects have any information about the Facilities Management strategies employed in buildings, making any deductions about the effectiveness of existing or future strategies impossible. Office and Education projects have around a third of projects with actual occupancy and operating hours data, more than they have information on the actual number of storeys in the buildings. Some automated entry systems count people in and out of buildings, making data collection easier; otherwise this can be difficult to collect and therefore a low proportion may be expected in the actual figures. However an assumed occupancy rate is required in NCM calculations and therefore should be available for all projects at design stage. (Appendix 16 in the Appendices volume illustrates this data).

Other carbon factors

The contextual pressures deal in energy consumption-related CO_2 emissions. Whilst CarbonBuzz also focuses on building energy-related carbon emissions, users are also encouraged to provide details of other factors that will impact on the wider carbon emissions associated with buildings. Table 6.3 shows the proportion of projects that contain information on CO_2 emissions and other carbon factors. Very few carbon factors are present in the CarbonBuzz database. The greatest amount of information is available in design stage CO_2 emissions, which is to be expected since this is a key component of the legislative framework and provided by NCM calculations; however, less than 20% of projects have this data.

CO_2 is the key metric for the UK Climate Change Act and forms the basis of many component parts of the contextual pressures. Figure 5.4 showed that carbon emissions are not as important to industry actors as energy consumption and occupant satisfaction. While it is not difficult to calculate the carbon associated with energy consumption, the lack of data in CarbonBuzz belies the lack of interest in this key metric. The lack of information makes tracking carbon emissions impossible and again suggests barriers other than those defined in the contextual pressures are at play.

Energy Data

The number of projects with design and actual total energy consumption data for comparison is small - just 10% of the total projects in CarbonBuzz have all four data totals entered. The literature review has shown that feedback requires extensive data to be useful for diagnostic analysis and comparative decision support and the CarbonBuzz data structure breaks down the energy use into detailed systems-level data specifically for this purpose. The NCM does not require detailed energy end-use breakdown at design stage but the building regulations stipulate a certain amount of sub-metering for new buildings and therefore should support the production of detailed end-use energy data. It could therefore be expected that there would be a greater amount of actual disaggregated data than design data. Whether the data is not available or there are other reasons why it is not making it into the database is unclear.

Table 6.3 shows that the proportion of projects with disaggregated energy data is very low, for example just 20% of design projects have a figure for 'Lighting'. As a fixed building service and part of contextual pressures design calculations, it is expected that projects would have this figure available. Like other information categories in the database, the numbers of users entering information in actual records is lower than at design stage. This is despite the contextual pressures specifically mandating sub-metering and making data available in actual buildings. Comparison between design and actual values is therefore impossible.

These patterns are also present in heat consumption data. Both heating and hot water use are considered fixed building services by the NCM and therefore should be included in all design stage records. Table 6.3 shows that like electrical building energy loads, the database contains small amounts of heating consumption information per project. There is less heat consumption data than electrical consumption data, perhaps reflective of greater numbers of all-electric buildings. However the low amounts of service type data makes this impossible to verify.

While the contextual pressures contain some barriers to the generation of detailed information at design stage, they actively mandate recording of detailed energy information from actual buildings through the use of sub-meters. The CarbonBuzz database does not contain this information, or the detailed information that the design stage NCM mandates – the regulated energy. The barriers may prevent sharing of data or uploading information to CarbonBuzz rather than data collection.

Occupant Energy Factors

Table 6.3 shows that, with the exception of Equipment and Appliances there is very little design stage energy end-use information in the database. This is not necessarily indicative of poor information provision, since a number of the end-uses – such as Swimming Pool - are unlikely to be in all buildings. However all buildings will use Equipment and Appliances and only 20% of projects have this information. There is a reduction in information available from design to actual. Approximately 10% of projects have actual equipment or appliance end-use information again despite the mandate being in place in the contextual pressures stipulating that individual systems are sub-metered. Similarly, occupant fossil loads illustrate very low levels of data.

Occupancy data for heat consumption is almost non-existent in the database. The implications of this will be explored in more depth in following sections. The contextual pressures have described some of the barriers making it difficult to collect detailed information that requires unhindered access to buildings. However, CarbonBuzz is a platform dedicated to collating this data and is used by interested organisations who, it might be expected, can overcome some of the barriers. The implications for energy consumption will be explored in the following sections and the barriers explored further in the following chapters.

Energy Targets and Data Sources

Data Sources

Design Data Source	No of Observations
"0"	146
SBEM	43
EPC	53
DEC	13
Ashrae	5
SAP	13
Full energy model	39
TM22	2
Other	78
Total	392

Actual Data Source	No of Observations
"'0"	293
Energy Bills	66
EPC	2
DEC	9
Energy Model	1
TM22	12
Other	9
Total	392

Table 6. 4 CarbonBuzz: Design and actual data sources.

This section explores the given data sources used to generate data uploaded to the platform. 58% of projects at design stage and 23% of actual records have a defined data source. (Appendix 17 in the Appendices volume illustrates this data).

Table 6.4 shows the data source of all projects, whether they have associated energy data or not. 'Other' is the most popular selection for design data source. The largest group where a data source is specified is 'EPC' followed by 'SBEM'. Both of these measures use the same calculation methodology (the NCM) and do not include the full range of energy end-uses; this is not to say that users have not supplemented predictions with other information. The next largest group is ‘Full Energy Model’, an assessment methodology that enables users to take into account the full range of end-uses. Others include SAP, ASHRA and DECs. ‘Other’ sources of design data are identified in an associated free text box. Appendix 18 in the Appendices volume shows the 22 alternative sources of design energy data identified in the 2013 audit data base. The largest ‘Other’ source of design data is ‘Bills’ followed by metered data. As this response is describing design stage data, it is not clear which project’s bills are being used as a data source. The rest of the other sources are various energy models.

Where the source of actual data is stated, the majority comes from ‘Energy Bills’ which by nature include all energy consumption but do not have detailed breakdowns of end uses. The majority of projects have no record of the data source. TM22 has been used as a data source on 12 entries; suggesting detailed disaggregated information is available. There are 9 projects using ‘Other’ sources of actual data including categories available in the drop down menu and all are based on Bills or Sub-Metered data. ‘Commissioned POE’, ‘Verified meter readings and surveys’ and AMR are all variants on meter readings. (See Appendix 19 in the Appendices volume for details).

Bills and Metered Data are the most common sources of actual data and the second most common source of design data. The most common source of design data is SBEM calculation software. The source of data is a key component of data quality and being able to ascertain where information has come from is a crucial factor in making a judgement about inclusion in a crowd-sourced database. The lack of this information in the majority of projects undermines the quality of the entire platform.

The depth and range of information required for effective feedback is not currently available in the CarbonBuzz database, however the potential of the crowd-sourced platforms is explored in the following sections.

6.2 Typical Energy Characteristics

This section looks at the typical energy characteristics of the projects in the database in different sectors, assessing the design to actual ratio when different projects are included in the comparison. Table 6.5 describes the projects that make up subsets A-D. There are 290 projects with any energy data (subset A), 64 with design and actual electricity data (subset B), 51 with design and actual heat consumption (subset C), and 47 with all four energy data types (subset D).

Sector	Subset A - No. of non-test projects with any energy data	Subset B No. of non-test projects with design and actual electricity data	Subset C - No. of non-test projects with design and actual heat data	Subset D - No. of non-test projects with design and actual heat and electricity data
Civic & Community	6	1	0	0
Office	74	27	18	18
Education	141	24	24	21
Health	12	2	1	0
Residential	22	5	4	4
Retail	11	1	0	0
Sport & Leisure	14	2	2	2
Hospitality	5	1	1	1
Industrial	4	1	1	1
Other	1	0	0	0
Total	290	64	51	47

Table 6. 5 CarbonBuzz: Number of projects with energy data by sector.

The following analysis uses the two largest subsets, the Office and Education sectors, to explore the relationship between design and actual energy figures. (Other data is shown in Appendix 20 in the Appendices volume). Table 6.6 shows the Office and Education sector mean design and actual values for heat and energy consumption along with the corresponding number of projects contributing to the mean.

		Design					Actual				
	Sector	Mean Design Total Electricity Use 2013 (kWh/m²/yr) Not Inc. test	No of observations 2013	Mean Actual Total Electricity Use 2013 (kWh/m²/yr) Not Inc. test	No of observations 2013	% difference 2013	Mean Design Total Heat Consumption 2013 (kWh/m2/yr) Not Inc. Test	No of observations 2013	Mean Actual Total Heat Consumption 2013 (kWh/m2/yr) Not Inc. Test	No of observations 2013	% difference 2013
Subset A	Office	135	63	186	37	37	47	44	75	30	59
	Education	67	64	131	98	94	79	59	153	95	93
	All	102	176	187	171	45	85	141	139	148	63
Subset B	Office	169		129	27	-24	N/A				
	Education	66		101	24	53					
	All	155		300	64	93					
Subset C	Office	N/A					46		73	18	59
	Education						65		89	24	37
	All						123		118	51	-4
Subset D	Office	71		121	18	70	46		73	18	59
	Education	56		106	21	89	57		84	21	47
	All	71		116	47	63	63		84	47	33

Table 6. 6 CarbonBuzz subset A design and actual electricity and heat consumption means by sector.

Subset A: The Education sector has both the greatest number of observations and the largest disparity between design and actual mean figures, an increase of 94%. The total data base shows an increase from design to actual electricity consumption of 45%. The lowest changes are in sectors with small numbers of observations. The database average change from design to actual heat consumption where there is a figure present is a 63% increase. Subset A observations in the design column are not necessarily the same projects that are in the actual column so comparisons between the mean values does not therefore represent a ratio between the same projects. CarbonBuzz currently makes this comparison: any crowd-sourced platform must take into account differences in the database arising from comparing different projects to each other. Subsets B, C and D do represent this ratio and demonstrate some different relationships; this is an important distinction for the future use of feedback platforms.

Subset B: Contains only those projects with design and actual electricity figures. Table 6.5 shows mean values for the 64 projects with design and actual electricity values in subset B. Education projects have a design to actual value increase of 53% whereas office projects have a reduction of 24%. The underlying causes of this difference will be investigated in following sections but raises the importance of a crowd-sourced platform comparing like with like. The reduction in mean consumption in Office buildings challenges the idea that the performance gap is always an increase from design to actual. This data suggests that the gap is perhaps the result of more general lack of understanding of end uses at design stage rather than a simple under-prediction.

Subset C: Subset C contains projects with design and actual heat consumption figures. Table 6.5 shows in contrast with subset B, there are more Education projects than Office projects, perhaps reflecting the greater use of all electric service systems in commercial buildings. Office and Education projects have a mean increase from design to actual values of 59 and 38% respectively. The total sample of buildings with design and actual heat consumption data showed a slight reduction from design to actual values of 4%. The disparity in Office buildings, a decrease from design to actual in electricity consumption mean values and an increase in heat consumption suggests that the improved fabric standards that have resulted in a negative heat consumption energy gap in Education buildings do not apply in Office buildings.

The data relating to other building sectors (shown in Appendix 20 in the Appendices volume) highlight some potentially anomalous entries that cannot be verified. One project in the 'Civic and Community' sector has a value of 46.3kWh/m^2/yr for both design and actual records. This may be a coincidence as 46.3 kWh/m^2/yr is a plausible figure (the TM46 benchmark is slightly lower), therefore the figure has been left in. It is much more likely to be a false record, as the figures are identical; this illustrates a weakness of a crowd-sourced platform like CarbonBuzz – it is difficult to establish the veracity of coincidental figures. This is a data quality issue addressed in chapter 8.

Different sectors have different energy gaps, suggesting a need for feedback focussed on different parts of a building, depending on the sector. The mean values for design versus actual energy consumption values in the database change when buildings with any data or both design and actual are included. When those projects with any data are included, the increase in consumption from design to actual values is 45% in electricity and 63% in fossil fuels. When only those projects with both design and actual values are included the relationship is a 93% increase in electricity and a 4% reduction in fossil fuel consumption. This difference represents a challenge for a crowd-sourced feedback database; how to truly represent building performance, particularly where sample sizes are small and design and actual data is not always present in each sector.

6.3 Energy distributions

This section examines the data distribution of Education and Office buildings in subset D, with respect to design and actual mean values. The first section looks at the subset as a whole and the following sections look at the sector groups.

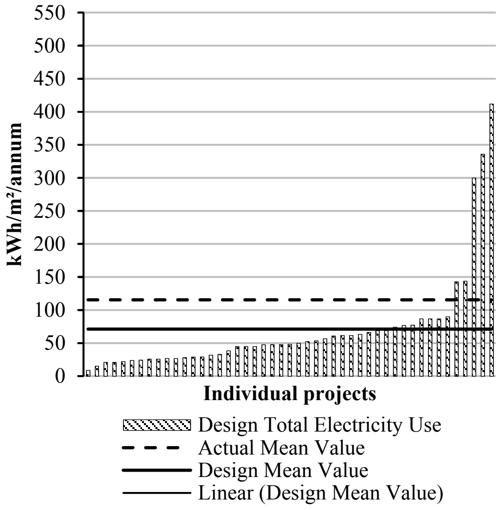


Figure 6. 2 CarbonBuzz Subset D: Design electricity use figures.

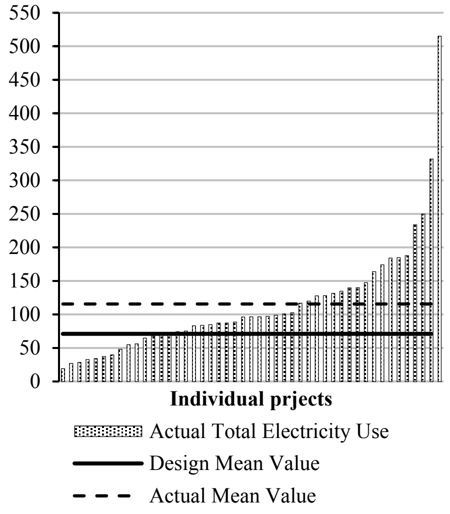


Figure 6. 3 CarbonBuzz Subset D: Actual electricity use figures.

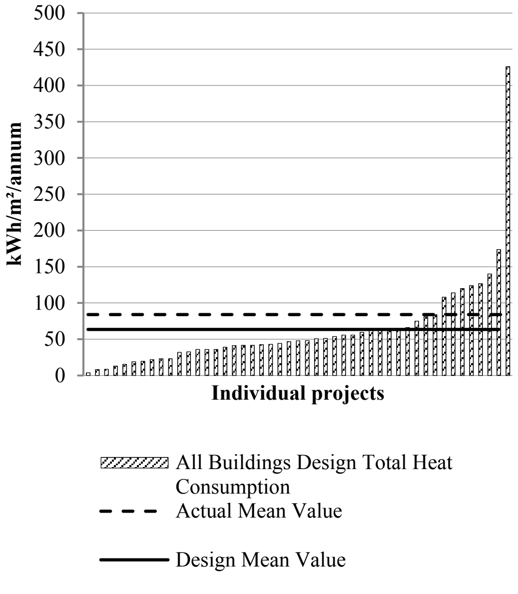


Figure 6. 4 CarbonBuzz Subset D: Design heat consumption figures.

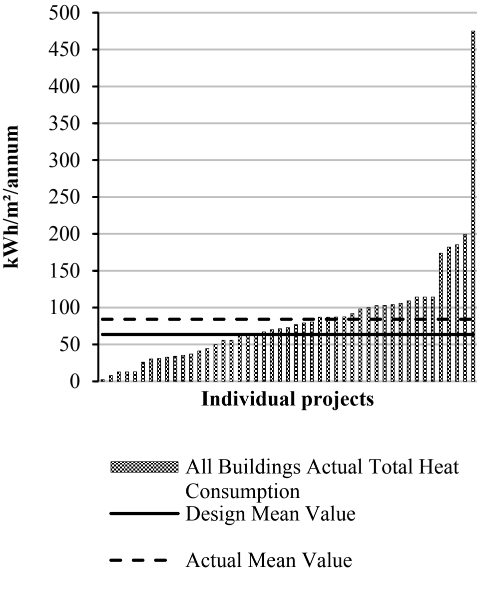


Figure 6. 5 CarbonBuzz Subset D: Actual heat consumption figures.

Figures 6.2 and 6.3 show the design and actual electricity values for subset D. The mean values – 71 kWh/m^2/annum at design and 116 in actual records – represent a smaller energy gap than the 2-3 fold increase identified in the literature review as typical. This may because users of CarbonBuzz have supplemented their design predictions to produce more accurate assessments, as is the purpose of the platform. The mean values are skewed by a large value at the high end of the scale in both design and actual. These have been left in the sample as high energy consumption is not necessarily an indicator of an invalid record – indeed it is the reason the platform exists; to identify high consumption, identify why it is happening and support activity to reduce it.

Figures 6.4 and 6.5 show design and actual heat distribution follows a similar pattern to electricity. However the mean values are much closer – 63 kWh/m^2/annum at design stage and 84 at actual, a 133% change. This supports the idea that improvement in the thermal performance of building fabric and warmer winters have reduced the actual requirement for space heating relative to design guidance. A crowd-sourced platform affords opportunity to identify these anomalies and adjust the benchmarks.

The energy gap in subset D is not as pronounced as suggested by the literature review and is different in electricity and heat consumption figures, confirming the different relationship between heat and electricity consumption. Both electricity and heat figures show some very low – and high - design and actual figures. While some seem improbable, they have been left in the sample. This again identifies weaknesses in the platform the aim of a feedback platform is to learn from the available data; discounting outliers could remove some valuable insight from the data set whilst leaving them in could erroneously skew the figures. A balance must be found between the two.

6.3.1 Subset D – Education

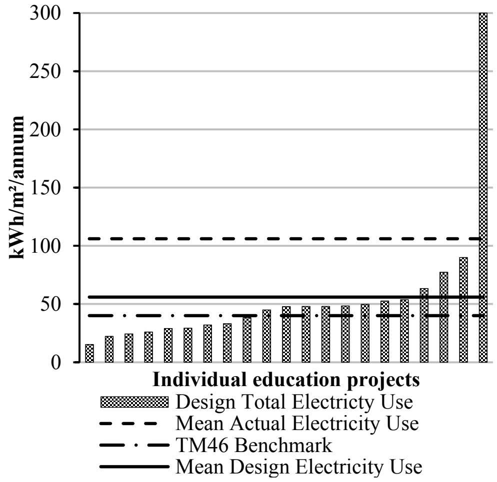


Figure 6. 6 CarbonBuzz Subset D: Education projects design electricity use figures.

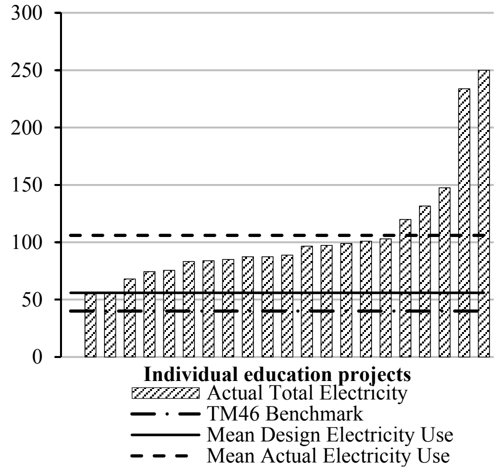


Figure 6. 7 CarbonBuzz Subset D: Education projects actual electricity use figures.

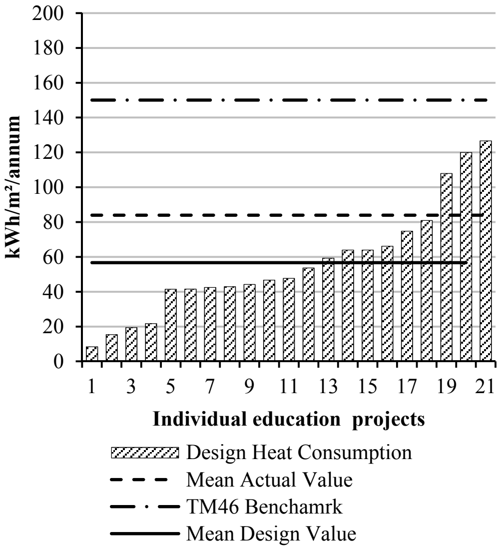


Figure 6. 8 CarbonBuzz Subset D: Education projects design heat consumption figures.

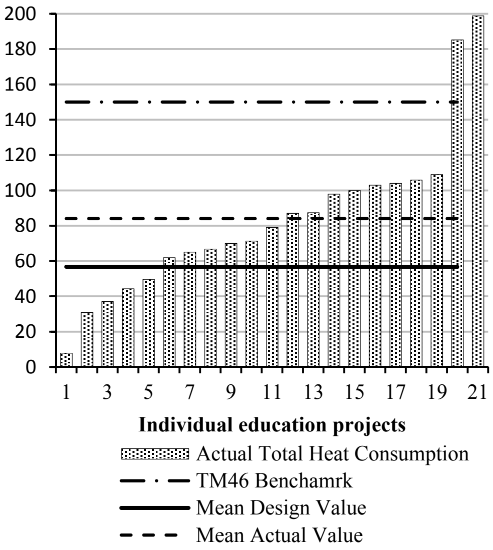


Figure 6. 9 CarbonBuzz Subset D: Education projects actual heat consumption figures.

Figures 6.6 and 6.7 shows a greater increase from design to actual electricity than in subset D as a whole; it is a larger than 2-fold increase from design to actual. The mean design value is slightly higher the TM46 benchmark but the actual value is over twice the figure. No actual records are below the benchmark. Figure 6.8and 6.9 show that in contrast to the electricity values, the actual heat consumption mean value is 1.5 times the design value. The relationship to the TM46 benchmark is also different - all but two of the actual values are below the benchmark figure. The benchmark is not reflective of design predictions or actual energy use but differs from these figures in different ways depending on the energy use, illustrating the disjointed contextual pressures.

6.3.2 Subset D – Office

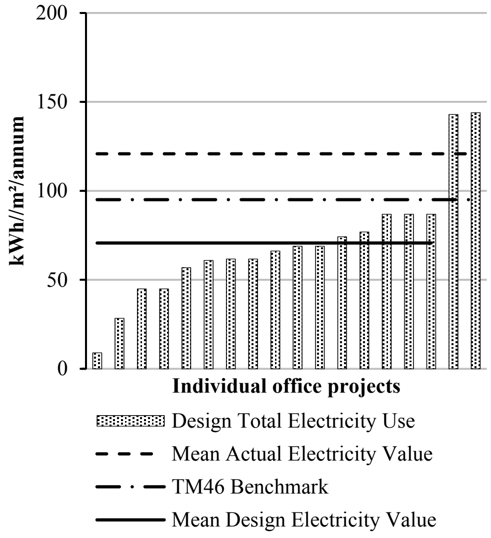


Figure 6. 10 CarbonBuzz: Subset D: Office projects design electricity use figures.

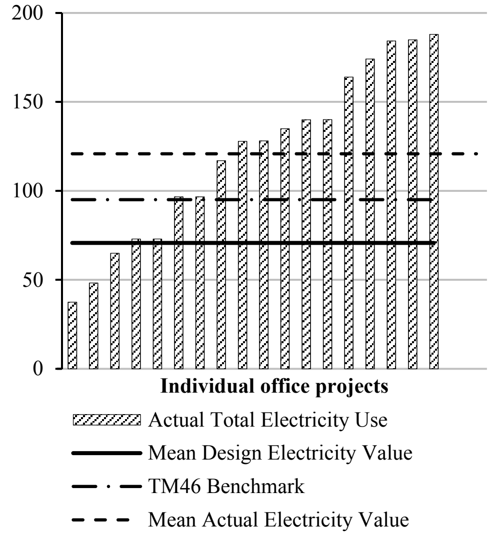


Figure 6. 11 CarbonBuzz Subset D: Office projects actual electricity use figures.

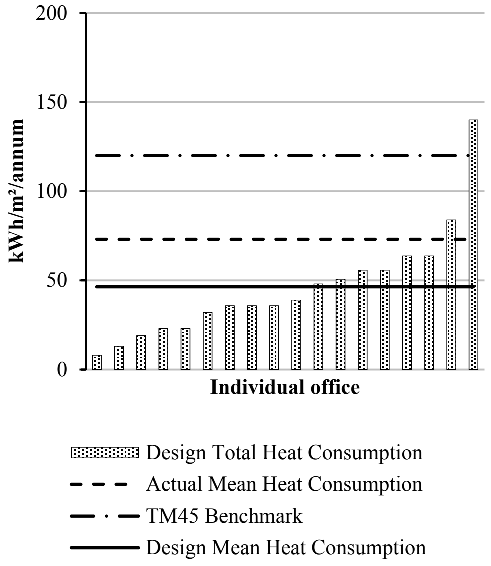


Figure 6. 12 CarbonBuzz Subset D: Office projects design heat consumption figures.

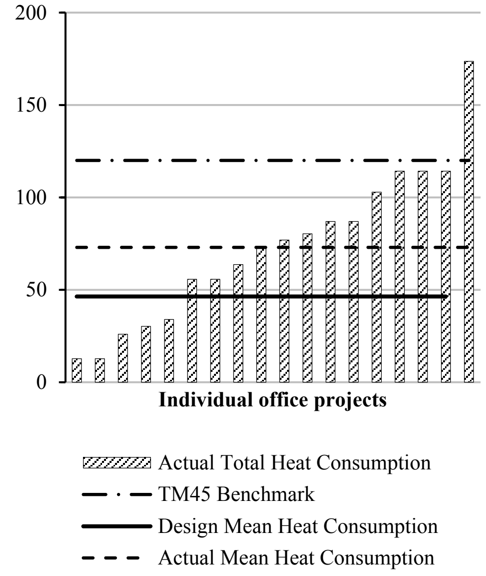


Figure 6. 13 CarbonBuzz Subset D: Office projects actual heat consumption figures.

Figures 6.10 and 6.11 show the design and actual electricity values for Office projects in subset D. In contrast to the Education buildings, the mean design value is below the CIBSE benchmark by around 25%. The actual mean value is 20% above the benchmark illustrating a relationship with the benchmark that suggests a more plausible value for Offices than the Education buildings. This is perhaps a reflection of the Office data origins of the original benchmarks, although use patterns in both building types have changed in the years since they were established

The relationship of office heat consumption figures with the TM46 benchmark is quite different to the electricity figures and is similar to education. Figures 6.12 and 6.13 show that all but one of both design and actual records are below the benchmark figure, again confirming the idea that improved building fabric standards, use patterns and climate have not been reflected in the benchmark values.

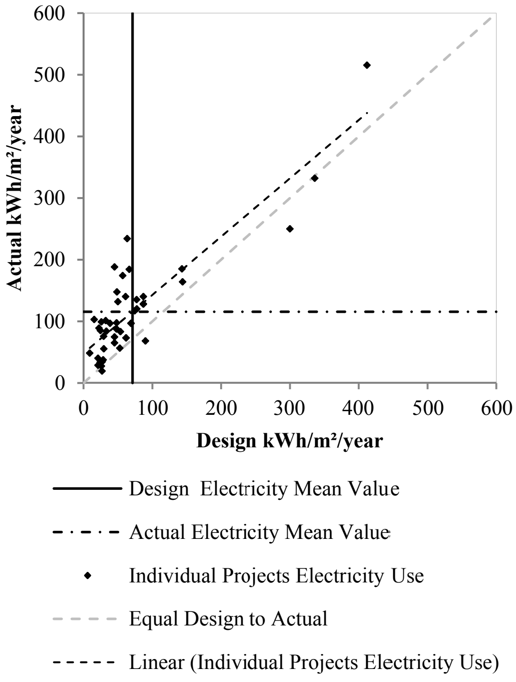
Benchmarks are a stipulation of the EPBD and therefore the contextual pressures. The CIBSE TM46 benchmarks do not appear to reflect either the design stage prediction data or actual recorded information in the CarbonBuzz database. While some aspects of the survey showed that the contextual pressures influence actors' behaviour and decision making, the distributions of data here suggests that some key aspects of the contextual pressures are not reflective of industry behaviour. TM46 forms the basis for DEC benchmarking therefore it is important that crowd-sourced platform can highlight the difference and offer a corrective figure.

One limitation of looking at distributions is that this does not expose the direct relationship between design and actual values in individual projects; this will be explored in the next section.

6.4 Performance Comparisons

To understand what CarbonBuzz can tell us about the energy gap and which parts of the contextual pressures, actors or sectors might influence energy consumption, the following section looks at performance comparisons between individual projects.

Figures 6.14 and 6.15 show a direct comparison between the design versus actual energy consumption of all 47 buildings with design and actual electricity and fossil fuel consumption data in subset D. The regression lines indicate that electricity consumption is generally under-estimated at design stage whereas fossil fuel consumption is sometimes over-estimated.



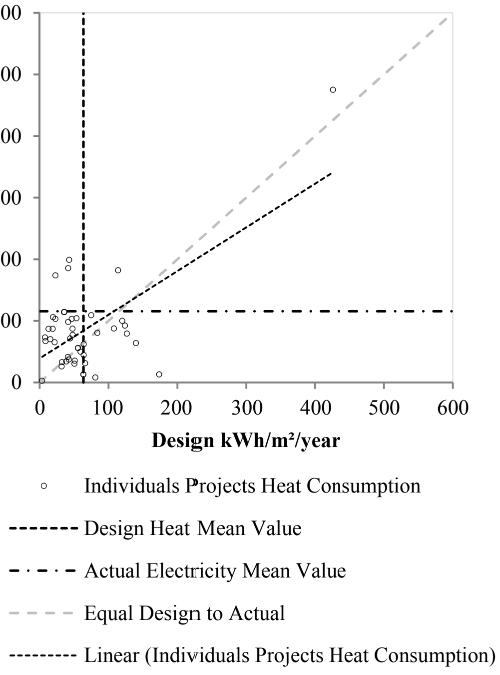


Figure 6. 14 CarbonBuzz: Subset D design v. actual electricity data.

Figure 6. 15 CarbonBuzz: Subset D design v. actual heat consumption data.

Table 6.7 shows simple statistics for the projects in subset D. (The very low fossil fuel consumption figure is a residential project). The Pearson's *r* correlations show a strong positive linear correlation between design and actual electricity and heat consumption values. The correlation is stronger in electricity than in heat.

	Electricity Use (kWh/m^2/annum)			Heat Consumption (kWh/m^2/annum)		
Total Sample	Design	Actual	Ratio	Design	Actual	Ratio
Max	412	515.3	1.25	426	475	1.11
Min	9	19.4	2.15	3.6	2.4	0.67
Median	48	97	2.02	48	73	1.52
Mean	71	116	1.63	63	84	1.33
Standard Deviation	80	86	1.01	66	74	1.12
Pearson's *r*			0.87			0.63

Table 6. 7 CarbonBuzz subset D statistics for all projects with design and actual electricity and heat data.

The ratios in table 6.7 indicate a larger energy gap in electricity values than in heat consumption. This is reflected in the closeness of the mean values in heat records. The heat records, while a closer prediction, have a less consistent relationship.

The direct comparison of subset D projects show a small variance in the nature of the energy gap between electricity and fossil fuel. The relationship between electricity predictions and actual records, while generally under-predicted, is more consistent that heat data. The contextual pressures and building regulations in particular focus on building fabric performance and fixed building services for environmental control 'heat consumption' energy use. In contrast, electricity use is much more influenced by unregulated end-uses (equipment and appliances etc) - the consistent increase is likely due to these unaccounted loads. The design value is always supplemented by 'unregulated' end uses in actual use creating a more consistent error. Neither electricity nor heat are accurately predicted; electricity simply has a more consistent error. The inconsistency of fossil fuel consumption predictions is somewhat of an indictment of the contextual pressures and the calculation methods employed.

The following sections look at aspects of the CarbonBuzz database to identify any changes in the relationship between design predicted and actual recorded data using criteria derived from building and occupant factors as well as sector and actor type and calculation method.

6.4.1 Sector

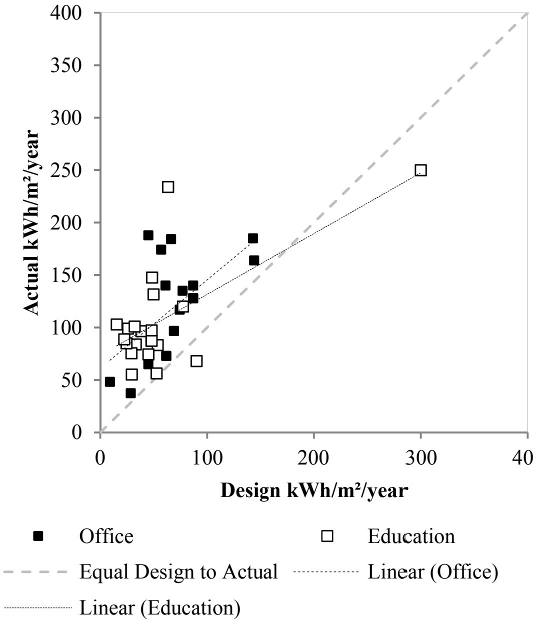


Figure 6. 16 CarbonBuzz subset D: Office and Education buildings: Design v. actual electricity.

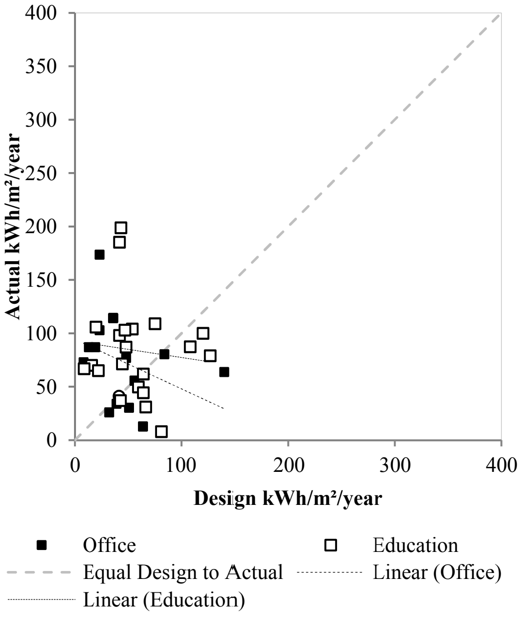


Figure 6. 17 CarbonBuzz subset D: Office and Education buildings: design v. actual heat consumption.

Figure 6.16 shows the electricity consumption for Education and Office buildings in subset D. Most projects are clustered above the 'Equal' line illustrating an actual figure greater than the design prediction. Both show a positive trend between design and actual figures.

Figure 6.17 illustrates the heat consumption data coded by sector in subset D. In contrast to the electricity data, the trend lines for heat consumption data show a negative relationship in education and office projects between design predicted and actual values for consumption. The disjointed contextual pressures must play a role in creating this relationship – low design predictions are encouraged while completed buildings are not investigated to remedy poor performance. The difference between design and actual is marked even in a platform designed to combat these impacts.

The different sectors are scattered throughout the sample with no apparent pattern. Table 6.8 shows exploratory statistics for the 18 Office and 21 Education projects in subset D.

		Education Projects			Office Projects		
		Design (kWh/m^2/yr)	Actual (kWh/m^2/yr)	Ratio	Design (kWh/m^2/yr)	Actual (kWh/m^2/yr)	Ratio
Electricity Use	Max	300	250	0.83	144	188	1.30
	Min	15.3	55.27	3.16	9	37.48	4.16
	Median	48	89	1.85	68	128	1.88
	Mean	56	106	1.89	71	121	1.70
	Standard Deviation	59	50		33	48	
	Pearson's *r*			0.68			0.58
Heat Consumption	Max	126.7	198.9	1.57	140	173.7	1.24
	Min	8.52	7.9	0.93	8	12.77	1.60
	Median	48	79	1.65	37	75	2.02
	Mean	57	84	1.47	46	73	1.65
	Standard Deviation	32	45		31	42	
	Pearson's r			-0.11			-0.34

Table 6. 8 CarbonBuzz subset D – energy use statistics.

The standard deviation figures in Office and Education sectors electricity use are large relative to the mean, indicating a large spread of values in both design predictions and actual records, although there is a small number of observations. Other differences between Office and Education projects are not pronounced; the ratios between values are similar. Perhaps the standard deviation is lower in Office buildings where occupant behaviour is more predictable (due to regular Office hours) so there is less of a spread of values. In heat consumption, the design-to-actual ratios are lower, and the Pearson's r test indicates a negative relationship between design and actual values.

There is a positive relationship between design predictions and actual recorded data in both electricity and heat consumption when the total sample is analysed. This changes when the projects are broken down by sector. Education and Office buildings have a positive correlation between design and actual values in electricity use with strong linear relationships, but a negative correlation in heat consumption values with a weak negative linear relationship.

The differences in the relationships between design and actual values can be explained by a number of factors. The contextual pressures lack of mandate for including all end uses in design predictions and the difference between the performance gaps in electricity and heat records could be explained by the fact electricity use has a greater range of unregulated end uses. The end uses that are included in Part L calculations and assumptions made are not reflective of energy use. However the design-to-actual ratios in CarbonBuzz indicate a more accurate series of predictions than the literature review suggests. This is to be expected in a platform aimed at addressing the energy gap, but the inaccuracies are still significant. The lack of a consistent pattern in heat consumption suggests that actors simply do not know how buildings will work.

6.4.2 Other factors

The following section discusses the data depending on various factors that might have an effect on energy consumption. These are; calculation method, building factors and occupant factors. The headline data is shown in Table 6. 9 overleaf.

Calculation Method	Analysis Software						SBEM					
	Electricity (kWh/m^2/yr)			Heat (kWh/m^2/yr)			Electricity (kWh/m^2/yr)			Heat (kWh/m^2/yr)		
	Design	Actual	Ratio	Design	Actual	Ratio	Design	Actual	Ratio	Design	Actual	Ratio
Max	87	184	2.11	140	114	0.81	300	250	0.83	174	174	1.00
Min	28	37	1.32	36	34	0.94	21	19	0.90	8	13	1.63
Median	51	94	1.84	57	80	1.40	62	97	1.56	64	73	1.14
Mean	54	102	1.89	68	80	1.18	85	108	1.27	70	73	1.04
Standard Deviation	23	43		37	28		84	71		57	55	
Pearson's *r*	0.747			-0.275			0.843			-0.361		
	Unspecified Method											
	Electricity (kWh/m^2/yr)			Heat (kWh/m^2/yr)								
	Design	Actual	Ratio	Design	Actual	Ratio						
Max	412	515	1.25	426	475	1.12						
Min	9	27	3.00	4	2	0.50						
Median	46	97	2.10	44	69	1.56						
Mean	73	123	1.68	60	89	1.48						
Standard Deviation	92	102		76	91							
Pearson's *r*	0.900			0.819								
Building Factors	With Net Floor Areas						Specified Ventilation Type					
	Electricity (kWh/m^2/yr)			Heat (kWh/m^2/yr)			Electricity (kWh/m^2/yr)			Heat (kWh/m^2/yr)		
	Design	Actual	Ratios	Design	Actual	Heat	Design	Actual	Ratios	Design	Actual	Heat
Max	412	515	1.25	174	106	0.61	300	250	0.83	127	199	1.57
Min	21	19	0.90	19	13	0.68	9	29	3.22	15	13	0.87
Median	29	89	3.01	41	50	1.22	48	97	2.02	48	87	1.81
Mean	99	147	1.48	62	54	0.87	60	105	1.75	61	92	1.51
Standard Deviation	128	152		56	29		55	56		33	52	
Pearson's *r*	0.97			-0.51			0.64			-0.01		
Occupant Factors	With Occupancy Data						With Operating Hours Data					
	Electricity (kWh/m^2/yr)			Heat (kWh/m^2/yr)			Electricity (kWh/m^2/yr)			Heat (kWh/m^2/yr)		
	Design	Actual	Ratio	Design	Actual	Ratio	Design	Actual	Ratio	Design	Actual	Ratio
Max	412	515	1.25	174	199	1.14	412	515	1.25	174	182	1.05
Min	9	19	2.11	4	2	0.50	9	19	2.11	4	2	0.50
Median	45	84	1.86	48	65	1.35	46	86	1.87	52	64	1.23
Mean	63	105	1.67	55	71	1.29	64	113	1.77	63	68	1.08
Standard Deviation	73	94		37	47		78	101		41	43	
Pearson's *r*	0.91			0.03			0.91			0.08		

Table 6. 9 CarbonBuzz subset D: Statistics for various factors in the CarbonBuzz database.

Calculation Method

‘Calculation Method’ has been used as a proxy for a limited energy assessment method (SBEM) and a potentially fuller account of energy end uses (Energy Modelling Software). Buildings with unspecified calculation methods have been shown as a comparator. There are nine projects calculated by SBEM, ten by analysis software method and the remaining twenty-eight are unspecified, the data is illustrated in figures 6.18 and 6.19 . There are similar relationships between those projects with both calculation methodologies specified. The subset with the strongest linear relationships is those projects with unspecified calculation methods.

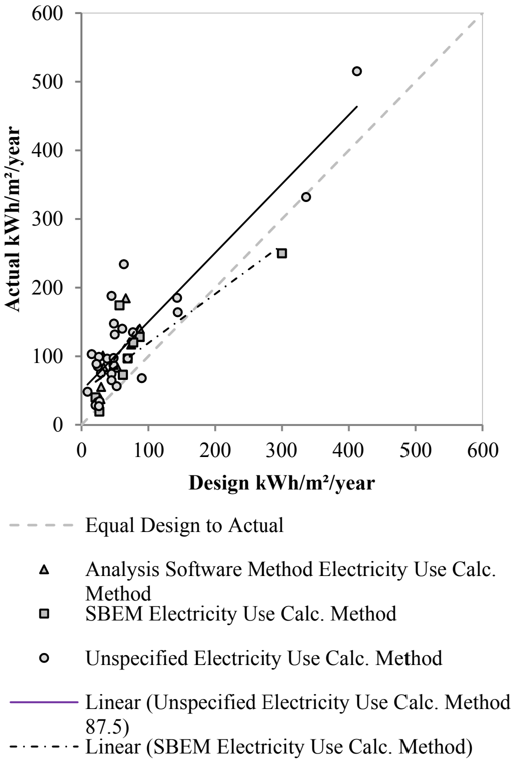


Figure 6. 18 CarbonBuzz: Subset D Design versus actual electricity sorted by calculation method.

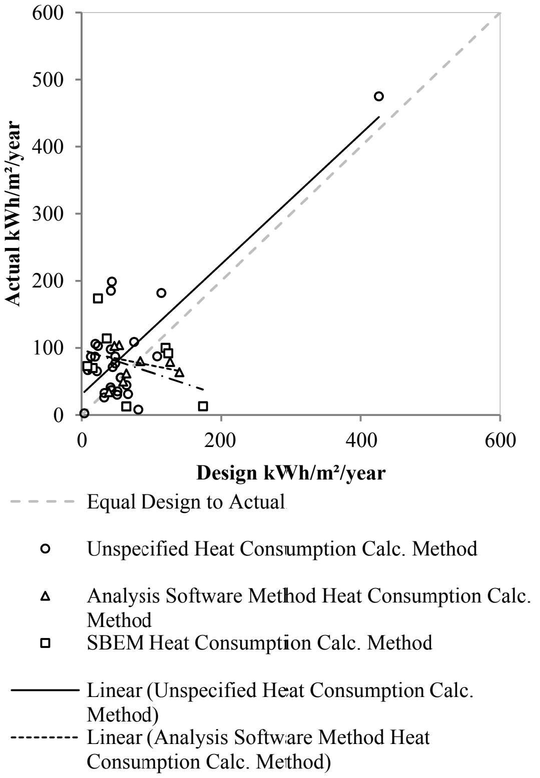


Figure 6. 19 CarbonBuzz: Subset D design versus actual heat consumption data sorted by calculation method.

Electricity values in table 6.9 confirm the strength of the relationship between design and actual electricity figures for those projects with unspecified calculation methods. The Analysis Software subset has the lowest standard deviation in both design and actual figures suggesting a lower spread of values reflecting the fact that this calculation method has the greatest potential for accuracy. However, these projects have the highest design to actual mean value change ratio. The literature review suggests that one of the causes of the energy gap is that energy assessments do not include all energy end-uses. This data presents a potential contradiction to this and suggests that more than simply accounting for an end use is necessary; an understanding of the building's use is needed.

In heat consumption, as in the electricity use data, those projects with unspecified calculation methods show strong positive linear relationships. Those with specified calculation methods show no real linear relationship and negative correlations between design and actual data although the mean design-to-actual ratio is close to 1. The SBEM subset has a mean ratio of 1.04, perhaps a result of the focus on building fabric and that the majority of heat consumption is regulated and therefore included in the calculation.

The projects using SBEM as a calculation method have a smaller energy gap than the analysis software calculation method. This is counter-intuitive because of the limitations identified in SBEM calculations raised in the literature review. However, the headline data does not show if the figures have been supplemented by additional end use values. The difference between the specified calculation method's Pearson's r value and unspecified methods in heat consumption is the most striking. This could be due to the ambiguity of the phrase 'unspecified'; this could actually be values with rounded predictions, not constrained by prescriptive calculation methods.

Building Factors

The availability of information about the physical or environmental strategies employed in a building may have an impact on the energy gap. Using the twenty-five projects in subset D with a design stage 'Ventilation Type' specified and the nine with 'Net Floor Area', performance comparisons are made between design and actual information described in table 6.9 and illustrated in figures 6.20 and 6.21.

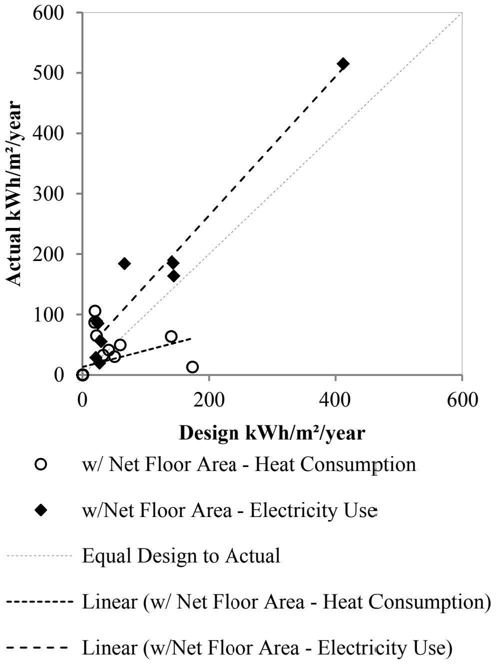


Figure 6. 20 CarbonBuzz: Subset D design versus actual values for projects with net floor area data.

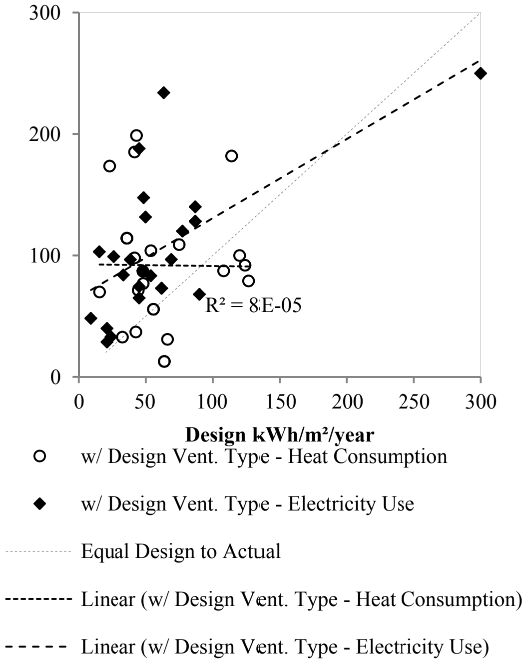


Figure 6. 21 CarbonBuzz: Subset D design versus actual values for projects with design ventilation type data.

These categories are used since they represent a service strategy and physical characteristics of the building as well as the largest subsets. Like other subsets, figures 6.20 and 6.21 illustrate little or no linear relationship between design and actual heat consumption data. The relationship between design and actual recorded values for buildings with Net Floor Area information show that all but one of the electricity values are under-predicted whereas the heat consumption values seem random. This is particularly surprising as the Ventilation Type field also specifies the heating type and therefore will provide data on energy consumption and better tracking of data. This data suggests that the presence of information about a system does not guarantee a good prediction and further contradicts the idea that the gap is generated by a lack of accounting.

Table 6.9 shows a reduction in the mean values for heat consumption and an increase in electricity values. There is a strong, almost perfect positive correlation between design and actual electricity in projects with Net Floor Area Information and a mean value ratio of 1.5. The projects with Design Ventilation Type show electricity is under-predicted at design stage, while the heat consumption figures are much more ambiguous with a non-linear relationship between the design and actual figures. The mean values at design and actual stages for heat and electricity use are similar, whether this is through careful consideration or chance is not clear.

Examining the projects with Net Floor Area and Design Ventilation Type data suggests that because information is available, this does not result in a more accurate prediction even where the information relates directly to the energy prediction in question. However, there may be mitigating factors to this observation. The ventilation type may have changed, or the buildings may be used differently; without this information in the platform it is impossible to make deductions.

Occupant Factors

Projects with design and actual occupancy data are used to ascertain whether the inclusion of this information has an impact on the energy gap. Table 6.9 shows the designed versus actual recorded values for headline energy data of projects with ‘Occupancy’ numbers and those with ‘Operating Hours’ data (the data is illustrated in figures 6.22 and 6.23). The range of projects in these two subsets is similar, with 31 with Occupancy data and 24 with Operating Hours information. These samples continue the pattern between electricity and heat consumption observed in previous subsets; there is a strong linear relationship between design and actual electricity values but not with heat consumption values in both subsets.

The design mean values in both subsets are very similar, with electricity higher in actual figures. The R^2 values confirm the strength and weakness of the linear relationships.

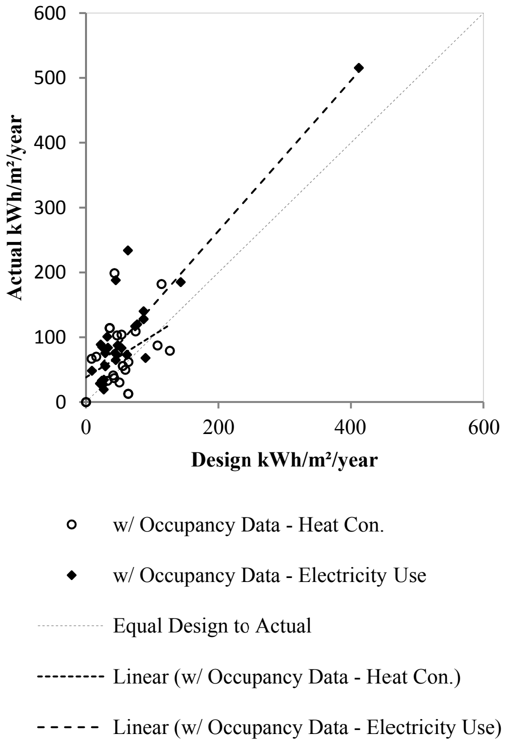


Figure 6. 22 CarbonBuzz: Subset D projects with Occupancy data.

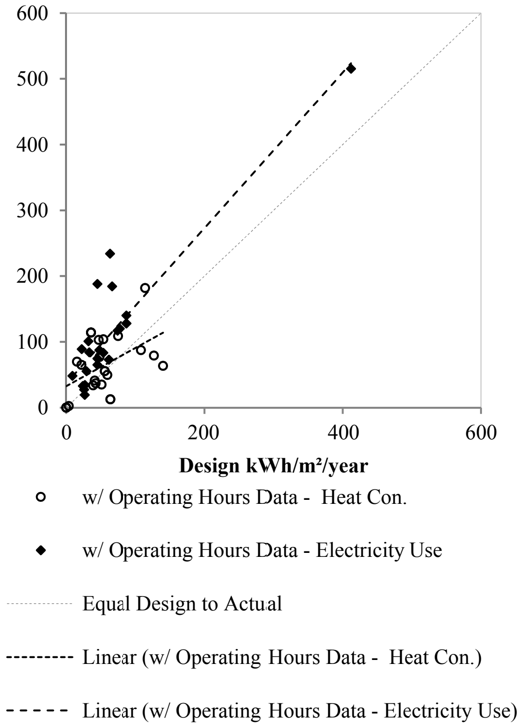


Figure 6. 23 CarbonBuzz: Subset D projects with Operating Hours data.

The Pearson's r tests in table 6.9 show a strong relationship between design and actual electricity, whereas again there is no strong relationship between design and actual heat values. The presence of occupant factor information at design stage does not appear to change the relationship between design predictions and actual values in the sample. There is still a degree of consistent error in electricity values and a seemingly random error in heat consumption values.

There is an observable pattern to the data entered into the CarbonBuzz database regardless of how it was calculated or how much information is used to make the decision: heat figures have no real consistent relationship between design predictions and actual records, and electricity use figures have a stronger linear relationship with a more consistent error. This generally describes an energy gap corresponding to a 1.5 fold increase. There are more unknown and occupant variables associated with electricity use, therefore one could expect more variation in the electricity figures, rather than more consistency. The contrary being the case suggests that the unregulated end uses that are not taken into account in compliance calculations are generating a consistency in the design versus actual relationship, not through actor understanding but through addition of a consistent unaccounted load. This suggests that actors have no real understanding of the end uses of either fuel type.

The contextual pressures require a focus on building fabric and fixed building services, the main components of heat consumption figures. This does not explain the randomness in the predictions or the inability of actors to make accurate predictions. The energy data describes predictions tailored to meet the contextual pressures, perhaps with some supplementing adjustments made in CarbonBuzz which accounts for the slightly better than industry-wide design versus actual ratios.

6.5 Disaggregated Data and Decision Support

This section looks at the projects in Subset E with disaggregated data, those projects with electricity and heat consumption broken down into at least two end-uses, one of which is Equipment and Appliances, an unregulated energy use. This will allow for an exploration of what the data in CarbonBuzz can offer as feedback to industry actors. There are 12 projects for analysis.

6.5.1 All projects

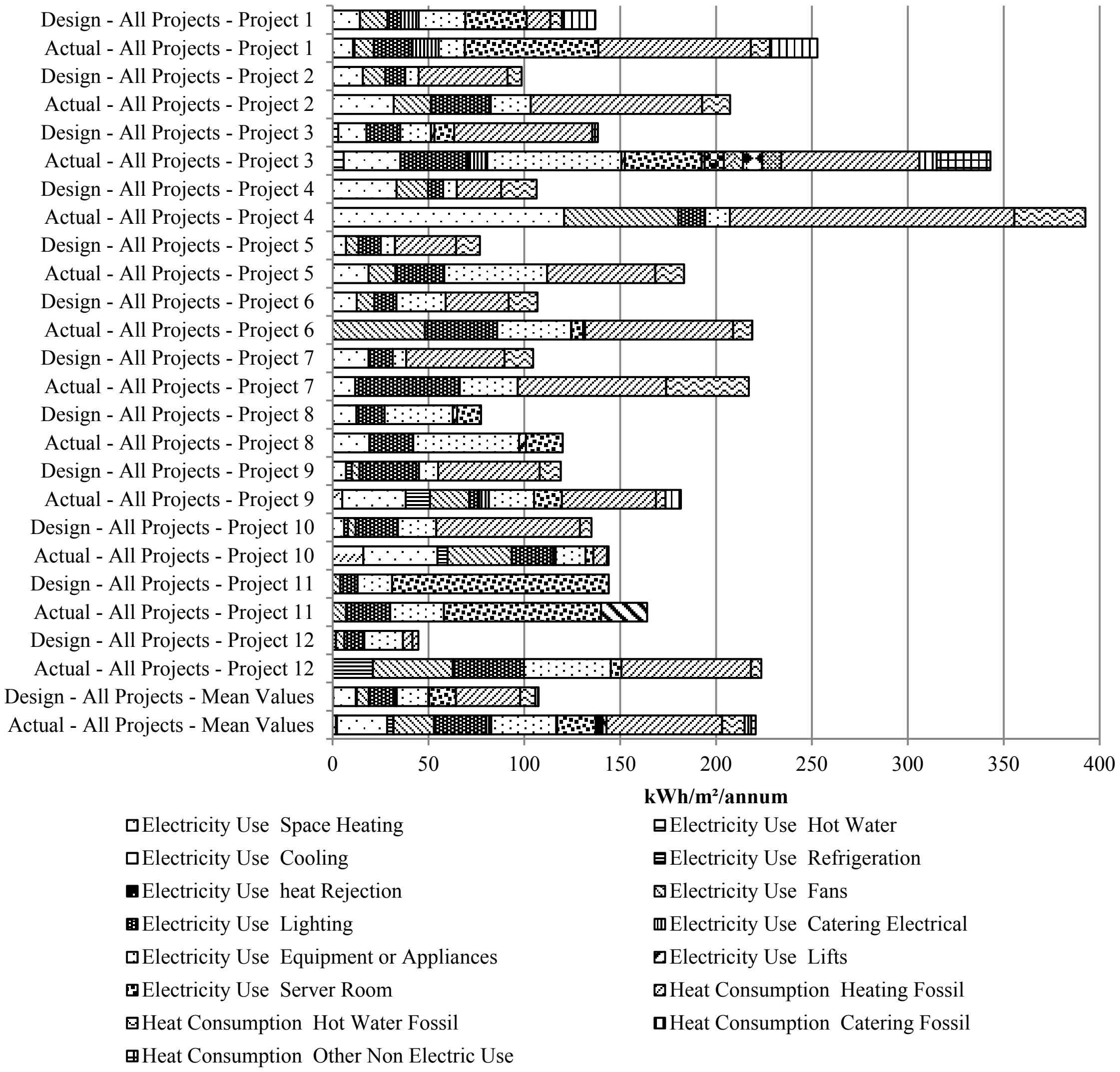


Figure 6. 24 CarbonBuzz: Disaggregated data for designed versus actual end-use values all projects.

Figure 6.24 shows the disaggregated data for all projects in subset F. All projects show an increase in total energy consumption from design to actual; some show a large increase whereas others show a very slight overall increase. For example, Project 12 shows a nearly five-fold increase in overall energy consumption while Project 10 shows an increase of less than 10%. Each of these projects illustrates a variation in the energy gap; not every energy use has a five-fold increase in Project 12 and similarly some changes in Project 10 are in excess of 10%. For example in Project 10 the value for 'Fossil Space Heating' goes from 75 to 33.4 kWh/m^2/annum from design to actual (a 55% decrease) while the electrical value for 'Equipment and Appliances' goes from 20 to 38.7 kWh/m^2/annum (a 93% increase). The simultaneous halving and doubling of two different end-uses is in the context of an approximate 10% overall increase illustrates the need for understanding of actual end-use consumption at design stage and the limitations of the contextual pressures. In Project 12 the 'Fossil Heating' value goes from 4.9 to 67.6 kWh/m^2/annum (a 1200% increase) and the Equipment and Appliances value goes from 20.2 to 45.3 kWh/m^2/annum (a 124% increase). Both of these changes are in the context of a near 5 fold increase in overall energy consumption.

The mean value energy bars are composed of the mean value for each end-use and show a doubling of the overall values. Relationships between end-uses are commensurate with this, for example the mean Equipment and Appliances values go from 16.5 to 33.9, while the Fossil heating value goes from 33.5 to 60.3 kWh/m^2/annum.

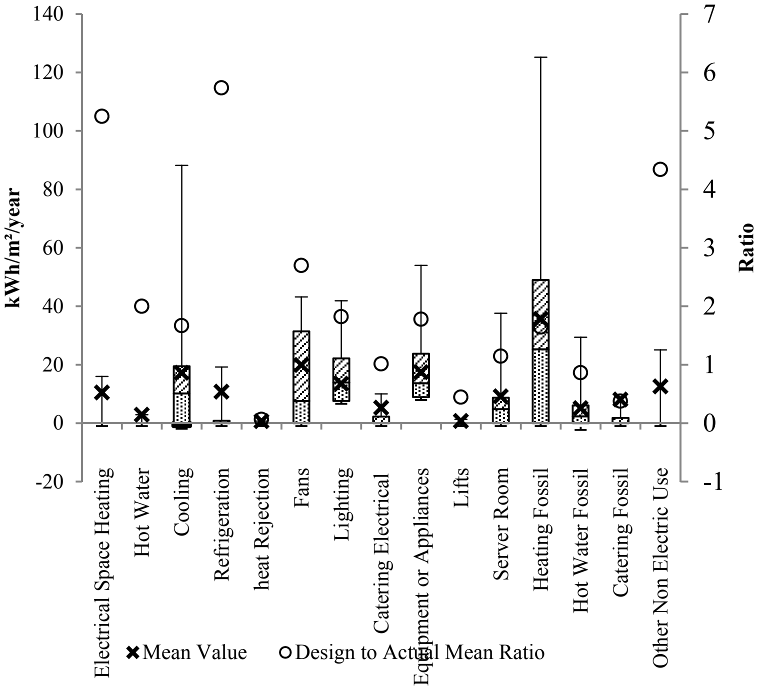


Figure 6. 25 CarbonBuzz: Box plot of the differences between design and actual energy end-uses.

Figure 6.25 shows a box plot of the differences between design and actual end-uses as well as the ratio between the mean design-predicted value and the mean actual recorded value. In subset F, ‘Heating Fossil’ has the greater range of values but a mean design to actual ratio of 1.64, whereas Fans have a smaller range but a ratio of 2.69. Fixed building services – regulated energy uses - have the largest ratio between design and actual records. This suggests that the contextual pressures and in particular the formal framework is not functioning as an effective predictor of energy consumption, rather as a compliance exercise.

Feedback and the energy gap is not just about improving the amount of information taken into account, it is also about improving the prediction and understanding of end-uses that are already accounted for. Regulated energy in the CarbonBuzz database is more likely to be inaccurately predicted than unregulated energy. This contradicts the idea identified in the literature that the energy gap exists because of a lack of accounting for end-use at design stage. It may be because all buildings – those calculated with attention to detail and those without – are represented in regulated energy but only those calculated with careful consideration have unregulated design information so skewing the results. A feedback platform must be able to take into account this variability in data quality.

The following sections aim to establish if there is a pattern to the end-use changes based on the same criteria used to look at the performance comparisons in section 6.4; building and occupant factors, sector types and the calculation method used.

6.5.2 Sector

The following section looks at the differences between the two sectors in the database that have projects with design and actual Equipment and Appliance data – Education and Office buildings.

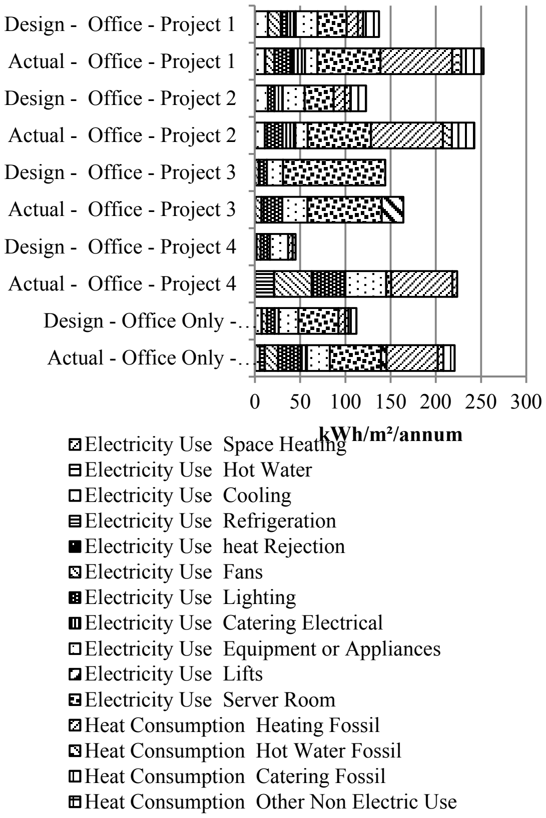


Figure 6. 26 CarbonBuzz: Disaggregated energy end-uses for office projects.

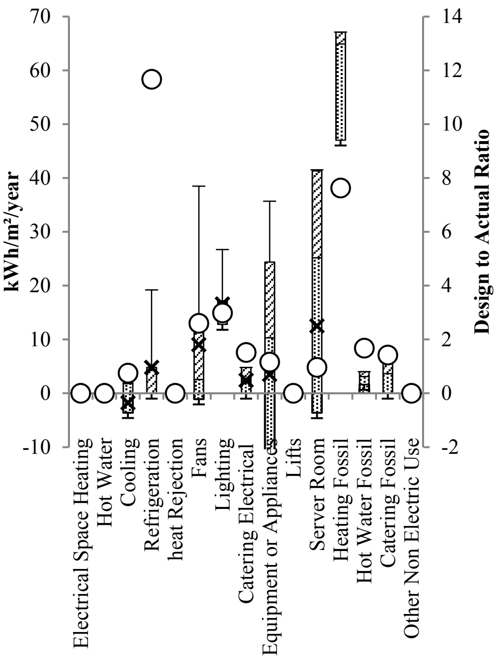
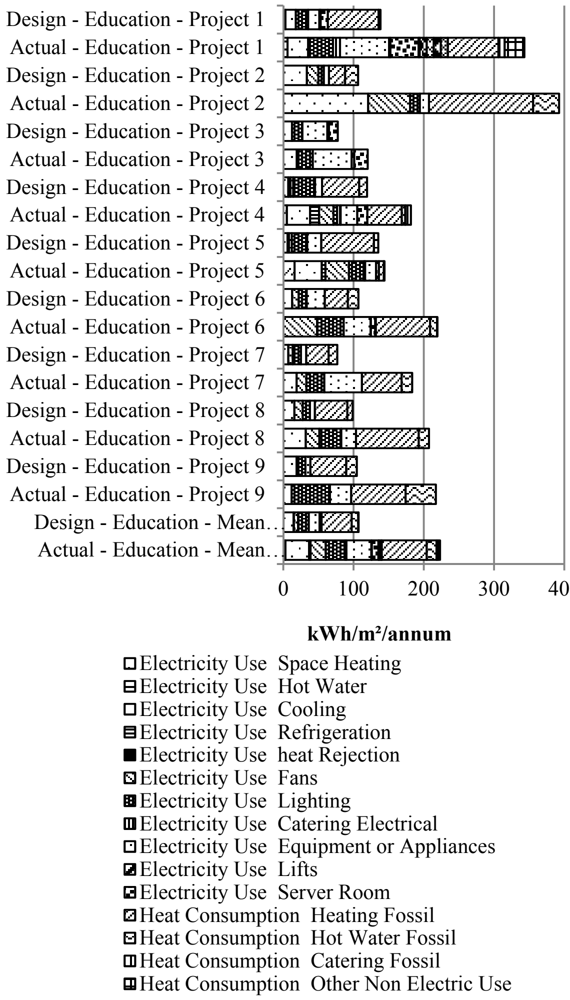


Figure 6. 27 CarbonBuzz: Box plot of the design to actual change in office buildings.

Figure 6.26 shows the disaggregated data for the four Office projects with design and actual ‘Equipment and Appliance’ values. All projects show an increase from design to actual values. The mean energy bar shows an approximate doubling. ‘Equipment and Appliance’ use, in the mean values, is relatively accurate going from 21.7 to 25.1 kWh/m^2/annum. The fixed building services however, are not as accurate – ‘Heating Consumption Fossil’ goes from a mean design value of 3.7 to an actual value of 56.7 kWh/m^2/annum. Figure 6.27 shows the change in energy consumption of end-use categories and confirms the findings of the energy bars. Refrigeration and Heating Fossil have large design to actual ratios; approximately 12 and 8 respectively while unregulated energy uses like Equipment and Appliances, although having a greater spread of values, have a low change ratio of 1.1. This is helped by some projects having an over-predicted value; however, this may also be due to a lack of sub-metering meaning that plug-load consumption is accounted for in other end-uses.



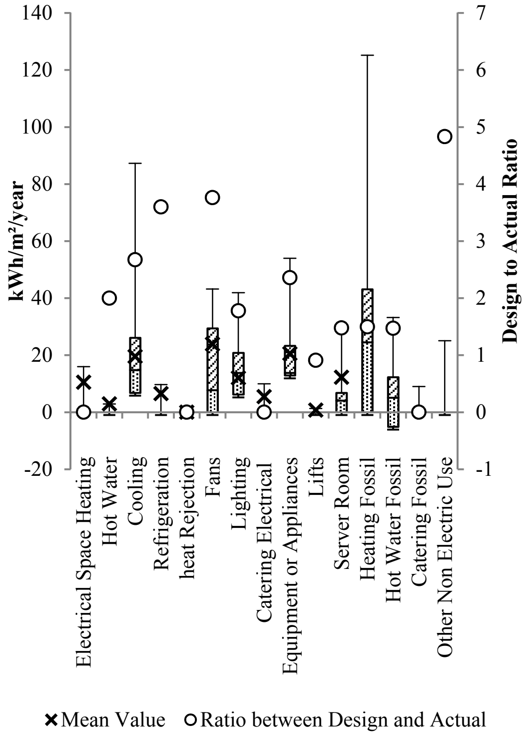


Figure 6. 28 CarbonBuzz: Disaggregated end-use data for Education projects

.

Figure 6. 29 CarbonBuzz: Box plot of disaggregated end-use data for Education projects.

1

The disaggregated data shown in figure 6.28 illustrates a range of changes from design to actual figures in the eight Education projects with design and actual Equipment and Appliance data. Project 2 shows a near 4 fold increase from design to actual with increase across all energy end-uses, whereas project 5 shows a slight increase from designed to actual energy use with a more diverse range of end-use changes recorded. Like Office buildings, the mean values show a doubling of the overall energy consumption value with Equipment and Appliance consumption going from 15.1 to 35.6 kWh/m^2/annum and Heating Fossil increasing from 42.8 to 64.1 kWh/m^2/annum. This change is in contrast to Office buildings.

Figure 6.29 shows that in Education projects, the largest change from design to actual relative to the recorded figure was in Refrigeration, Fans and Other Non Electric Use.

Hot Water Fossil shows some under prediction, the only end-use to do so. There is also a large increase in Equipment and Appliance use – a factor of 2.3.

Office buildings had the largest change in fixed building services, which are regulated energy uses. This again challenges the idea that the energy gap exists because information is not used properly at design stage and suggests that poor understanding of how buildings will actually be used. Education buildings showed several a large changes from design to actual energy end-use values. This is perhaps down to the more diverse use patterns of Education buildings (the School day, after school clubs, local community use). This places more reliance on supporting data to ascertain where the changes come from.

6.5.3 Calculation Method

This section looks at the four projects in Subset F with design and actual Equipment and Appliance data and a specified calculation method, the analysis begins with those projects using Analysis Software.

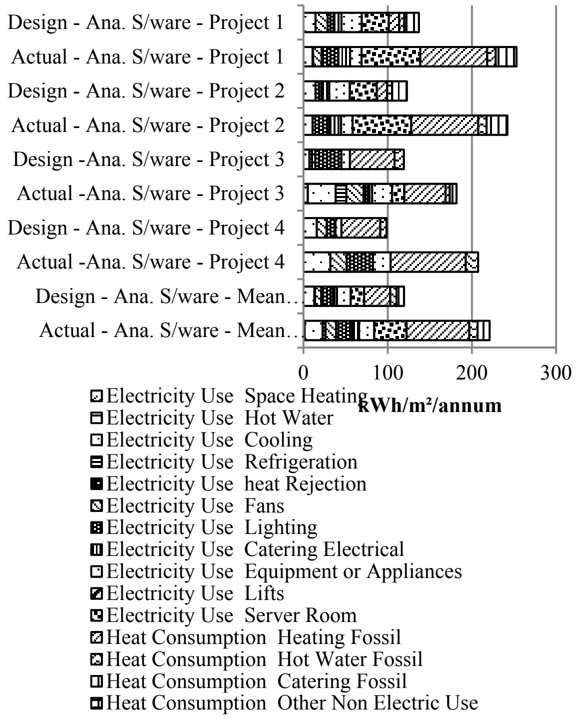


Figure 6. 30 CarbonBuzz: Disaggregated data for projects using Analysis Software as a calculation method.

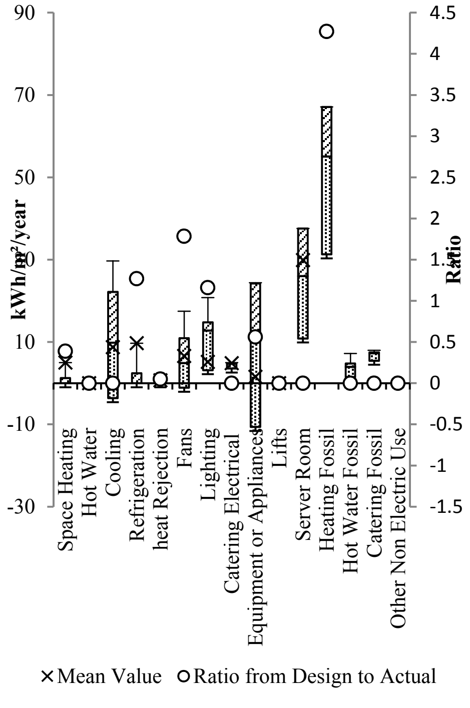


Figure 6. 31 Box plot of the difference in disaggregated data for projects using Analysis Software as a calculation method.

Figure 6.30 shows the disaggregated data for projects with design and actual equipment and appliance data. All projects again show an increase from designed to actual, with a variety of proportions in end-uses. While overall mean values are double the proportion appear to be more consistent than in the sector data. The box plot of the change in end-use figures for those projects using analysis software in figure 6.31 shows that the end-use with the largest difference between design and actual values is Heating Fossil with a ratio of approximately 4.5. This could be because regulated figures are simply dropped in from NCM calculation software while the unregulated energy figures are based on more considered evaluations of the specific buildings equipment and consumption patterns.

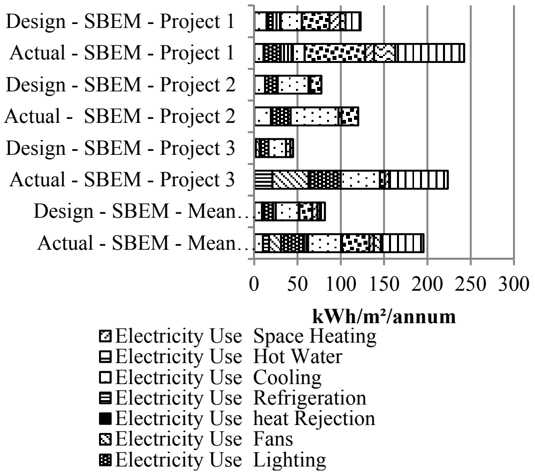


Figure 6. 32 CarbonBuzz: Disaggregated data for projects assessed using SBEM.

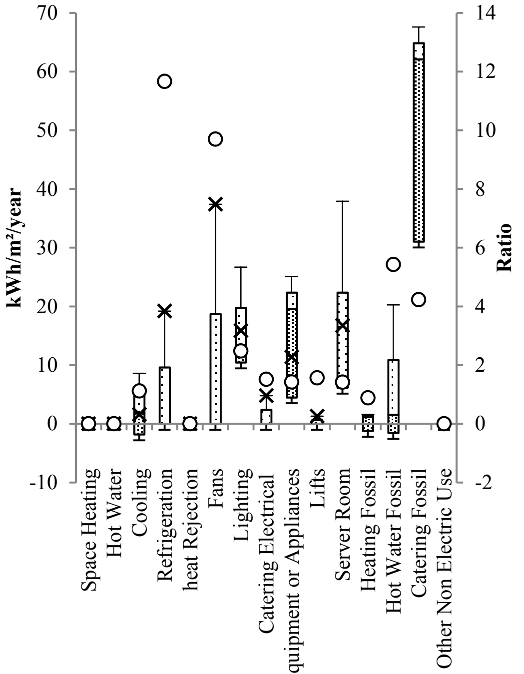


Figure 6. 33 CarbonBuzz: Box plots for difference in disaggregated data for projects assessed using SBEM.

Figure 6.32 shows that like previous subsets, all projects show a total increase from design to actual values but with variable proportional increases in some end-uses. For example Project 1 has an overall recorded consumption figure of approximately 240kWh/m^2/yr, twice the design value whereas the ‘Fossil Catering’ figure shows an increase from 17.4 to 79.5 kWh/m^2/year; a four-fold increase. Figure 6.33explores these differences in a box plot of the changes in end-use energy consumption from design to actual. The largest changes are in Refrigeration, Fans and Catering Fossil. In contrast to those projects using Analysis Software methods, Heating Fossil - the main focus of SBEM calculations - has a low change ratio of 0.8.

The two calculation methods examined have different characteristics in their energy gaps. The energy gap is most pronounced in 'Fossil Heating'. The SBEM-based calculations have a reduction in Fossil Heating from design to actual but much higher increases elsewhere.

The calculation methods and the wider standards they are associated with represented by the contextual pressures have different implications for the energy gap and by extension feedback requirements. One role of a feedback platform may be to highlight particularly weak areas of prediction. This data supports the survey findings that decisions based on SBEM figure may have different outcomes than those based on Analysis Software values.

6.5.4 Building Factors

There is only one building in the subset with specified Net Floor Are information and disaggregated data, this is illustrated below only to illustrate the lack of consistency in some records.

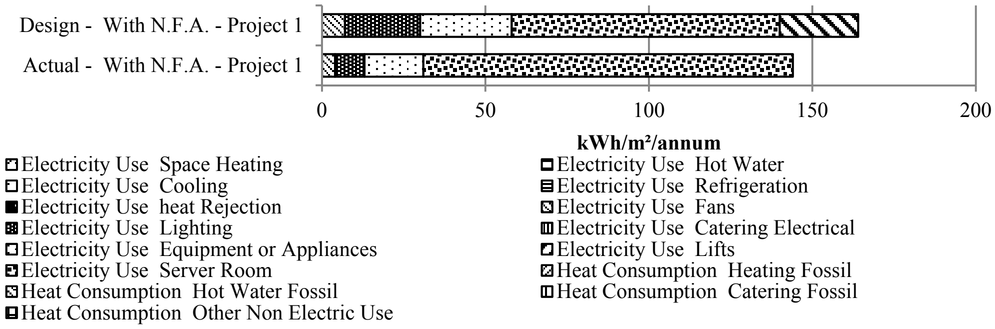


Figure 6. 34 CarbonBuzz: Disaggregated data for projects with net floor area

The only project in the subset that has Net Floor Area data and design and actual Equipment and Appliance loads illustrated in Figure 6.34. This particular project shows a reduction from design to actual total values but with an increase in Server Room use. It is included since it illustrates the often-observed occurrence that shows buildings with changes in overall number of end-uses, in this case changing from five to four, losing Electricity Use – Other Electricity Use.

The implications for this are that either this Other end-use has not been sub-metered and therefore is included in one of the other actual records, or the end-use is no longer required in the actual building. In the former case, one of the end-uses is skewed. In the latter the record needs to be backed by information detailing the changes that occurred. In this record, it is not clear which is the case. There are ten projects in subset E that have design and actual Equipment and Appliance loads and a specified Design Ventilation Type.

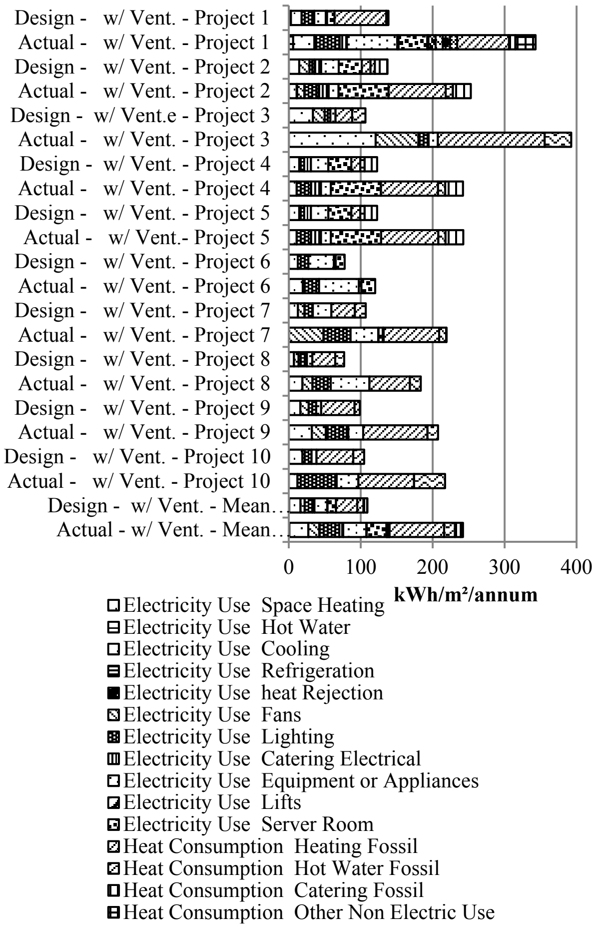


Figure 6. 35 CarbonBuzz: Disaggregated design and actual end-use data for projects with specified Design Ventilation Type.

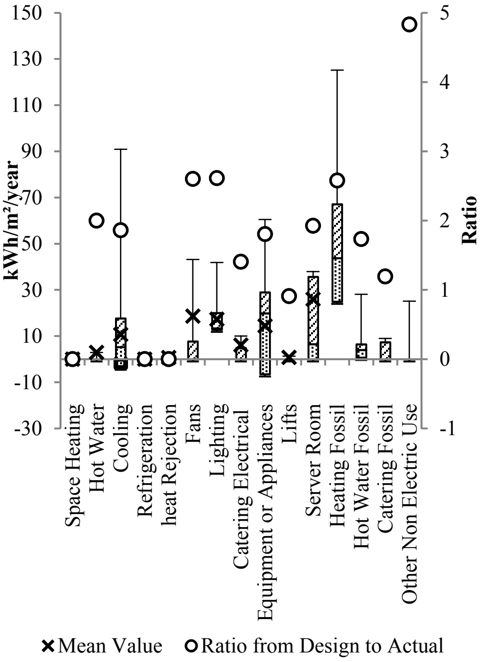


Figure 6. 36 CarbonBuzz: Box plot of disaggregated design and actual end-use data for projects with specified Design Ventilation Type.

Figures 6.35 shows the disaggregated end-use values for the sub-set E projects with specified ventilation type. All projects show an increase from design to actual values, again with the mean values approximately doubling. The key end-uses in this group are those related to ventilation, heating and environmental control as this has been specified in the data set. The mean value for Fossil Heating increases from 29.4 kWh/m^2/annum at design stage to 75.9 in actual records. Cooling increases from 15.7 to 26.4 and Fans from 5.8 to 15.1 kWh/m2/annum. Figure 6.36 shows that again the greatest change is in fixed building services, Fans, Lighting and Heating Fossil. All have a change ratio of over 2. The number of end-uses that records are broken into can change from design to actual. However, this introduces some ambiguity in the data that a feedback platform must be able to account for in order to provide sound information to base decisions on. The inclusion of information in the platform does not necessarily mean that a record is more accurate, simply that there is information on which to base decisions.

6.5.5 Occupancy Data

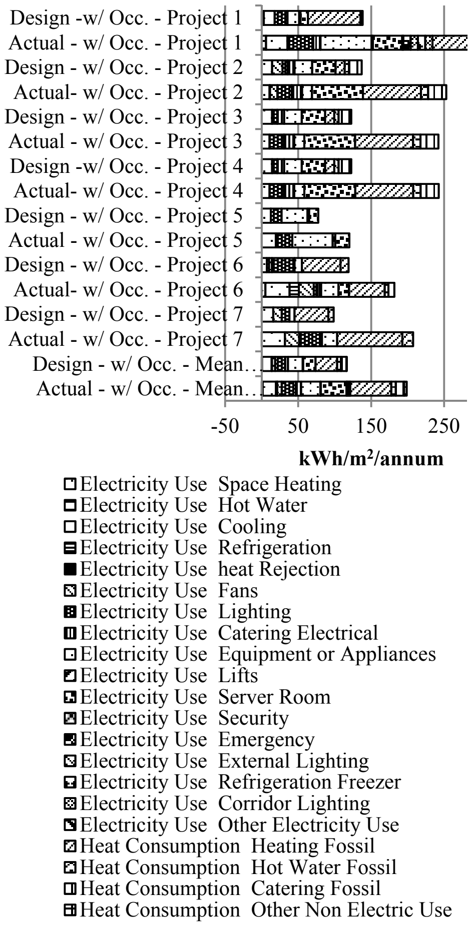


Figure 6. 37 CarbonBuzz: Design versus actual disaggregated data for projects with occupancy data.

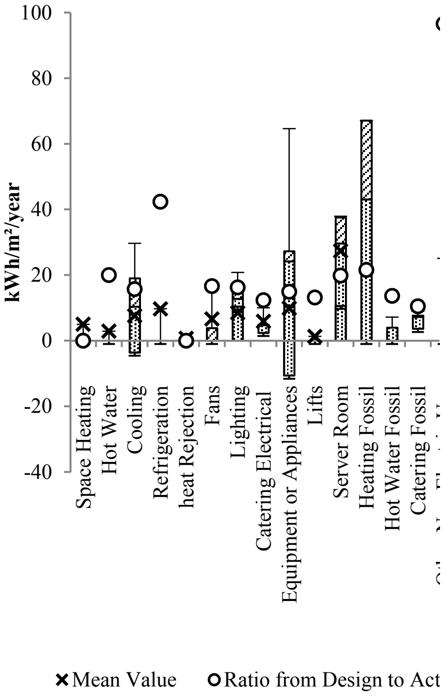
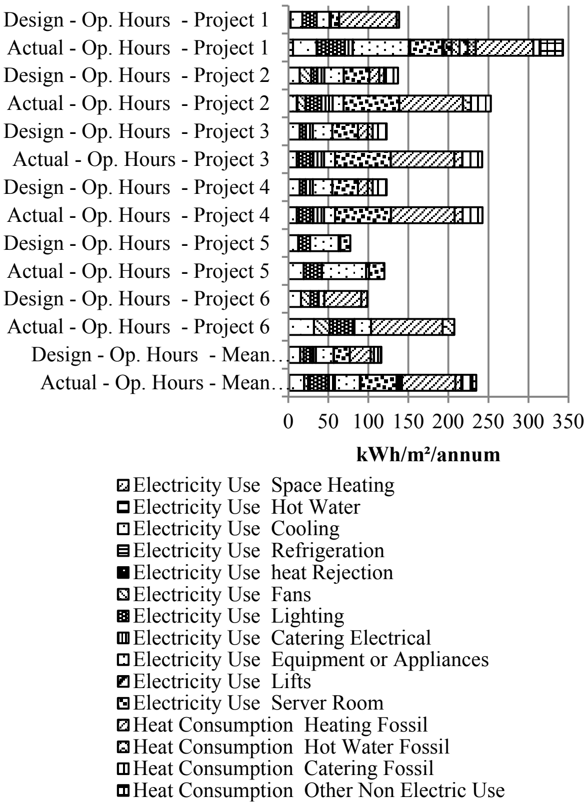


Figure 6. 38 CarbonBuzz: Box plot of difference in disaggregated data for projects with occupancy data.

There are seven projects with Occupancy figures in the subset; figure 6.37 shows increase in all projects' disaggregated data. Most have large increases in Other Electricity

Use and Electricity Use Lifts and smaller increases in Equipment and Appliances. This may be reflective of metering strategies rather than changes in energy use patterns, but perhaps having an idea of occupancy numbers at design stage allows for more accurate prediction across end-uses, particularly unregulated uses. The changes from design to actual values illustrated in figure 6.38. The change ratio from design to actual in Equipment and Appliances is 1.4; others are all around 2 with the exception of Other Non Electric Use, which is near 10. The occupant driven loads like Equipment and Appliance loads and Heating and Cooling do not have particularly large changes.



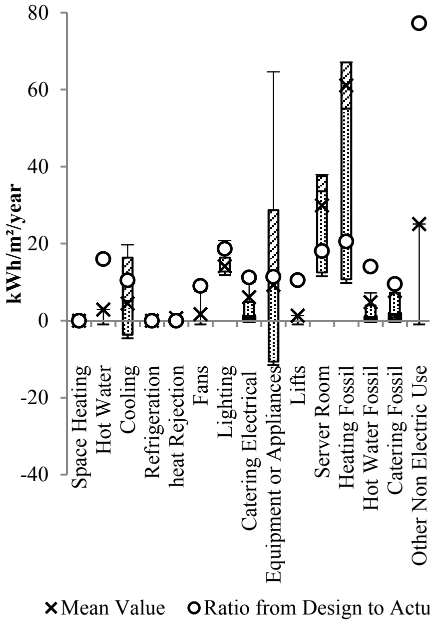


Figure 6. 39 CarbonBuzz: Design versus actual disaggregated data for projects with Operating Hours information.

Figure 6. 40 CarbonBuzz: Box plot of difference in end-use energy value for projects with Operating Hours information.

Figure 6.39 shows the changes in disaggregated data from design to actual projects with operating hours information. The mean values, in common with other subsets, show a doubling of overall values with variable changes across end-uses. Figure 6.40 illustrates the changes in end-use energy consumption. Similarly to those projects with Occupancy data (many of which are the same projects) there is a degree of consistency across the end-use figures. Most change ratios are between 1 and 2.5, with the exception of Other Non Electric Use.

Those buildings with Occupancy and Operating Hours data appear to have greater consistency in the relationship between design and actual end-use values. This may be because consideration of the number of people using a building and the length of time they will be there for allows some measure of accuracy in the predictions.

6.5.6 Disaggregated Data Summary

The energy gap does not exist purely because of an absence of end-use data in design predictions. This section has shown that in projects where rounded energy predictions are made, the discrepancy between design and actual records is still often over two-fold. The presence of information alone does not mean accurate predictions will be made; the interaction is more complex than this. The changes in end-use consumption vary depending on the calculation method used: the contextual pressures influence actors' decisions. The role of a feedback platform is to offset the negative influence of the contextual pressures.

The building use type also influences where the energy gap exists. The arguably more homogeneous sector of Office buildings showing a consistency in the type of energy discrepancy and the more complex Education sector showing much more variation in the nature of the gap. The presence of occupancy information seems to have a stabilising influence on the energy gap however this could be down to other factors.

6.6 Disaggregated Benchmarks

Given the variability in end-use energy consumption, this section looks at using the data in CarbonBuzz to assess the relationships in crowd-sourced data has with existing targets in the contextual pressures and the potential to provide new benchmarks. The Education projects from subsets A and E are used for this analysis. Comparison is made between TM46 benchmarks and both actual and design figures because, although TM46 is an in-use benchmark, one of the purposes of CarbonBuzz and other crowd-sourced data platforms is to make more realistic design predictions. Sung et al. (2013) have shown that the TM46 benchmark for ‘Schools and Seasonal Public Buildings’ do not reflect energy use in schools in the DEC database; the same benchmark is used for comparison here.

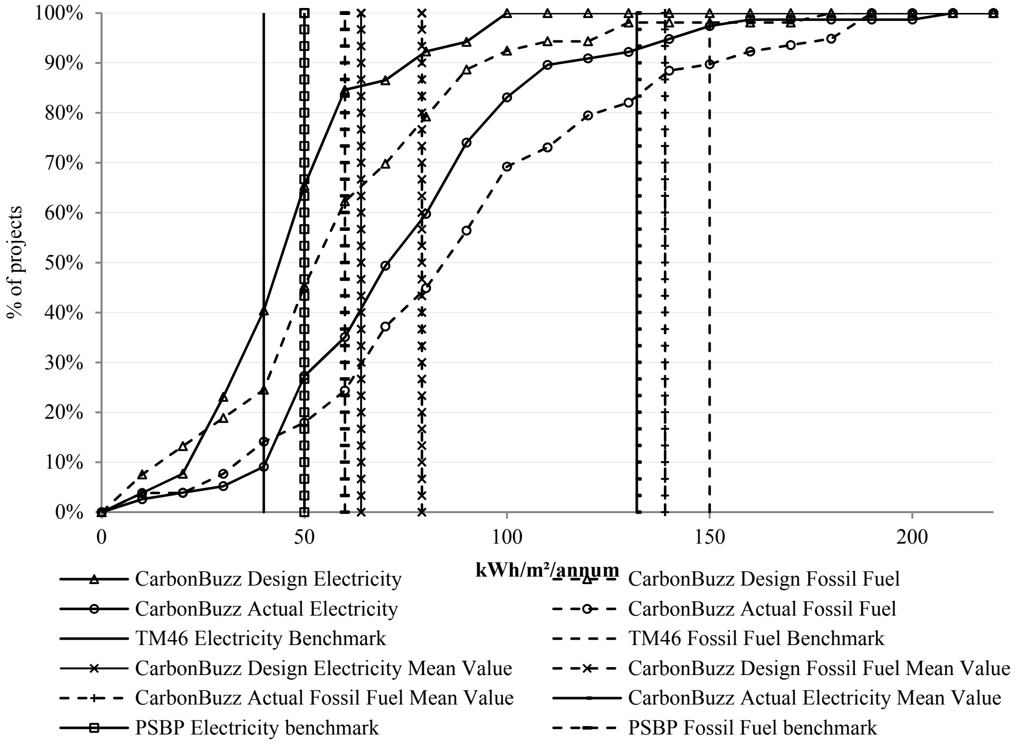


Figure 6. 41 CarbonBuzz subset A: Cumulative frequency of design predicted and actual electricity and heat consumption records.

Figure 6.41 shows cumulative frequency curves of the design data in CarbonBuzz subset A. The curves show that 60% of design electricity records sit above the TM46 benchmark level whereas nearly 100% of projects have predicted heat consumption lower than this. The actual records have a similar shaped curve, shifted approximately 50kWh/m^2 up on the x-axis. This illustrates the energy gap as well as showing that neither actual recorded nor design predictions are well represented by the TM46 benchmarks. In both design and actual records, the fossil fuel benchmark is higher than the majority of buildings’ consumption and the electricity benchmark is well below most buildings' (60% at design stage and over 90% in actual records). In both cases, the electricity benchmark seems too ambitious and the fossil fuel benchmark too easily achievable. The newly introduced Priority Schools Building Programme (PSBP) target offers very ambitious targets for both electricity and fossil fuel consumption in the CarbonBuzz actual sample.

The data shows the legislative and behavioural changes in building energy consumption described by Bruhns et al (2011) since the benchmarks were established. Recorded crowd-sourced data stored in CarbonBuzz may provide the insights required to understand where this variance lies and make better predictions at design stage. The following analysis looks at the eight Education projects in Subset E, adjusted for weather conditions as per the CIBSE TM52 methodology and expressed as a percentage of the benchmarks.

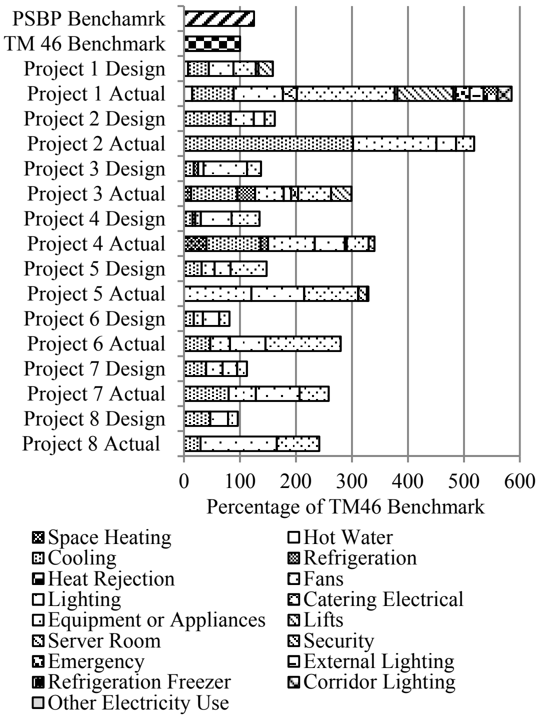


Figure 6. 42 CarbonBuzz subset E: Electricity energy breakdown as a percentage of the benchmarks.

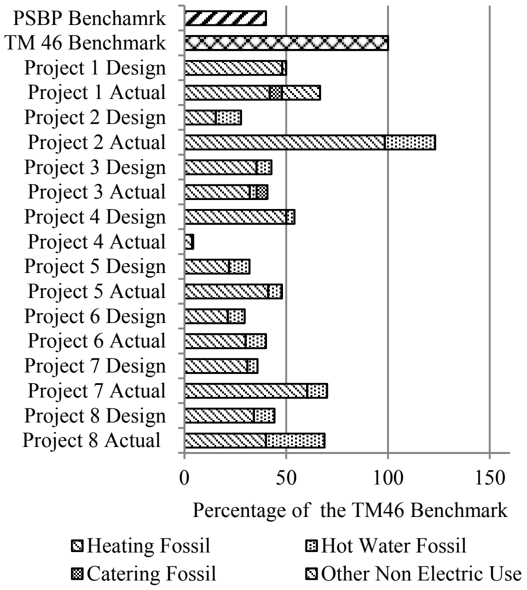


Figure 6. 43 CarbonBuzz subset E: Heat energy breakdown as percentage of the TM46 benchmark.

Figure 6.42 shows disaggregated electricity consumption data as a percentage of the TM46 and PSBP benchmark values. Four projects have individual end uses that have a greater consumption value than the benchmark total. Project 2's 'Cooling' and 'Fans' figures are individually greater than the benchmark; cooling alone is three times the benchmark. It is notable that the proportion of each energy bar represented by the unregulated Equipment and

Appliances is much greater in the actual energy bars than the design. The proportion of end-uses changes from design to actual, for example project 8’s cooling figure changes from 47% of the benchmark to 29% while the lighting value goes from 31 to 136% of the benchmark. The headline compensation between total end-use data (lower than expected heat consumption cancelling out higher than expected electricity consumption) also happens to a lesser extent with smaller loads.

Figure 6.43 shows the disaggregated heat energy data from the subset as a percentage of the TM46 benchmark. The heating figure has been adjusted for weather and location. In marked contrast to the electricity data illustrated in figure 6.19, Project 2 is the only project to have an actual heat energy consumption figure higher than the benchmark. In this case the heating energy consumption represents 98% of the benchmark. TM46 assumes that 55% of fossil fuel will be used for space heating while the other 45% is used for hot water. Of the projects in Subset 3 Projects 9’s actual consumption is closest to this split, with a 58:42 ratio of heating to hot water. Other projects are as high as 98:2. The following charts look at the data as absolute values.

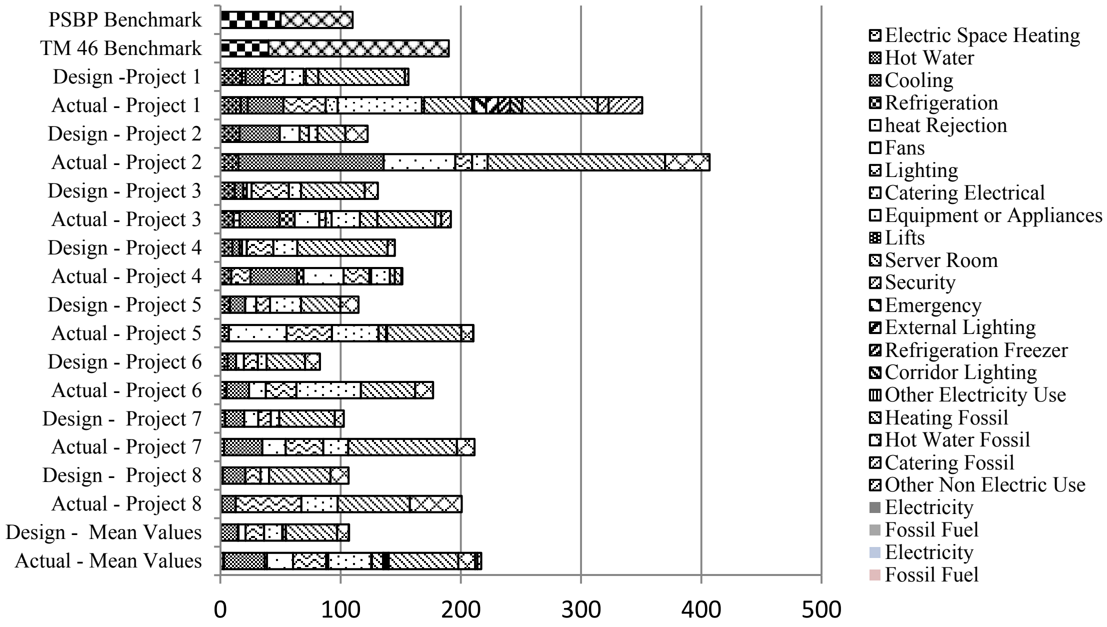


Figure 6. 44 CarbonBuzz subset E: Disaggregated energy end use breakdown.

Figure 6.44 shows the breakdown of design and actual electrical and heat energy data in the eight projects in subset E. There is an increase from design to actual total values in all projects; however the design to actual relationships of end uses varies within this. For example, Project 4, which has the closest relationship between design and actual total figures

– a 5% increase from 135 to 142 kWh/m^2 – shows changes in end-uses that are quite different. Heating Fossil goes from a design figure of 75 kWh/m^2 to a recorded actual figure of 33 kWh/m^2 while Equipment and Appliance Loads go from 20 kWh/m^2 at design stage to 38.7 in actual records.

While figures 6.42 and 6.43 showed single electrical end-use values greater than the benchmark and heat consumption lower, figure 6.44 shows projects' total energy use around or under the benchmark figure. The key findings from this section are that the compensatory impacts of variations in design-to-actual relationships can create the appearance of an accurate design prediction. A 'good' design-to-actual ratio does not necessarily mean that an accurate prediction has been made. End use benchmarks derived from crowd-sourced data could highlight these discrepancies and may be able to offer insights to designers to improve design and management decisions, certainly drawing attention to the end uses that are larger than expected.

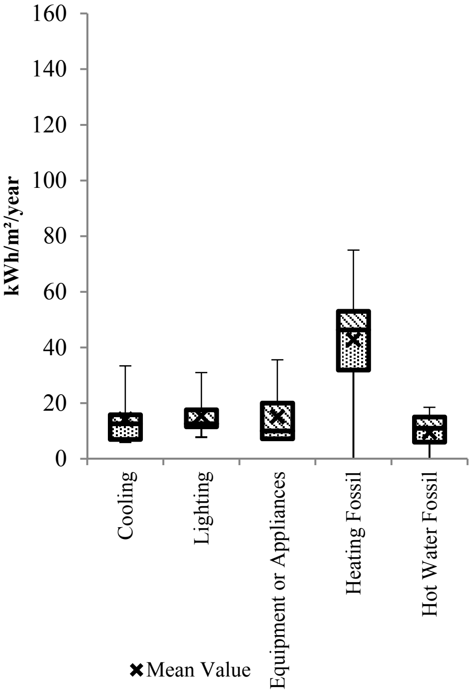


Figure 6. 45 CarbonBuzz subset E: Box plot of design end-use energy figures.

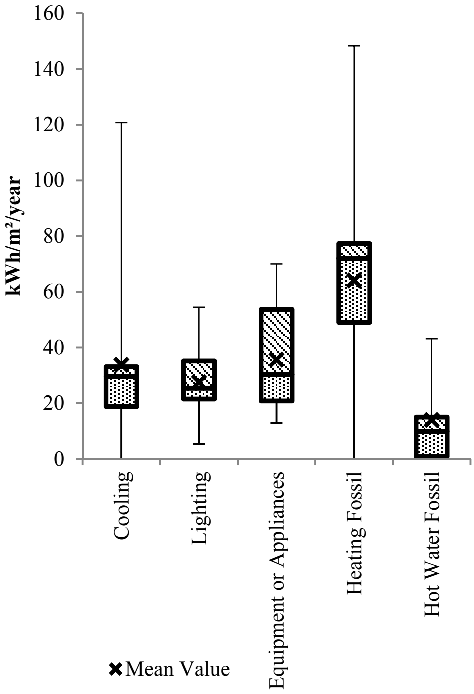


Figure 6. 46 CarbonBuzz subset E: Box plot of actual end-use energy figures.

Figures 6.45 and 6.46 show box-plots for only those end-uses represented in all eight projects. Heating Fossil represents the value with the greatest range in both design and actual despite being the focus of the regulatory framework and the National Calculation

Methodology (NCM). Although table 6.10 shows that this end use also has the lowest change from design to actual.

Energy End-Use	Design Mean Value	**Actual Mean Value (potential end-use benchmarks)**	Ratio
Cooling	14	**34**	2.4
Lighting	15	**28**	1.9
Equipment or Appliances	15	**36**	2.4
Heating Fossil	43	**64**	1.5
Hot Water Fossil	9	**14**	1.6
Total	97	**175**	1.8

Table 6. 10 CarbonBuzz Subset E: Potential end-use benchmark values.

Table 6.10 shows the mean values for energy end-uses of subset E and actual mean values as possible benchmarks. 8 projects contribute to this value. The mean energy gap is 1.8 with variance across end-uses. The potential total benchmark value is 92% of the TM46 value. The headline figures do not illustrate the underlying variance a crowd sourced platform must address this.

The potential for crowd-sourced data to generate end-use benchmarks is large; table 6.10 illustrates five end-use categories and demonstrates where the energy discrepancy is greatest and which contribute the most to total consumption. However, this section also illustrates a key weakness of a crowd-sourced platform: there are eight projects contributing to the above values, so the end-use benchmarks are based on very small subset and are therefore of questionable value. Supporting information is scant – without significant increases in energy and supporting characteristic data, crowd-sourced benchmarks effective feedback' will not be viable.

6.6.1 Diagnosis

Section 6.1 illustrated the lack of supporting data available in the 2013 database generally and the energy consumption figures illustrated throughout this chapter have shown the kind of issues that a feedback platform must be able to highlight. They offer insight into and help uncover where increase in energy consumption come from. Section 0 showed how little supporting data exists in the CarbonBuzz database. Table 6.11 shows the available supporting information for those projects with detailed energy data in Subset E.

The data available for diagnosis or understanding of where the energy increases occur in Subset E is extremely limited. The information in the database cannot be applied to diagnosis, advocacy or the design process in anything but the most basic details. This may help identify end-use increases in individual buildings; it is not helpful to those attempting to make detailed design or management decisions based on crowd-sourced data.

The exploration of benchmarks and diagnosis has shown that existing benchmarks that form part of the contextual pressures do not reflect actual building energy consumption and do not offer ambitious targets. The analysis has confirmed that the split of heat consumption data assumed in TM46 is not accurate and that an 80:20 split between heating and hot water is more accurate. The mean values showed that often single energy uses represent more than the total benchmark figures and that a feedback platform has the potential to generate new dynamic benchmarks. However, this section also highlights the dearth of supporting information in the database.

	Observation	Project 1	Project 2	Project 3	Project 4	Project 5	Project 6	Project 7	Project 8
Change	Electricity Consumption	3.7	3.2	2.2	2.5	2.2	3.4	2.3	2.5
	Heat Consumption	1.3	4.4	1.0	0.1	1.5	1.4	2.0	1.6
Compulsory Fields Inc. Sector	CompletionDate	X	X	X	X	X	X	X	X
	ProjectValue	X	X	X	X	X	X	X	X
	Location	X	X	X	X	X	X	X	X
	RegionID	X	X	X	X	X	X	X	X
	SectorID	X	X	X	X	X	X	X	X
	CategoryID	X	X	X	X	X	X	X	X
	GrossFloorArea	X	X	X	X	X	X	X	X
Occupant factors	DesignTotalPersonHours								
	ActualTotalPersonHours								
	DesignNumberOfOccupants	X		X	X				X
	ActualNumberOfOccupants	C		X	C				
	DesignOperatingHours	X		X					X
	ActualOperatingHours	C		X					
Building Factors	DesignSpecialFunctions	X							
	ActualSpecialFunctions	X							
	DesignLowCarbonTechnology				X	X			
	ActualLowCarbonTechnology				X	X			
	DesignVentilationType	X		X					
	ActualVentilationType	X		X					
	DesignNetLettableArea								
	ActualNetLettableArea								
	NetFloorArea								
	DesignNumberOfStoreys				X	X			
	ActualNumberOfStoreys				X	X			
	DesignFloorToFloorHeight								
	ActualFloorToFloorHeight								
ment F	DesignFacilityManagement								

	ActualFacilityManagement	
	DesignWaterUseTotal	
	ActualWaterUseTotal	
	Key	X = Data Available C = Data Available and change indicated between design and actual

Table 6. 11 CarbonBuzz: Supporting information in the Subset F project records.

6.7 Summary

This section has illustrated the need for a descriptive explanation of building energy performance and has investigated the potential for crowd-sourced data to provide this. The study has confirmed that current industry benchmarks and targets as defined by TM46 and the PSBP are not an accurate representation of typical total building energy consumption or individual fuel types. The ratios of heating and hot water fossil fuel consumption in the current building stock vary from the TM46 assumptions. There are mitigating circumstances for both: TM46 benchmarks are based on old data and PSBP targets are based on a new design methodology. Neither represents the current building stock, fabric standards or use patterns; the case for a contemporary benchmark based on end-use data is clear.

Headline data in CarbonBuzz does not offer the end-use insights to allow designers and managers to challenge traditional architectural and engineering solutions. One weakness of crowd-sourced platforms is that they can give a false impression of robustness of the figures displayed when actually they can illustrate only to a very limited degree where energy is used, where the energy gap exists and where designers and managers should focus their efforts to make reductions in consumption. They give the illustrative data on a few projects but cannot provide industry wide feedback. For crowd-sourced data to successfully fulfil its potential and offer meaningful alternative benchmarks and strategic design advice, significantly more data is required to provide robust figures and supporting information. A suggested data quality check is outlined in chapter 8.

The survey showed that feedback information is not generally available or collected; this is confirmed by the data in this chapter, even for users of a platform which is dedicated to promoting and sharing information. Where data is currently available, it is most often sourced in formats that do not reveal detailed insights – from bills or other headline data sources. Carbon is rarely entered into the database and while a conversion factor could be easily applied in a crowd-sourced platform, the lack of data on carbon confirms the lack of importance attributed to this metric by the survey. Building emission rates, embodied carbon and other sustainability metrics are poorly represented in the reported data. This has implication for tracking national progress in meeting carbon reduction targets

A crowd-sourced platform must exist in a context where data is habitually collected. This is beyond the remit of a platform, but the existence of a platform itself could highlight weaknesses in the contextual pressures and actors’ behaviour. The feedback information analysed in CarbonBuzz cannot be used to inform design change or management of buildings; there is simply not enough information available. The data quality in feedback systems must overcome the inherent weaknesses in users’ collection methods.

The reported data has shown that different building sectors have different energy gaps. The energy gap is different between electricity and heat consumption data and generally more consistent in electricity use than in heat consumption. This is despite – or because of - the focus on fixed building services in the contextual pressures and the lack of accounting for equipment loads creates energy values that are frequently under predicted. This chapter has shown the potential for a crowd-sourced platform to highlight this.

The disaggregated data illustrated in this chapter challenges one of the central themes of the literature review; the energy gap does not exist simply because of a lack of inclusion of end-use predictions. In all projects with detailed energy predictions, the design-to-actual energy gap was still more than two-fold. A platform can illustrate where this occurs, however it is impossible to ascribe any concrete reasons for these changes without further supporting information. The disaggregated data also shows the compensatory impacts of different variance in end uses. Design to actual increases can be higher in some end uses and lower in others, masking an overall inaccuracy in a prediction through a relatively accurate headline figure, with more data; a crowd-sourced platform can expose industry to more realistic prediction totals and breakdowns.

The CarbonBuzz data raised a number of issues about platform mechanisms generally. A key challenge is to overcome the data flittering requirements to generate statistically robust feedback information while delivering meaningful information. Outliers, duplicate records and unlikely but plausible energy consumption values complicate this. A crowd-sourced platform is reliant on actors of varying ability to provide data; it is difficult to account for the robustness of collection techniques or the subsequent information. A means of assessing data quality is required and is discussed in chapter 8.

The analysis of the data has highlighted a number of issues with the existing contextual pressures. Aspects of the pressures such as the CIBSE benchmarks do not reflect current energy consumption or design stage predicted consumption. Crowd-sourced data could be used to challenge existing aspects of the contextual pressures like the TM46 benchmarks to generate new, relevant benchmarks for industry; for example, the CarbonBuzz data shows that the TM46 heating ratio is incorrect. The focus of the contextual pressures influences different sectors and calculation methods in different ways. Feedback must be adaptable to meet these different needs.

CarbonBuzz has some very basic information missing from the database that cannot be solely due to the barriers described in the contextual pressures, there are other reasons why the data is not there. Crowd sourced platforms must play a role in demonstrating the value that this information has to overcome the disincentives.

7 What does the relationship between the contextual pressures; building energy data and actors' experience tell us about the future role of energy feedback?

Interviewees came from a range of organisation types and demonstrated a range of attitudes to energy, carbon and broader sustainability issues. Appendix 21 in the Appendices volume contains a brief description of each actor. Transcriptions are included in Appendix 22. The discussion section of this chapter is organised into a set of themes that emerged through analysis of the interview data. These are:

Aims and Targets: this section discusses how organisations set energy targets, how individual project targets are defined, where existing legislative targets fit into these aspirations and how feedback is used to help meet targets.

Decision Making: themes include the impact of project team relationships, client relationships, how decisions were justified and how design iterations were made.

Assessing implications: this section focuses on how interviewees understand their decisions through design predictions and integrating data into decision-making processes.

Informing decisions: how decisions were informed through client and design requirements and how interviewees used information to persuade clients of the robustness of their decision making.

Barriers and disincentives: one of the larger areas of discussion was the barriers and disincentives inherent in the procurement process centring on the cost of POE, the potential liability and other financial and reputational risks, how responsibility is attributed and some other factors.

Causes of poor performance: the causes of poor energy performance were discussed with interviewees, centring on the conflicting aspirations that can be found in project teams, the lack of expertise available to make decisions at the correct time and the need to improve information flow to facilitate decision making.

Incentives: potential incentive mechanisms were discussed and concentrated on the need to make POE profitable through realising the value of the work and through this, realise the reputational benefits available to those who produce low energy buildings.

Procurement: there were several issues raised with the typical procurement set-up that could influence energy consumption. These included the ownership of buildings, designs and information and the responsibilities that accompany them, who has responsibility for meeting legislation and how any changes in standards are managed.

Interviewee	Organisation/ Experience	Work	Clients	Motives	Attitude to Energy
Architect 01	7 years with a small architectural practice	*'mixed use brownfield development'*	Small scale developers and owner occupiers	Profit driven clients	Building energy consumption is not a priority
Engineer 02	Mechanical and electrical engineering manager for a large developer	Residential projects	Works for the client side of the construction process	Commercially driven organisation	A legislative and reputational point of view
Architect 03	Own small architectural practice	Mainly residential and commercial projects,	Small scale developers and businesses	*'primary focus is to create low energy buildings'*	*'Where it fits happily with their budgets'.*
Architect 04	A medium sized architectural practice	Mixed general practice	Range of private and public clients.	*'design is the prime concern'.*	Energy is '*secondary to the design'*
Architect 05	An associate at a medium sized practice	Education, housing, commercial and cultural buildings.	Mixed private and public clients.	Sustainability is at the forefront of his practices *'fundamental design'* approach	Try to develop '*sustainable ways of doing things'*
Engineer 06	Senior mechanical engineer at a large multi-disciplinary practice	Mixed general practice.	Mixed private and public clients.	Commercially driven organisation	The sustainable building physics department has an overseeing role on all projects.
Architect 07	Freelance consultant and university tutor	A range of commercial and charitable organisations	Mixed private clients	Has an interest in naturally ventilated buildings	Teaches on a sustainable building course
Architect 08	Large private architectural firm	Education, healthcare, cultural and residential.	Mixed private and public clients.	Commercially driven organisation	Practices ethos is to *'go above and beyond, not just meet the code'*
Contractor 09	Architect by training, works for a large multinational contractor as a 'Design Manger'.	Education and residential projects.	Mixed private and public clients.	Commercially driven	Sustainability is that it is something that needs to be done to remain commercially competitive
Developer 10	'Sustainable Development Executive' for a high profile commercial developer	Retail and commercial projects.	Financial institutions.	Commercially driven organisation	Job is to *'look after environmental and ethical issues on their construction and major refurbishment programme'*
Building Performance Consultant 11	Local authority energy manager and building performance advisor	School procurement and post occupancy evaluation	A range of local authority clients	Self employed and so his and his organisation's views on energy the same	Aim to design and manage buildings for optimal energy performance.
Local Authority Policy Maker 12	Inner city local authority.	Develops policy for all building types.	Work is used by developers and designers.	To reduce borough wide energy consumption, carbon emissions and fuel poverty.	Energy is central to activity.
Central Government Policy Maker 13	Develops departmental policy in line with central government policy	Work to inform the activity of her own organisation and their Education buildings	Work is used by government department developers and designers.	Ensuring that her department met a series of sustainability key performance indicators.	Energy and sustainability is central to activity.
Manufacturer 14	Technical director in charge of research, development and production of natural ventilation and day lighting equipment	Develop products that are low energy and market them as such in what they see as a very competitive market place.	Designers, developers, building owners.	Commercially driven organisation.	*'leads from the front of the industry and are very considerate on our energy consumption'.*
Local Authority Energy	Energy conservation officer for an	Runs the monitoring and targeting	Own organisation.	Carries out energy audits in order to implement measures	Falls under central government energy reduction targets.

Officer 15	inner city local authority (LA).	programme for the LA's own building stock.		to reduce energy consumption.	
Sustainability Consultant 16	A multinational engineering company.	Work with project teams who are designing new buildings.	Internal project teams.	Commercially driven organisation.	Job is to support decisions to help buildings use less energy, water and materials.
Engineer 17	Operations manager with own consultancy	Works on *'whatever comes my way'*.	Range of private clients	Self employed so his and organisation's views on energy are the same	Focus is on energy conservation
Facilities Manager – Developer 18	High profile commercial developer	Office and retail buildings.	Organisation is the client side of the procurement process.	The organisation is unapologetically commercial	Responsible for energy reduction and sustainability across the organisations existing portfolio.
Facilities Manager – Local Authority 19.	For a large Local Authority in the south east of the UK.	Local authority portfolio of buildings.	Works impacts on own organisation.	Energy and cost reduction at a strategic level.	Energy is linked to cost reductions and CRC commitments.
Architect 20	A small architectural practice.	Education and residential projects.	A range of private and public clients.	Focus is very much on architectural design;	Environmental and energy concerns are low in their priorities.
Central Government – Consultant 21	A building services engineer, works at central government funding agency	Education buildings.	Own organisation.	Work specifically focussed on reducing energy consumption and costs.	Energy is central to activity.
Energy Consultant 22	A small energy consultant company.	Retail and industrial buildings.	Large retail organisations and industrial companies.	Commercially driven organisation.	Purpose of role is to reduce Client's energy consumption.
Surveyor 23	Commercial director for one of the largest construction companies in the UK now has own consultancy	A range of building and infrastructure types.	A range of commercial clients.	Commercial organisation dealing with commercial management issues and claims – settling contractual disputes.	Energy treated as any other contractual issue.

Table 7. 1 Characterisation of interviewees.

7.1 Aims and Targets

The survey data in chapter 6 showed the importance of mandate for actors' target setting. Those with an interest in energy were more likely to go beyond this and engage with feedback data collection. With this as a starting point, this section looks at interviewees methods of setting targets. Interviewees had two methods of setting energy performance targets; those with an organisation-wide policy for energy targets on every project and those who set energy targets that are project-specific and made on a job-by-job basis.

Organisation Targets

Those actors employed by organisations that have an overarching target for all projects use a variety of sources as the basis of this target. Targets can come directly from the formal framework of contextual pressures such as CRCs, or can be self-imposed reduction targets defined by the organisations themselves or by outside agencies. These are often influenced by the informal framework. For example Local Authority Energy Officer 15's organisation was working to a self-imposed energy reduction target that was defined by an external environmental group:

> *"We used…to have a 15% target…and we were supposed to have a 40% target by 2020… it was Friends of the Earth or someone's initiative that we signed up to and a lot of councils signed up to a 40% target but, [in] the current economic climate appears to have dropped off most people's radar."*

These kinds of targets, developed by organisations not identified by the formal contextual pressures could be considered social pressures and part of the informal network (despite being formalised). In contrast, Facilities Manager – Local Authority 19's organisation was driven by and forced to look for innovative solutions by the financial penalty represented by his organisation's Carbon Reduction Commitment:

> *"we have got this thing called CRC that each year is going to come and bite us on the bum…because it is going up each year and it could be significant amounts… so we look at alternative sustainable green energy scenarios."*

This direct application of part of the formal framework is a straightforward example of the contextual pressures operating as they are intended. In some instances the motivation of the personnel who happen to be working on a project at the key stage has the greatest influence on determining what kind of environmental aims are set. Architect 05 described a rather haphazard approach to creating an environmental policy at his practice that depended on the individuals involved:

> *"it's more; if the Director and Project Architect have a keener interest in it [low energy design] it will probably be more prevalent in that project…than in another."*

When a particular environmental attitude is taken to a project, he went on to say that it is less about a particular legislative or numerical target (the compulsory targets have to be met whatever they do) and more about the kind of innovative solution that might be used to reduce energy consumption and improve a building more generally. He said that the question asked of a project might be:

> *"'what is the potential for natural ventilation to this building?' or 'what are the opportunities to increase natural lighting?'"*.

This describes a potential future use of feedback, not necessarily picked up in the contextual pressures; where no particular energy target exists other than a general desire to reduce consumption. There is a role for energy-focussed exploratory analysis to support ambitious actors in the identification and development of innovative design solutions. In contrast, where there is no particular drive to achieve a low energy building, or at least other priorities overtake the ambition of the interviewee, energy legislation and energy targets can become an inconvenient box to tick. For example Architect 20 describes coming to a compromise on an energy target with a Local Authority:

> *"we also did a deal with the local authority building control department to, basically, we snuck it [the project] in to get into Part L 2006 regs…by getting it in before a certain deadline in October 2008."*

This treatment of the mandatory components of the formal contextual pressures as something to be negotiated and avoided rather than an incentive to take action is countered by some interviewees. The parallel interplay between national targets and legislation and an organisation's goals can to offer some reassurance to interviewees. Engineer 06 said:

> *"We recognise the fact that obviously the current legislation is moving that way but the company itself has a drive…to promote sustainability and be as sustainable as it can in everything it does. We have a corporate sustainability department… that oversees our company sustainability but also advises on… large scale sustainability items like public consultation on new planning requirements…ecological things like that, whereas we in sustainable building physics are very much focussed on the sustainability of the building."*

The boundary between 'formal and 'informal' pressures is blurred – the formal pressures create a general and informal pressure on activity. The interplay between the contextual pressures and corporate targets can also be manifest as an adoption of national standards as a corporate goal. A recognised benchmark helps actors compete. Developer 10 also talked about the need to meet mandatory aspects of the contextual pressures whilst acknowledging the limitations of the targets to other aspects of her company's work. She talked about their desire to reduce total energy consumption (i.e. beyond regulation) while 'proving' this with existing certification schemes:

> *"[we] have corporate energy targets in our …existing portfolio properties, in our new builds we go for BREEAM 'Excellent' for offices and BREEAM 'Very Good' for retail and that drives us to the minimum standards within BREEAM to meet regulated energy use. So BREEAM excellent, it is an EPC rating that we have to meet…that goes back to some sort of EPC related formula of calculating it going forward but… it's regulated energy that BREEAM is interested in which is a smaller subset of total energy use."*

The acknowledgement of the weaknesses inherent in the EPC rating and BREEAM energy targets does not mean they are without merit, rather, it means that organisations with a desire to go beyond these targets must run a parallel assessment system. The issue of the disparity between some organisations' targets and general targets stipulated by the contextual pressures is reflected in the different motives of actors. Some were therefore described as the product of a more complex set of drivers. Facilities Manager – Developer 18 talked through the energy target drivers that his organisation is responding to, beginning with acting with integrity:

> *"We want to do the right thing in everything that…we do through our CR [Corporate Responsibility] strategy but…one of our core values is we want to be, we want to do things with integrity"*

While his organisation and he personally want to act with integrity and *'do the right thing'* they are a commercial organisation; there is a dual driver, they can see the potential market benefits in offering low energy buildings to potential clients:

> *"I suppose the other key thing… we've got investors and occupiers, customers, also saying well you know this is also important for us …resulting in minimum standards being set by occupiers which is driving landlords now to be greening their buildings … I think that is where we really need to focus."*

In order to take advantage of the potential market available in this area he, like Engineer 06, spoke of the importance of the role that broader national targets play in creating an informal setting for his organisation's operations:

> *"…I think that there are legislative and government drivers…the government has made climate change targets public and legally binding… so there is the Carbon Reduction Commitment and the minimum energy performance standards and all these sorts of things; basically government has flagged clearly that they see that this is important…"*

Facilities Manager – Developer 18 raises an important point about how a number of interviewees felt about attempting to act with integrity and respond to customer need. The fact that central government is mandating energy and carbon targets means that he and his organisation feel some security in investing in measures to achieve this. Without the knowledge that others are obliged to take similar action, it is questionable as to whether he would be doing this at all, despite wishing to do the right thing. As the commercial benefits to low energy building become clearer, this will filter into development briefing. The informal pressures created by the formal framework are effective.

Interviewee discussion around their organisations' institutional targets provides some insight into how the contextual pressures might influence thinking on energy targets. Other social pressures can interact with formalised targets; the use of targets from outside the industry contextual pressures can help organisations go beyond their obligations. Individual actors with motivation and ambition to drive an agenda within the procurement – or any - team is effective and sometimes a necessary part of low-energy design. The financial penalties represented by CRCs are a motivator for Facilities Managers and actors with direct influence over energy consumption and a responsibility for running costs. However, the existing contextual pressures do not necessarily mean minimum standards have been met; there is some room for negotiation.

The parallel between the contextual pressures and corporate goals can offer reassurance to organisations to go beyond the minimum standards. Where organisations do go beyond these standards they often run a parallel system in order to prove compliance to the broader industry and meet their own targets. There are commercial benefits underpinning energy efficiency in the commercial sector that need to be more effectively exploited.

Project Targets

A number of interviewees said that while their organisation has targets, they indicated that project targets are often driven by their clients' wishes. For example Surveyor 023 suggested that more enlightened Clients should be able to amend their building contracts to insert whatever standard they would like met on a given project:

> *"if your contract is set up correctly to start with and we have a set of standards, and say the standards are not delivering what you want for whatever reason...particularly with a design and build contract...I see no reason why you can't put in the performance standards that you want."*

However this approach relies on a proactive client. Where clients are not interested in energy, it is difficult to persuade them to be otherwise. Architect 01 finds that her client base is in this camp:

> *"[Energy is] not a priority, the approach is, well most of our Clients want everything done on a small budget – an impossibly small budget - and they are not interested really in anything other than making a profit or possibly making it look slightly okay; they are not really interested in energy concerns at all."*

Where actors' clients do want to engage with energy, it is not always possible to communicate clearly. The abstract nature of the notion of energy and particular of carbon makes the communication of targets easier in financial terms. Architect 03 described the difficulty of communicating an energy target versus the universality of a metric like costs:

> *"I think it's quite difficult… it's even difficult for people to get their head around kilowatt hours…Obviously cost is one thing because people can relate to pounds but then it's always marrying it up with understanding how comfortable they are going to be because…you can have no energy bills and be bloody freezing."*

The abstract nature of energy consumption as a metric with its relationship to costs and user comfort was raised by a number of interviewees. Engineer 17 sets out an example of the conflicting aspirations that can exist within the building design process where energy targets can often take less of a priority than other, more basic briefing targets:

> *"So the client…let's use a school. Your client is your teacher, you're headmaster, the local authority and they want that school to be fit to deliver … education. You get a good architect and he designs a building that has all of the right shaped spaces, they orientate properly, they talk to their structural engineer and their services people and they tweak it and they fine tune it and you get the best out of that building you can after it's delivered the education. Because it doesn't matter how energy efficient it is, if it doesn't deliver education it's failed."*

As the literature review demonstrated, energy consumption is dependent on many interlinked aspects of a building. Synthesising a solution that combines the complexity of the various pressures in a brief and results in an energy efficient building is a challenge. Making a client aware of the options available and the implications for a particular project is a process that all designers discussed. Engineer 06 talked about client discussions being based on the costs of particular solutions and of meeting legislation, and where possible the potential costs of going beyond the legislation:

> *"when we come up with the designs we will always try and give them the minimum they need and then as a bolt on we will say 'but if you do this, you can realise this saving, you can realise this efficiency, you know you can consider this that and the other and that would get you even further along'. I just try and make them aware that there are options out there. Where possible we give them a budget cost and that could be based on a number of things whether that's a schedule of rates or we go to specialists and ask for quotes or what have you. Then we'll just say, these figures need to be verified but this is possible."*

Engineer 06 raises an important point central to this thesis: in trying to persuade a client that a low energy building is possible, without defendable assurance or evidence that it is affordable or will actually deliver the predicted savings, how can consultants drive forward the low-energy agenda?

The discussions around how actors establish project targets established a few main themes. The information needed to communicate the implications of energy consumption to sometimes reluctant clients requires a flexibility in the metrics used and feedback has key role in doing this: helping support decisions, predictions and providing a solid evidence base for consultants' relations with their client base.

Importantly, the complexity of buildings and project briefs means that energy is just one aspect of a much wider set of project requirements and pressures. Some of the most important of these are the costs of energy consumption and capital expenditure; these are also often the most readily understood metrics.

Finally, target setting, predictions and communication of information are often issued with caveat by consultants as they do not have the ability to guarantee performance and are concerned over the implications of giving 'bad' advice.

Legislative targets

Legislative targets were identified in the survey as the most often used means of establishing project energy targets. However, some interviewees showed some resentment with how the legislation is framed to target individual actors; Engineer 02 bemoaned what he perceived to be the onus placed on house builders to reduce the energy consumption and carbon emissions associated with the UK. He said:

> *"We are house builders, we are not utility companies, we do not supply energy ...me sitting here and saying we use cost as a driver, well no shame on us because we use a fraction of the energy that utility companies waste…so why beat us with a big stick over a tiny bit of energy you know."*

Some interviewees had the impression that the contextual pressures impact disproportionately on different construction sectors. However, designers with ambition to deliver low-energy buildings felt that they were a useful tool; building regulations and often more stringent targets set by a planning permission dependent on a commitment to a BREEAM standard meant that they had some leverage over their clients; they were forced to engage with energy. Architect 05 said:

> *"to some extent BREEAM is helping architects achieve, what you'd like to achieve anyway…because someone's setting you these high targets…of set*

> *BREEAM or LEED ratings, you've got that in your pocket to kind of say well, 'we need to do this.'"*

In this way formal targets have a dual role; ensuring that all buildings meet a minimum standard and that the construction sector as a whole contributes to carbon reductions by creating an informal pressure. They also help those with more ambitious targets to persuade clients to invest in better buildings. This clearly has implication for the future use of feedback; a less aggressive relationship may be possible through persuasive information rather than forced action.

The targets themselves were questioned by some. Where statutory policy targets are developed, there is concern that they are not reflective of the reality of finished buildings and are perhaps exacerbating the energy gap. Local Authority Policy Maker 12 raised this issue:

> *"I have become more interested in… this potential to kind of close this feedback loop having become aware of all this evidence about this big performance gap… and so I'm starting to think well actually even if our policies are extremely effective at getting all these modelled schemes 'Yes you've hit your targets, this is going to be a brilliant sustainable building and everything else' if actually the reality is something totally different then that's a big problem…"*

Feedback has a further role to show policy makers what is a workable policy, where the policy failures are and how it must be targeted in the future. The resentment showed by some interviewees at the focus of the contextual pressures was reiterated by some policy makers who were beginning to identify a need for a change of focus from carbon to the less abstract notion of energy. Central government Policy Maker 13 echoed the sentiment of some designers that carbon is not an appropriate metric:

> *"the drive for a carbon target was actually a complete distraction from energy…you know building regs are energy efficiency but not energy management or energy reduction or building physics".*

This reflects the discrepancy in the importance of carbon and energy identified by the survey. It suggests that a role of feedback is to clarify issues regardless of legislative drive and to overcome the opacity of the contextual pressures. A feedback platform can easily accommodate a multiplier to create a range of metrics appropriate to actors and their colleagues and clients.

The current legislative component of the contextual pressures is looked upon in a number of ways by the interviewees. It is resented by some, particularly those with a direct financial interest in capital and running expenditure. Others, often not those with a direct financial interest in capital or operational expenditure, felt that the contextual pressures could also be used to persuade clients to go beyond mandate.

Those writing policy are aware of the complexity of energy targets and are trying to refocus legislation onto more relevant or easily understood metrics. Despite this drive, where the legislative framework creates opacity and confusion, there is a role for feedback to overcome this and provide a clear picture of where building energy is used and therefore where designers and policy makers need to focus.

7.2 Decision Making

Looking at the decisions made in different organisations is complex as they are made in the context of many different pressures and motivations. One of the overriding aspects of decision making and its justification to come from the interview data is that 'good decisions need good information'. The flow of information is affected by the contextual pressures both directly and indirectly.

Project team relationships

The importance of project team relationships in making decisions and procuring buildings was raised by the majority of the interviewees. Architect 04 raised the relationship between the quality of the relationship with the rest of the project team and the ease of communicating information in a typical set-up where energy is not necessarily a high priority:

> *"If it's a good relationship and then we will just try and contact them to provide us with the data. So it's our initiative, it's not something they come and bring to us. We have to call them and see whether it is possible."*

This reinforces the idea that motivated individuals are required to raise energy up the project agenda of design work. A future role of feedback is clearly to overcome bad relationships or to help those teams with poor communication to exchange information more easily. Engineer 17 expanded the definition of a good relationship to that of trust in fellow consultants. He used the specific example of working with an unfamiliar project team on each new project:

> *"…we developed a relationship with the project managers and the architect, [where] it was quicker to pick up the phone than it was to write a letter so we had to get to the point where individuals trusted each other to answer those questions...if you are forming a relationship with every project with a new team… you don't build the relations; you don't build the common core understanding and you don't build the trust in each other, if you don't have*

> *those things then the communication is always gonna be fraught because there is always 'will they stitch me up?', 'will they do what they say?' 'Will they deliver?'' Can they deliver?' "*

The inherent suspicion of other actors and the need for reassurance is a reflection of the contractual relationships in the construction industry. This fear and lack of trust was raised by most interviewees. A future role of feedback therefore could be to provide not just information on building performance but a consultant track record. The importance of relationships was not only raised in building design and procurement but also in facilities management. Facilities Manager – Developer 18 spoke about the importance of developing long-term relationships and trust in order to create an environment where innovative ideas can be developed. He raised the importance of developing the relationship with tenants and tenant facilities managers in order to properly communicate specific information and reduce energy consumption:

> *"we basically had to give, we had to explain how the costs would be apportioned and allocated within a building, how we would seek to recover the investment costs. We had to give them comfort that it wasn't in any way going to impact on the operation and it wasn't going to create any disruption…and I suppose the other thing is that in most cases …we had had environmental working groups in place for two years or so, so I had working relationships with these people already."*

These relationships were built on the need for trust in order to build a convincing case for energy improvements, combining many aspects of the role of feedback: apportioning costs and responsibility, understanding energy consumption, and creating value. Similarly Energy Consultant 22 commented on the importance of a good relationship within project teams to ensure that the necessary information flowed between the relevant parties. Raising the importance of having the correct people in the project team, she said that she needs to be very specific in requesting the necessary expertise when assessing a project:

> *"we are going to go and see this store, in this order and [in order to do our job properly] we are going to need all of these people with us and those people normally are the controls guys…so the BMS controls guys, an electrician and sometimes a mechanical specialist as well because they have got more knowledge of the estate and of their specific building services areas…than we do as consultants."*

Cross-disciplinary teams like the one described above are dependent on the clarity and communicability of information. Many interviewees highlighted the positive impact that good relationships can have on a project, particularly in the context of atomised procurement routes and competitive tendering for services. However, interviewees often also raised negative project team relationships when talking about the process of making decisions and the impact this process can have on energy consumption and the quality of buildings generally. Architect 01 described the strains that a poor relationship in a design team put on other project relationships because of the serial changes she has had to make to a building due to the slow response time of the project energy consultant:

> *"…we have got a rather unhelpful energy consultant, it's a builder we are working for and he is a reasonable guy and I have explained the difficulties I am having so he hasn't objected to me doing that [making multiple design changes] but nonetheless it's not a very good way of working."*

The impact that one relationship can have on others is relevant when actors are reliant on good information flow. Architect 07 raised the influence that the potential of liability can have on project relationships, particularly where innovative or unconventional design solutions are being developed. The perception is that such designs could more easily go wrong; she talked of the need to create a scenario where:

> *"everyone will supposedly pull together instead of covering their backsides which is what we do now, so something goes wrong, well, not me! Not me! And your insurance company won't let you do more than just keep your mouth shut. So whether you can foster an atmosphere of people all pulling together to get a building the best; I mean we have done that to some extent at [Firm Name] by using contractors design as part of the contract for small stuff but you can use it for big stuff, where at least it is one person and all the specialists answer to the top guy…but at least the liabilities are there with one person."*

Architect 17 raises two important factors that ran through a lot of conversations and seem to influence not only project relationships but all aspects of construction industry practice: procurement and contractual relationships and the perceived risk of liability in industry. The contextual pressures define external influences but do not look at internal project team pressures. Surveyor 023 raised the importance of establishing good project team relationships throughout the procurement process and described the constant review of these relationships and the contracts that define them:

> *"we always fed back information to our procurement guys to improve how we procured new things and as to how we set up our contracts, we continually changed our contracts and how they were set-up, what*

> *information they included, what information they didn't include within them on the basis of having what I will call good contracts where you didn't get into claims if at all possible…everything that went wrong if it was demonstrated to be a procurement issue in some way…that was always followed through as to how to do things in the future."*

Project team relationships are important to the development and design of buildings in many ways. The need for motivated individuals to drive the agenda within a team is clear from the interviewees; however they need to establishment trust across the team to ensure that a project can run smoothly and that objectives are met. The relationship between project team members can also have an impact on the development of innovative thinking in a project. Poor relationships can result in inefficient working practices and lower the quality of finished buildings.

The relationships between what can be very different professionals in multidisciplinary teams needs to be managed well, with good communication lines along common values. Contractual set-ups can establish the basis of these relationships but transparency and trust are the most important factors. A move from the current litigious culture of industry is required; this means a rethinking of intra-project team relationships. Feedback has a role to provide evidence not just of building performance but to communicate consultant track records and prove innovative design ideas.

Client relationships

Relationships within the project team are important to actors' decision-making and their relationships with their clients are also central to the creation of good buildings. Many interviewees spoke of this relationship and how it ensures that they have repeat business. This often results in establishing an informal feedback loop in place. Architect 08 said that:

> *"…we do try to maintain that relationship with our Clients. We have oftentimes a lot of repeat jobs from Clients who are satisfied with our initial designs for a former project and they definitely like to nurture that process and build a strong relationship with a client."*

A strong relationship with a client is needed; feedback has a role to prolong and strengthen actor/client relationships. Many design consultants, in the spirit of keeping clients happy and the prospects of further work alive, talked about the ongoing relationship they have with their clients. Architect 01 said:

> *"you know if we have got a Client and a few years down the line they have a problem we will go back. So it's not like we don't offer any sort of help afterwards."*

Architect 20 reinforces the idea of maintaining contact with a client to maintain a good relationship, to ensure future work and to learn from previous work:

> *"he's one of our best clients, we don't say 'no' to him, we keep in very close contact and we get a lot feedback from him and from the [building users] and that definitely feeds into what we do next."*

Using casual feedback to keep repeat clients happy is part of ongoing professional relationships. The informal nature of the feedback could be part of the strength. The use of more formalised reporting methods could help communicate a broader range of information and result in service improvements beyond the existing scope of actor-client conversations but could equally damage what maybe a delicate relationship. However, when probed on the type of POE information and feedback that he was able to get from his client, and how it related to energy, Architect 20 was less precise:

> *"in terms of looking at the bills and figuring out exactly how much, what the difference is, I don't think we will be looking at that stuff…[we got feedback like] 'it's much warmer in here' 'isn't this nice', 'how lovely and comfortable it is.'"*

This is an important point in the client-consultant relationship: there is often an existing feedback loop based on casual communication channels such as phone calls and conversations used to convey anecdotal but extremely useful information. This information is not often formalised and therefore is not used beyond the most limited scope.

Others talked about this feedback loop only coming into use when a client had a complaint to make about a building, but most interviewees acknowledged the existence of this method of conveying information. Facilities Manger – Developer 18, as a client procuring design services and as a landlord 'employed' by tenants, is in a uniquely central position. He is able to comment on information flow from landlord to building management and from client to designers:

> *"there was no emphasis, direction from the landlord to building management that managing buildings efficiently was important, so building [design] engineers ignored the implication, the cost implication particularly in building and they just focussed on comfort."*

The implication of the above is that if something is not regarded as important during the operation of a building, then it will not be regarded as important enough to be included in the design brief for a new building. Feedback could help formalise and identify these issues at an early stage. Developer 10 also raised the issue of communicating with tenant occupiers in a neutral manner, without the appearance of a conflict of interest, as important to the delivery of low-energy building management:

> *"We have quarterly working group meetings where we get all the occupiers in the same building around a table with someone from [R's company] who is not the person the deal with in leasing negotiations with. "*

This point of view raises the relationship between energy efficiency and profitability, and the need for information to be uncluttered by other information. The relationship between energy efficiency and profitability will be explored in more detail in later sections. Even with good communication, the uptake of energy-saving measures was based on a complete reassurance backed by the removal of financial risk.

The main findings of this section are that good relationships are essential to the communication of information in design and construction. Repeat business requires a good working relationship between actors and clients and this often includes a casual feedback loop. Casual feedback loops are used to communicate a lot of generally qualitative data about finished projects. Where clients are the primary actors, they find that providing strong direction to design teams is necessary to get a building with the focus that they want. Whilst trust and communication are essential for good client relationships, a financial motivation is also sometimes required to implement change.

Justifying decisions

The dynamics of sending information around a team to gain consensus on a decision is important. Architect 08 described the project team communication essential to setting up an efficient energy model on which to base decisions:

> *".. we usually sit at a table with the architect the sustainability consultant and the mechanical engineer and we strategise how to set up the energy model and we coordinate what information needs to be shared ... to develop an energy model whose inputs are accurate for the specific building design."*

It is important to develop information requirements at an early stage to help the whole team do their jobs. However, the accuracy of the inputs is only measurable relative to the model being used and the output required. If the project team is only looking to comply with Part L then the model only has to fit with those limitations. For example, some interviewees talked about the use of assessment methods as exploratory mechanisms for identifying optimum performance. Engineer 07 described one such process of using SBEM as a compliance tool:

> *"we found tightening up the fabric actually had very little effect on the overall performance of the building whereas when we trimmed down the lighting loads, that had a massive effect on the building".*

In other uses, Architect 05 described using energy software in a 'value engineering' meeting (where potential savings are identified). SBEM was used as an exploratory tool to identify how to comply with building regulations with the minimum possible cost to his client. He said:

> *"SBEM was then flipped on its head and used as a method to see what you could not do but still pass".*

SBEM is not a design or costing tool and using it as such changes the focus of the output from carbon and energy to costs. This could have implications for the accuracy of energy predictions and the systems designed as a result. That parameters other than energy are important in the design process comes up repeatedly. The use of energy compliance software to meet cost requirements is one example of the misuse of the contextual pressures. Architect 01 talked of coming to a rapid conclusion about the limited possibilities of using particular technological solutions on her projects to reduce energy requirements:

> *"the sorts of building that we work on have often got limited possibilities so, I think, they're generally quite awkward…there's certainly very limited opportunities for say ground source heat pumps in existing buildings in the middle of the city and the roofs…are so intensively developed that often the roof spaces are amenity space."*

Assumptions made about the suitability of low-energy technological solutions that are used to dismiss the possibility of their implementation, in a practice that admits that it does not consider this as important in the first place, suggest a need to access information that can quickly debunk any myths surrounding what is or is not possible. In contrast Engineer 02 (who works for a developer) takes a calculated look at the most cost-effective way of achieving energy targets in legislative compliance:

> *"we quickly look at the respective costs of various technologies and again …when you look at the price per kilogram of carbon dioxide equivalent that you knock out of your scheme per pound, there are couple of these things that are options that we originally laid out on the table that are a country mile in terms of cost ahead of the rest."*

The contrast between these approaches, using a rule of thumb or a simple cost analysis, shows a need for a more complex feedback mechanism that can give insight into the interlinked impacts of decisions.

The way that interviewees justify decisions about energy-related design and management aspects varies. There is a need for clear project-wide assumptions in energy models to ensure that everybody is working to the same standards. The fact that different calculation methods may have different impacts on the energy figures is recognised. This has been shown in chapter 7 and reinforced by some interviewee comments. Using compliance calculation tools as design or cost support tools may alter the way buildings work and impact on the energy consumption. However, there is clearly a requirement for quick and robust means of narrowing down options. Currently assumptions are made based on site specifics, or rough calculations based on cost and convenience. Feedback could provide more robust means of assessing the options.

Design Iterations

When decisions need to be revised following assessment of preliminary models, the iterative process varies. The division of labour in the project team means that the project relationships described earlier become crucial when the design is being developed and the communication of information becomes an important factor, particularly where engineers are being relied on to produce accurate documentation for the overall project. Architect 04, who works for a practice where the architectural design of a building is the most important factor in their work, but has a personal interest in low-energy design, talks of her reliance on engineers in the design process and her frustration with their inability to offer more constructive solutions:

> *"To get numbers [on energy consumption or compliance] we send it off…Sending it off and getting it back, but a lot of dialogues, so not only 'these are the numbers' but also 'where do the numbers come from' and 'how can we [improve them]'…It's always a big gap in communication with that… I think it is also a big part of why it is secondary in the design process because it so much numbers-driven…: and putting it into sheets that it becomes quite distanced from the design process…and…not really understanding what would really, what would be the alternative options or how to be more creative with solutions."*

Architect 04, in making a point about communication, introduces the issue of the disparity in expertise across the design team, which can also be problematic. For example, where the architect does have the expertise, there is still a requirement for a 'qualified' practitioner to carry out the compliance calculation. Architect 03, who is herself an expert in low-energy building design, still needs to rely on others to carry out compliance calculations.

She describes the use of an engineer to validate Part L calculations following her own PassivHaus Planning Package (PHPP) design calculations:

> *"they actually come up with slightly different U-Values, because the PHPP is slightly more in depth in that it allows you to put in cold bridging specifically...but once you have got those in you can start fiddling around and then once you got kind of your main data in you can then start playing around with your U-Values and it very quickly gives you an indication of your energy consumption at the end."*

Architect 03 describes a situation where the main drive for energy efficiency in a project does not come from the person with responsibility for the compliance calculations. This variance in aspiration within the project team has been discussed in chapter 6. Architect 20 uses an example of a decision made on an assumption, using his own judgement to shortcut a potentially time-consuming calculation and justification process:

> *"we had our service engineers demonstrated the difference in energy efficiency… I don't know how accurately it was done it was so obvious…It just didn't really need demonstrating."*

This seems a cavalier approach to an investment decision on behalf of a client and one that could lead to some form of litigation, but again those making the decisions and those with responsibility are different people. A role of a feedback platform could be to quickly challenge and confirm design options. Engineer 06 describes a more technical process, looking at the systems in place in the building following an initial sketch design and the subsequent communication that takes place between the sustainability unit that he works within and the project engineers in his organisation:

> *"we will run a preliminary model jut to get a feel for what the building's doing and what it's not doing and how it's performing, we will then discuss that with the M and E engineers, who will then go away and they will come with lighting schemes, heating and cooling schemes, taking on board any advice we've got for renewable systems."*

Developing and assessing options at an early stage and communicating the findings is key to a successful design process. Architect 08 described the process tracking the iterative process throughout the procurement of a building:

> *"for HVAC and electrical, again like the description of the system accompanying the drawings we kind of usher that to the sustainability consultant who plugs it into their energy model…they come to us with a report that describes all of the inputs that they had made and any*

> *assumptions that they had to make...We kind of mediate between the mechanical engineer and the sustainability consultant and…sometime there's a few revisions that need to be made to that report until we are satisfied with the accuracy of what we get. That happens during design development and again during construction documentation just to make sure any changes to the project were properly recorded or included or incorporated into the report."*

This communication process means that the iterative process can be disruptive to the main motivations of architects; information coming back could impact on other aspects of a design. The potential for changes to occur between 'design' stage (planning) and 'construction' stage means that recording change is important. For this reason Building Performance Consultant 11 talked about the benefit of spending time on the iterative process and refining the design prior to commencing building work:

> *"We spent a long time getting the basic design right. We built two [buildings] and went over them with a fine tooth comb before we handed the plans over to the constructors. Then we reviewed everything with the clients, finalised detail items and locked-down the design. Then we built another 25…With no changes, we did not need our own internal staff dealing with variations…We didn't have any cost variations, we didn't have any claims for additional time."*

The idea of constructing all buildings with no changes is perhaps unrealistic but Building Performance Consultant 11 does raise the contractual importance of accounting for changes. The main themes to come from discussion about design iterations centred on the need for good communication; the need to ensure that the project team is aiming towards the same goals, coordinating data so that information is current and relevant. The atomisation of the design team can make this difficult: architects do not necessarily get the support they require and conversely, engineers do not get the information they need. Taking or attributing responsibility for decisions needs to happen with greater clarity; for example sometimes the person with the drive to engage with energy is not the person with the responsibility for compliance calculations. Sometimes responsibility for decision lies with those without the expertise. The speed of information exchange can help the decision-making and procurement process. A feedback platform could assist with the quick justification of early design decisions.

7.3 Assessing implications for meeting your energy target

When progressing through the design process using modelled iterations to help meet design targets, understanding how these iterations influence the overall energy consumption of a project is essential.

Making Predictions

As has been shown, the under-prediction of energy consumption is the source of the energy gap. The process of making and calculating a prediction is therefore crucial to the development of a project and understanding how it might work. Some actors are entirely reliant on other members of the design team to test the implications of their decisions. Architect 05 for example says:

> *"SBEM has got massively more complicated in 2010 so we steer pretty well clear of it to be honest. We give the engineer all the information they ask for; wall build ups…"*

Architects forced disengagement from the assessment process is a concern because, as the contextual pressures show, they have a key influence in the design process and they are the actors responsible for a large proportion of decisions that affect energy consumption. Architect 08 recognises the risks associated with relying on others to produce predictions and in particular the impacts this can have on energy consumption. He identifies not only the lack of expertise but the timing of when it is available:

> *"one of the challenges that I feel that we face in our office is that we often bring in these sustainability consultants to the table a little bit too late, they are loosely part of the discussion in the concept phases of development but don't provide these types of service where they are getting very involved as a team player in the beginning phases just to provide feedback and comments on how to either improve on or make changes to ...some of the concept design in order to push it to a higher performance from the beginning."*

Again, the internal contextual pressures – the project team set-up – are a strong influence. Perhaps, earlier involvement of relevant consultants could overcome some of the weaknesses in the system of modelling energy consumption and in actors' expertise. A role of feedback is to provide the steer at an earlier stage in the process.

As described in the account of the contextual pressures, the standard calculation and assessment methods often do not take into account all of the energy end-uses or use factors that can influence final energy consumption. The weakness of compliance calculations is explicitly acknowledged by Developer 10 when she talks of the assumptions that she is required to make:

> *"you do have to do predictions but a lot of those are based on a very theoretical assumption of how the building is going to be operated. So there is going to be very few cellular offices, mostly open plan [at] a density of one person per 10 metres squared operated from 9 to 5 … everybody has a computer at their desk….that's actually not the way most of buildings are fitted out."*

The lack of expert input and actors knowing that the calculation is wrong is a symptom of the discrepancy that can exist between design assumptions that are based on very rigid compliance calculations and the actual use of buildings. This is acknowledged by Engineer 06; he talked of the difficulty in creating a credible energy prediction for his clients using modelling software without having the certainty of how the building will ultimately be used. Instead he relies on modelling. He refers to a particular project for a public sector client:

> *"Usage patterns: that's the big tricky one because obviously in [modelling software]you can input occupancy profiles and switch things on and off… we were quite fortunate in that we were able to get hold of a training programme for the year…so we could see which areas of the building were being used on which days and from that we managed to build up quite a detailed occupancy profile to say, well look, most of these rooms aren't going to be on for quite a lot of the week…So that's dropped your energy consumption right down. We said, but obviously this is our best intelligent guess as to how you are going to operate the building. If you operate the building differently, your energy consumption could vary wildly."*

Feedback could offer comparison with typical buildings. The complexity of predicting the energy consumption associated with an entire building is contrasted with predicting single-aspect systems like the day lighting available through a building component. Manufacturer 14 is able to make prototype building components and test them in laboratory conditions before putting them to the market. This allows his organisation to not only refine the design but also to provide accurate data to feed into design prediction models:

> *"in the outset we did a lot of research and we had a long-term monitoring station built at [University name]...and we data gathered over a 5 year period I think, that information was then fed back into a computer programme which we developed so we could accurately predict what sort of light level we are going to get inside the room."*

Testing and understanding the performance of a component is quite different to a one-off building. This is sometimes difficult to communicate to clients. Sustainability Consultant 16 describes the process of explaining the uncertainty in building a model to a client:

> *"getting people to understand the difference between what we can realistically model and what happens on the ground and that we can't model accurately. People just don't think of that, think of it as something that, if we just tried a bit harder we could do."*

Compliance calculations therefore offer an easy way out of any requirement to make accurate predictions. Policy makers acknowledge the complexity of making accurate prediction and in writing new guidance are attempting to integrate post occupancy checks on predicted energy consumption to reassess assumptions and make amendments. Central Government Policy Maker 21 describes such a piece of user guidance intended to counter the unpredictability of energy consuming equipment use patterns:

> *"we have got legacy equipment coming across from [building type]s…they have not got new equipment… they have got old furniture, old ICT equipment, old…could be anything so based on the actual equipment we expect them to do a TM22 type analysis to collate all of the data plus model simulation of the thermal and lighting… to get more accurate assessments and put that into the TM22 model with the hours of use that are assumed."*

This acknowledgement of the need for greater accuracy in design predictions and checks on resultant consumption from a central government policy maker supports the literature review and statements from other actors that assumptions are often incorrect and that the prediction can be misleading.

The current process of making energy predictions is flawed. The complexity of this process often results in those with most influence over building characteristics in the design and management process having the least involvement in the compliance calculation process. Often decisions are made without the input of key expertise. Designers acknowledge the flawed nature of the compliance calculations but due to the atomised nature of the process and unavailability of data, are not positioned to change this. Overcoming this requires information about use patterns of spaces and equipment; however, actors may still be reluctant to give guarantees about performance. Making clients aware of the uncertainties associated with predictions is difficult, and policy writers are trying to overcome the limitations of existing compliance calculations.

7.4 Using feedback to inform decisions

Just as the survey data illustrated, the use of a formal feedback mechanism is not common among the design industry interviewees. There is however acknowledgement that a tacit feedback loop exists and that some feedback does filter into new decisions made in design projects. Architect 03 articulated this process:

> *"Well it is kind of learning by experience, we don't really formalise the knowledge other than… err, building it into the next project if you see what I mean."*

Architect 03 acknowledges that her practice is small and therefore a formally organised system is perhaps not necessarily required but could also see the advantages in an industry-wide feedback platform. Architect 05, who works for a much larger practice on much larger buildings across a greater range of sectors, describes a similarly casual system involving their own designers' tacit knowledge:

> *"the last building you worked on; you know what went wrong and they don't go wrong on your next building…because they are sort of the forefront of your mind but other things might do which went okay last time…so I suppose any kind of things that went wrong you'd tell people about, you know, make sure you don't do this because this happened. We do always plan to have kind of end of project reviews and kind of sit down and say, 'right we must never do this again'… …'this was very successful', let's replicate it and I think partly in the past we haven't done very repetitive work. So whilst it's all useful to sit down and analyse what went wrong… I think that some people by the end, by the time that that comes that point comes to sit down and assess, you're on to the next project and it doesn't seem important anymore…"*

The acknowledgement that Architect 05's practice views the collection of information as important but does not *'get round'* to carrying out design reviews to exchange information in the practice reflects the survey findings that practices want to do this work but are stymied by costs and other barriers. In this case it seems time and other priorities are the main barriers. This is not confined to design practices. Engineer 02, who works for a residential developer also, describes a situation where there is a casual relationship between knowledge of what has been done previously and new projects:

> *"for some reason it doesn't happen and you get onto reviews of the next project and it probably only filters through by your reviews – general design*

> *reviews – and knowing what went wrong last time and not suggesting people do them.”*

A crowd-sourced feedback platform could assist with information communication but also provide details of common errors. In other commercial organisations, particularly landlords, the situation is different. Facilities Manager - Developer 18’s organisation has a formal feedback system in place, outsourced to a data monitoring company:

> *“we have got the data online; building management engineers can actually see the data, [management company] in [location] can see the data. [management company] is looking at our buildings on an ongoing basis and identifying opportunities for savings …they produce a report that for each particular observation, they show the observation graphically to show actually what the anomaly is. They then show what the opportunity saving is on an annual basis in financial terms and also in kilowatt terms but we don’t necessarily understand completely what the issue is it, it may well be that they find that there is a three kilowatt constant use in the building and they know that the building isn’t occupied 24/7 …they have an inventory of all of the meters but they won’t necessarily be able to isolate exactly what that usage is so then the engineer is tasked to go away and to find out what it might be. It may well take the engineer several weeks to find that out.”*

This kind of systematic review procedure is only available to those with access to buildings. However, the information can be fed into briefing for new projects. Manufacturer 14 can easily collect information and make amendments to the functionality of the components that they have installed. His organisation installs a product and returns to the site to carry out maintenance checks and gather data. He describes the need to also ensure that occupants know how the system works:

> *“So we go back a year later half the people have left, they don’t understand the system they have got so we have to do a retraining exercise and we offer a free software tweak at that moment in time just around the building, ‘my room’s too warm, too hot, too cold’ you know we can just make those changes there and then.”*

The opportunity for buildings to become more like products with a similar culture of review is offered by a feedback platform. The issue of personnel change in buildings is in part addressed by Soft Landings in the initial stages of a building’s occupation through commissioning and training, and may establish a longer-term culture. Architect 03 describes how a low-energy approach is used to encourage clients to engage with their buildings and invest in fabric, technology and training:

> *"I suppose we just kind of plug away at it really…we just encourage people, we just explain, we do a lot of explaining about why they need to and how their comfort levels will increase, lower energy bills and a lot about you know, the building's going to last x number of years, you're not going to do it again, the regulations will increase so you're getting ahead of the game by insulating more now because it is only what is going to be expected later… most people are pretty receptive although clearly it does have an impact on cost"*

Facilities Manager – Developer 18 talked of the communication of information between his organisation and tenant organisations and of also persuading them to engage with energy in a meaningful way and how this relied on trust generated by a financial guarantee. This is something that echoes designers' requirements for some security in the calculations:

> *"I wasn't going into them cold and they knew that we were looking at ways to try and look at energy reduction and typically there were quite high levels of scepticism from most of them…but basically on the basis that we said look we will guarantee this and we will run it completely transparently and we got acceptance to do this in all but three buildings."*

A guarantee is offered by an organisation that is confident of its ability to deliver; this is not always possible with designers. Integrating energy and environmental concerns into the design process is carried out by interviewees in a number of ways. Building designers have a design process that is structured by other concerns: planning, the tender process and client requirements which can be incompatible with low-energy design.

Architect 01 talked about a situation on one of her projects where, although there was no particular briefing target for indoor comfort levels, a problem arose related to the heavily glazed south-facing façade. This was on a design that her practice inherited when they were employed to produce a set of working drawings and were unable to change due to the already obtained planning permission. She describes a problem-solving process that is based in starting with the simplest and cheapest measure and working from there:

> *"It may not do enough but in conjunction with internal blinds maybe it will make it reasonable. I don't know, it is kind of a trial and error thing you know,* **we have had a few discussions about it and we have agreed that the way to proceed is to fit the blinds, see what difference that makes, fit solar**

> *film, see how the effect of that is and then and only then consider more extreme options."*

This typifies the casual feedback loop but also an avoidable problem generated by initial poor design and the contextual pressures. Currently, even in organisations with stated interest in this topic, data is not always passed on but in organisations with a financial interest in building energy consumption, feedback is more likely to be habitual. The comprehensiveness of the data collection and interpretation is motivated by financial savings.

Because the contextual pressures create a range of barriers, often only tacit feedback loops exist in other organisations. They are informal and reliant on individuals passing on information, which may or may not happen. The kind of information that is currently likely to be passed on in these situations is very particular, probably only negative, and of importance to individuals and individual problems rather than a broad range of information about a project.

Component manufacturers can also carry out comprehensive data collection and review procedures. Building managers and users can learn from developers and manufacturers to carry out periodic system - and building user – updates to keep buildings running properly and to learn for future projects. Converting this into remedial action and developing new ways of working are key components of casual data collecting.

7.5 Barriers and disincentives

As the survey showed, actors do not necessarily check whether their buildings operate as they thought they would. An essential tenet of the idea of feedback is learning from mistakes and ensuring that future buildings are better, or at least do not repeat the same mistakes as those that have gone before. The contextual pressures describe a wide range of barriers to collecting information. A lack of obligation in the contextual pressures leads to a situation where only problems are investigated; Architect 04 said:

> *"we only tend to revisit buildings when there is something wrong"*

As well as costs and liability, the logistics of carrying out Post Occupancy Evaluation were often cited by interviewees as reasons for not being able to collect data. Sustainability Consultant 16 cited the impact that the building type has on access:

> *"we have got more schools who are always a bit more enthusiastic about letting you come back than say offices where we can ask if we can come back but they are not always interested."*

Many interviewees indicated a combination of perceived disincentives associated with collecting and using building performance information. Engineer 06 typified the range:

> *"I think the cost of who collects it…and also the liability if it's one of our buildings, are we potentially putting ourselves in the firing line… the barriers are money and liability."*

In contrast to the survey respondents who generally cited costs as the main reason for not collecting information, most interviewees cited liability (as well as costs) as the main reason for not collecting data, Architect 20 said:

> *"you know we don't make profit, all we do is pay the salaries, I think there is that kind of, if you start kind of poking around too much you will find, you know, bits and bobs and you are opening yourself up to sort of liability".*

Those who do collect information about buildings most often cited circumstantial and anecdotal evidence as one of the main forms of information 'collection'. This is often about aspects of buildings other than energy. Architect 03 expanded on the idea of maintaining a relationship with clients:

> *"you still tend to keep in touch with Clients and…have conversations with Clients about performance…I suppose a lot of the time it's, less tangible things than how much energy is used."*

This is consistent with the idea that some only get information back from a building when something goes wrong because of the intermittent contact with clients and occupiers. The central themes of the disincentives are the cost of collecting data – as opposed to processing it or analysing it – and the potential liability of finding out faults with a building that could be attributed to the designer. Engineer 06 expands on costs as a barrier and introduces the idea of attributing the benefits of any work.

> *"we are looking to increase the amount of POE that we do but again it is who is paying for it…I think the big sticking point at the moment for a lot of this energy gathering thing is just money, who is going to pay for it, what are we going to get out of it, what benefits are we going to see. "*

The initial costs of the information collection are important, but so is the attribution of benefits and the payback on the investment. Engineer 17 was explicit in his evaluation of the profitability of POE activity for his consultancy when answering the question 'do you do any Post Occupancy Evaluation?':

> *"there is no money in it, is the frank [answer], I mean I talked to the [building manager] a couple of times, I get messages but real post occupancy evaluation, no."*

A feedback platform must therefore provide evidence that this is a worthwhile exercise in respect of both financial outlay and financial benefit. It is not just with the design of buildings where the costs associated with collecting data to check the efficacy of decisions are prohibitive. Local Authority Policy Maker 12 would also like to be able to spend more money assessing the effectiveness of changes to his policies:

> *"if we wanted to measure the actual impact of our planning policies across the borough you know there is always going to be a limit to what data we can actually collect…you know there is a whole lot of things beyond energy and carbon that we would like to collect and in an ideal world if we had more staff and more resource I would be undertaking a lot more or I would be undertaking any follow up visits to completed schemes to actually see what it looks like on the ground and again perhaps a bit of visual verification of what's there and what's being used and so on."*

Costs associated with the collection of POE data are a significant barrier to any action being taken; a feedback platform could overcome this. The benefits of making the investment, particularly to designers, are less clear. This is a clear future role for a feedback platform.

Facilities Managers were able to overcome the cost of carrying out post occupancy evaluation and justify the time and resource. They are in a position to assess costs, make changes to buildings' operation and continually monitor what they are doing. They are crucially responsible for the running costs. Facilities Manager –Local Authority 19 described the process of cost-based justification in his department:

> *"I suppose really the only barrier will always be is there funding available to undertake certain activities… we often work to the benefits realisations and you know if the benefits are beneficial to the authority as a whole you we will no doubt find the funding."*

A feedback platform must demonstrate the value of data collection to designers, owners and other members of the project team. Beyond the costs associated with POE, Architect 07 articulated the fear and risks associated with finding out that a building does not function as intended:

> *"if you have it on record that you could have done a better job, anybody that finds that out who's got their building they are naturally going to be pretty peeved and they are going to take you to court."*

Architect 07, or any other interviewee, could not cite a specific example of legal action based on energy performance but most raised liability as a real barrier to POE. Architect 08 expands:

> *"information is not extensively pursued for liability reasons…when an owner finds out that their perhaps building isn't performing as well as an initial concept model did perhaps that could be a legal battle that we don't want to face, but you know I am almost positive that in our contractual agreements and in our disclaimers, whenever we share a design-phase energy model, it's always design and not contractually binding…there is reluctance because of that kind of legal side but also embarrassment or it could be what if the project is not performing how we said."*

This came up repeatedly and is counter to Surveyor 023's remark that performance requirements can be simply added to contracts. The reputational value of being known to produce functional buildings that comply with design predictions is only there to be lost by carrying out POE. Why would actors voluntarily question their own reputation? A feedback platform could support predictions but could not guarantee them. Engineer 06 talks about the attitude to risk in his organisation and the attitude to potential liability:

> *"there is always that danger; I know a lot of guys in the upper echelons of the company who are very risk averse."*

This perception of risk exists across industry, however Sustainability Consultant 16 thought that the barriers that currently impede her organisation were not individually insurmountable but cumulatively represented a risk too large to tackle:

> *"I think the barriers, the big issue is that there is lots of very small barriers and you can't get any where until you break them all down and they are all sort of break down-able on their own but it is not worth it… I think that's unspoken but I think it is much bigger than anybody is prepared to acknowledge: the risk of if we went to look at it and it was crap."*

A feedback platform must therefore look at the problem as a rounded whole rather than a series of individual issues. Returning to the idea of liability and risk to the relationships in the project team, Engineer 17 lamented the way that he saw the industry evolving into a blame-orientated culture. The kind of open discussion that POE could stimulate to improve understanding of the built environment to rectify problems is almost impossible:

> *"there is always a junction that is not quite how it is supposed to be and you need a bit of money to deal with it…it is not anyone's fault but it needs to be dealt with and it is not unreasonable that the contractor should be asked to do it for nothing because he should have read all of the drawings … there is so much blame culture in it now, I mean, it's been sad watching the way the industry has evolved down to a pure blame culture now."*

It is telling that Engineer 017 places the blame on the contractor while simultaneously bemoaning the blame culture of the industry; but he does raise another aspect of internal project team barriers. Central Government Policy Maker 21 has acknowledged that the prospect of legal action over building performance is a problem and has taken steps to overcome it in new policy. When talking about the need to carry out POE in a new piece of building-specific guidance she proposed a means of overcoming the blame culture:

> *"we ask for it to be done, so as a client, any other client could do the same. There is still that thing in certain, previous [procurement programmes], 'would the contractor want to do it' but it can be anonymised and as it is product-based and zone-based rather than building-based it could get rid of the blame game a bit, because the idea is just to make the data transparent not to penalise anyone, it is to find out what works and what doesn't and gradually improve things. "*

This is not only an acknowledgement that the liability implications of POE need to be overcome to create an atmosphere in which all actors can learn from the process, but also of the sensitivities in the project team, particularly the contractor. This is reflected by those writing policy at a local level and trying to encourage an atmosphere in which they can make appraisals of the performance of new buildings within the jurisdiction of the policy that they have written. Local Authority Policy Maker 12 identified this as one of the aims of his policy writing:

> *"that seems to be the biggest issue, that kind of concern over litigation and that impact over reputation … we tried to package this whole thing as, you know almost in a user-friendly feel and really tried to emphasise that this a lesson learning process and it is not about trying to kind of identify shortfall and immediately try to pin the blame on someone, I mean we are not going to kind of drag the people through the dirt or something."*

The need for a blame-free environment of knowledge exchange is clear. This can only be partly created by a feedback platform; an important part lies with the culture of the industry and the adversarial relationships between actors:

Engineer 06 articulated the tension that this created between the desire to carry out POE work and the opportunity it represents and the perceived risk of liability:

> *"we are really struggling because our own internal sustainability groups, they want to demonstrate in our annual sustainability report how our intelligent and efficient design has saved our clients' carbon emissions… it's kind of a double-edged sword, it could brilliant or the client could turn round and say well hang on you haven't given us the flipping building we paid for!"*

Feedback must create an atmosphere in which this can happen. The barriers associated with POE and feedback are seemingly built into the procurement process and in particular the set-up of project teams. These centre on the cost of carrying out POE work, the perceived lack of value in the data, and the fear of uncovering evidence that a building is not working properly. In the design professions these barriers, coupled with a lack of obligation to assess buildings, has led to the current practice to return to a building only when something goes wrong. While some feel that the barriers are surmountable through data exploration, their very existence prevents any data exploration to prove this.

Actors therefore ensure that advice about energy consumption is not contractually binding, that they cannot be held accountable for the figures, rendering them mere compliance checks and meaningless for energy consumption. This situation is driven by an inherently risk-adverse industry coupled with a blame culture that creates a constant fear of litigation. The need to create a blame-free environment in which to explore building energy consumption is acknowledged by local and national policy writers. However, the intra-team relationships are not something that the energy regulations can influence easily.

Risks and attributing responsibility

The perceived risks associated with using feedback and the procurement of buildings generally can give some insights into the mentality of industry. Surveyor 023 describes the way that risks are traditionally dealt with in the construction industry:

> *"I think over the years...risk has tried to be channelled down the ladder, all risk has been pushed down the ladder - risk should lie with the person who is best qualified to deal with it. It shouldn't be just pushed down the ladder because you think you are going to get a cheaper job, you know, risk costs*

> *money and therefore if you take on more risk, generally speaking prices go up further down the ladder".*

The idea that risk should lie with the person most able to deal with it is a powerful one. However, this would require a sea-change in industry to allow main industry actors to take responsibility in a blame-free environment. The implications for energy predictions would be to ensure that those with expertise are involved in the decision-making process and take responsibility for those aspects that they influence.

Contractor 09 also outlined the risks associated with the procurement process, particularly when a designer is attempting to synthesise a solution that takes into account the concerns of a diverse project group, including a funding bank, a financially motivated client, an end-user who is interested in the quality of the building and value for money, and a contractor who is driven by profit:

> *"the bankers will have an agenda…they'll be just asking relevant questions about have we considered this, have we considered that, what's our risk? We don't want to be flying out and finding out we've got a risk, we're bankers, we don't do risk… the housing association or local authority who it will be delivered to as the end-user are interested in getting the best they can for what they are willing to spend and we [the contractor] will be interested in making a profit out of the whole process, pouring concrete. At the end of the day, it's the poured concrete that makes the profit."*

Integrating a low-energy agenda into this mercenary set-up requires feedback information to demonstrate the profitability of this approach. This is true of any particular approach; information must be framed in terms that appeal the audience. Facilities Manager –Local Authority 19 outlined how his organisation deals with simpler perceived risks associated with technical innovation:

> *"a barrier probably is proving the technology because we wouldn't jump into something that hasn't got a proven track record…"*

A feedback platform can provide a track record for technology as well as actors. Taking account and responsibility for risks associated with the procurement of a building means that energy consumption is a risk too far for Engineer 17. His firm is not obliged to take responsibility for it:

> *"you can't then say 'building regs say you are liable for the amount of energy this building uses and it's over energy so here is your bill' when you are not being paid for that risk."*

Associating every risk with particular actors in the procurement process is difficult because of the way that buildings are designed, the complexity of the finished systems, and how responsibility is attributed via the contextual pressures. Architect 05 raises the limitations of the designer's influence over the finished building when working on a design and build contract:

> *"the things we can do in achieving these, beyond the design [of the building and fabric form] are actually quite limited because a lot of the system that will be measured ...a lot of it is the services, and the detailed design of the services that will, you know, using different fans or contractors substituting fans."*

Particular procurement routes that break the chain of responsibility in order to increase competition, reduce costs, increase value and avoid risk are potentially damaging to the outcome of the project. Surveyor 023 expands on this kind of poorly-managed design and build contract and describes how contractors might operate in this situation:

> *"Builders are cutting their costs, they are just putting all of the risk down the feed-chain so to speak, you know, they are saying that 'you are responsible for that Mr [company name]', 'you are responsible for that Mr [company name]...they don't spend the right amount of time or resource on the planning and coordination."*

The planning, coordination and attribution of responsibility is a key point for energy and feedback. A platform could help identify who is best placed to deal with an issue. This is confirmed by Engineer 06's method of working:

> *"more frequently they are tending to go with a D and B [Design and Build] so we'll produce the design at stage F probably with a performance spec, equipment schedules and everything, then hand it over to the contractor. What tends to happen is that we are then retained as the client's technical professional. The contractor will then run away and design it and we will just get technical submittals to review and approve. Well not approve, we comment. That's the other consideration I know a lot of people a bit higher up in the company might have. If we go in and do this post occupancy evaluation and we find out that it is not running as efficiently as we said it would, what does that expose us to on design liability?"*

Engineer 06 corrects himself when he says 'approve' – approve suggests responsibility and therefore liability. In this kind of procurement route, responsibility becomes a grey area: not being able to follow a chain of responsibility back to the original designers not only makes the costs associated with carrying out POE less recoverable but also make POE less likely to be carried out in the first place, particularly by designers who see the finished building as not representing their original specification. The focus of a contractor's design may not be the same as that of the original design team as their priorities are likely to be quite different.

Building Performance Consultant 11 describes a process that he has instigated to overcome this problem, designed to make people take responsibility for the performance:

> *"Well I used to do charretes. To one of the groups in the charrette 'cause we normally had an initial session and then we split [into] groups for 90 minutes. 'Who owns the windows?' 'Daylight?' 'Cold spill?' If the glazing was single, some people were still proposing that, as it satisfied the building regs. 'Ventilation' they said well we pass it on to a window supplier, a glazing supplier. Sorry, 'what does he know about ventilation?' 'Is he trained on ventilation? 'No.' So who's taking responsibility for when it doesn't work. Very quickly the people in the charrette realised that they had to take responsibility. And the project's manager started assigning responsibilities."*

Attributing responsibility in this way at design stage may force actors to take more interest in carrying out POE. However, whether current contractual models and insurance policies would allow for this is a different matter. Central Government Policy Maker 13 describes a contractual arrangement in which those responsible, in this case the contractors are obliged to carry out a TM22 assessment and resolve problems:

> *"at 9 months they needed to have reported and know what their end-use has been on a quarterly basis. End-use is energy based on the TM22 end-use data so that we know at 9 months, we haven't got a full year, we know that but we will have been through a full heating season and a hottest season so at 9 months (and we want an occupant survey done as well), in 9 months the [organisations] and those who are responsible need to be in a position to know whether the building systems are working."*

This again attempts to set up a contract that assigns responsibility early in the process to attempt to overcome the existing culture within industry. The perceived risks inherent in the procurement process are currently dealt with in a way that can damage the process of designing, building and managing buildings. Risks are passed down the supply chain; they do not lie with the actor most able to deal with them. This can increase costs and impede information flow. Within this set-up, where all actors wish to avoid risk and they can have quite different agendas, reconciling these is difficult. The complexity of the energy systems represented by buildings makes accepting overall responsibility for the headline consumption figures difficult. Coordinating responsibility in the design process is often poorly managed with designers actively removed from the process. This kind of contractual set-up means that designers are unlikely to accept responsibility for a project that has been procured through a process where their design intent is not explicitly followed.

7.6 Causes of poor performance

There were a range of factors that actors believed led to, or could lead to, poor performance in their building designs or managed buildings, beginning with the conflicting aspirations that can be present in a design team. One of the recurring themes of the conversations was the conflicting aspirations of project team members, legislation and in individual actors' priorities. Architect 04 who works for a design-orientated architectural practice describes what takes precedence in her firm:

> *"sometimes the design image can be really strong in your mind, especially with architects. So if it's for instance ventilation, an idea of how to ventilate a building and a design idea but they don't match very well then we would adjust the ventilation idea and not the design."*

This does not necessarily mean that the ventilation strategy cannot be made to work but in the case of an industry with limited funds and limited time to spend amending designs, perhaps the ventilation is not optimised at the expense of the 'architecture' (that they are not integrated as essential parts of the building is illustrative of the atomised responsibilities). Engineer 06 describes the idealised process of getting involved in the design process early to ensure that any conflicts like this are resolved before decisions are made that are difficult to reverse.

> *"we very much want to work hand in hand with people because at the end of the day we want a building that works on low energy, the architect wants a building that's visually stunning, but we both want the same, we want it to look good and we don't want to sort of stomp all over the architect' s design to achieve that, we are trying to get in right at the early stages ... we would get involved very early on, do preliminary feasibility studies on renewable, things like that, advise the wider design team as to what could be achievable, what's not achievable either due to site constraints or budgetary constraints or what have you."*

This builds on the previous section's commentary on risk and responsibility. While conflicting aspirations were often identified between design team members (and even within individual organisations); this also extends to conflicts between actors and legislation. Facilities manager – Developer 18 identified an aspect of the building regulations, designed to help him lower energy consumption, but that moves the focus from monitoring and engaging with energy to compliance and costs more than it should.

> *"there's a sort of culture…between building design and well particularly at building design of sort of almost ticking boxes around metering, and it is Part L specifications, I mean typically you know once we find if we follow Part L guidance that we end up putting far more metering in than we actually need to put into a building."*

Building regulations do not provide good predictions; they also do not allow for efficient good data collection. As well as conflicts between designers, and between actors and legislation, there can be conflicts between the configuration of building components. Consultant Policy Advisor 021 described a situation where engineering good practice and the demands of an installation and maintenance contract conflicted to create a poor building:

> *"the plant room on the roof, which was meant for the vent plant hasn't got any plant in it because the contractor wants to put the plant direct on the roof, outside the plant room in the rain. So you have got an empty plant room on the roof…. [and plant sitting beside it]…outside! Because it is easier to install. So stuff like that, which is disconnect between design and contractor…it is not a PFI it is a design and build… with PFI they will have to maintain it still, so if they put the plant outside that would be the main problem, not the energy efficiency but keeping it working."*

The above quotes combine many of the themes identified in this thesis – design intent, risk, communication, contractual set-up, responsibility and disconnect between different actors and stages of the process. Conflict of aspiration can include a disparity in the importance of certain aspects of the building design. For example aesthetic concerns may be considered more important than engineering performance. This can be driven by individual actors, planning policy or other parts of the contextual pressures. The lack of early involvement of all of the necessary expertise to make robust decisions can contribute to this and create conflict where ideas become so established they are difficult to challenge at later points in the process. The contextual pressures can be the source of difference in the aims of a project. While the legislative components are there to ensure action is taken, they can mean actors are asked to do what they believe is unnecessary, or even damaging. Finally, the contractual set-up can be the origin of disagreement; opposing pressures such as maintenance, convenience, costs and responsibility can result in decisions being taken that do not have the best interests of the building performance at the root of them.

Lacking Expertise

Often projects' performance can suffer from a lack of expertise in the project team to convince clients to invest in low energy measures. Architect 04 describes a 'catch 22' situation where she knows that something could be done better and there would be a benefit to her client to do it better, but her practice is not perceived to have the expertise to convince her client that this is the case. Her client is therefore unable to justify the expense of paying for somebody with the expertise:

> *"I don't think that we have the expertise in house and there is absolutely no way that any of these clients would pay for a consultant unless we could really demonstrate that it would be beneficial right from the outset which because we don't have the expertise, we can't."*

A feedback platform could provide the evidence to convince clients that expertise is a valuable investment. A lack of expertise can lie outside of an actor's organisation, but have impacts on their work. Engineer 02 talks of the impact of a lack of expertise in consultants and installers that he employs. He finds actors specifying and installing equipment that they do not truly understand but that is compliant with legislation. This can result in untestable plant:

> *"All of these problems [of poor performance] are not addressed by policy in any kind of prescriptive way so the consultants and the contractors haven't done their job properly is much what it amounts to…We are able to look and see the various problems that are occurring ... I have now got a whole series of issues that I know right, next time we need to do that, we need more monitoring, you know we need more commissioning valves because sometimes going back to hotels and things we have built, the contractors going 'Yes, commissioning valve here, here, here, here and here' and then the last bit you need to trouble-shoot it, there isn't a commissioning valve - no means of measuring the flow rate!...suddenly at that point you have done a lot of work and don't where it is actually going wrong because you've found the fault but you can't test it. It is not following good practice you know. I must confess that the consultants and contractors that we use, we don't pay a lot of money. We get very competitive rates from these people."*

The causes of poor performance in this case may stem from consultants not understanding what they are specifying, or may be due to a lack of time and resource to get things right, driven by the fees they are able to charge or that Engineer 02 is willing to pay. Engineer 02 does acknowledge later that his organisation may need to invest more in consultant teams in order to improve the build quality of their projects. The ability to not only produce a good building, but to find faults and gather information is hampered by the project set-up and lack of knowledge.

Returning to the issue of lay clients, Architect 03's client base is often made up of people with no or little expertise in energy and she finds herself having to explain the concept of her work to them:

> *"I think a lot of people come wanting 'low energy' without really understanding what it means, often you have to explain what that involves… data is quite difficult for most, or a lot of clients aren't really able to digest data because it is kind of alien"*

The communication of concepts between expert and layperson is a crucial one with the project team, between actors and clients and in the wider industry. The issues surrounding risk and responsibility make it particularly important. Architect 05 is aware of the limitations of his practice's expertise in setting project targets and developing low-energy designs:

> *"we are not in a position to set any of these levels so really we would work then with the engineers as a kind of…aspiration on our part because it's beyond our sort of experience really to then design it any further. So in terms of what energy it might save you, we're not really into enough to be able to just tell, tell people how…we don't have that information at our fingertips. We work with an engineer."*

The relationship between designers is therefore crucial. The survey demonstrated that there can be conflicting aspirations in the project team. Lack of expertise can also, in the case illustrated above, simply be a function of actors' jobs. Architects are not trained in energy and therefore need to rely on the expertise of others, making project relationships and information communication increasingly important as the contextual pressures get more complex. The literature review raised this as an issue.

A lack of expertise as the root cause of poor building performance can be driven by a number of factors. There is the 'Catch 22' of needing the perceived expert gravitas to convince clients of the need to employ greater expertise or even to take building performance seriously. This lack of expertise, or at least a lack of need to be an expert, is encouraged by the contextual pressures in which a tick-box approach can be taken to engineering systems without truly understanding what is being installed. This can be extended to other aspects of buildings. The lack of expertise could be driven by a lack of time or resource in the experts who are involved in a project. The atomised procurement set-up of project teams, the dispersion of risk, the increased complexity of systems and specialisation of actors within the project team all mean that coordination and communication of expertise is increasingly important, particularly between experts and laypeople.

Poor Information Flow

The use of information to support and justify decisions is important, particularly when actors are trying to develop designs and track changes. Interviewees raised poor information flow as a cause of poor performance. Engineer 02 describes a problem associated with the failure of a community heating scheme, attributing this to poor information flow, through inadequate reporting.

> *"…our whole 'reporting change' actually looking back isn't really set up to deal with those kinds of faults and problems. So first of all is the problem of picking up what happens very shortly after it happens, that's not working."*

There is an obvious role for real-time feedback in this situation. The need to quickly detect and diagnose problems in order to counter poor performance is hampered by poor information flow. Facilities Manager – Local Authority 19 describes the situation in his organisation when attempting to get information from management departments:

> *"all I am after is very simply is you tell me the base load of these buildings, what our minimum energy requirement is and then I just want how we are going to monitor and target the degree day activity and we can then monitor and target and predict and do some forward thinking. They just don't seem to grasp that for some reason in terms of providing that information back to me."*

Obviously with no information, no action can be taken, or any action taken will be speculative at best. Poor information flow can impact on intra and inter-organisational performance. The use of a formalised platform could combat this.

Poor information flow can affect building performance and actors' and organisations' performance in a number ways. It can prevent problems with performance from being drawn to the attention of those able to deal with it. This can have reputational impacts on the organisation as well as cost and comfort implications for building users. A combined lack of expertise and poor communication can mean the necessary information required to make a design or management intervention is not available.

Ownership

All of the barriers and opportunities discussed so far are influenced by the ownership of a project. Actors' client type is an important factor in their ability to carry out energy-related POE, or indeed POE of any kind. Contact must be maintained with the owner of the building to gain access to data or the building itself to carry out assessments. Architect 01, whose clients are largely motivated by financial gain without much regard for the quality of their buildings' outlines one major obstacle in engaging not just her practice with the finished building but also generating any concern with the performance of the finished building in her clients:

> *"I am not sure what percentage of our projects end up getting built by the client who [commissioned] us to get the planning for [them]; a lot of our repeat clients are people who buy up sites and get planning [permission] and then sell them on, so they are not interested."*

This fundamental barrier of engaging with a completed building raises important issues for any future legislation. The chain of responsibility must be followed through the commercial exchanges. The other side of this arrangement was also raised by Architect 01. Her practice also picks up work to produce construction drawings for projects that have already been awarded planning permission through other designers. In the following quote, she is talking about a project previously discussed in this chapter where a residential tower had been designed with floor-to-ceiling south-facing un-shaded glazing:

> *"We did try and alter the design to incorporate some panels rather than have it fully glazed but the planners were really hard-core about it and they were saying that we would have to submit a whole new planning application. The planning permission was got some years ago and since then there have been changes in the planning legislation; [our client was] concerned they wouldn't get the planning permission again so they didn't want to risk [reapplying] and the planners wouldn't let us do a minor amendment or a non-material amendment."*

Architect 01 has tried to rectify this poor design and although she admits that has very limited impact, she has managed to make some minor changes to reduce the solar gains through the south façade. Architect 01 has taken responsibility for the poor performance; in this case the residences were extremely warm, with 34°C recorded in the living rooms in mid April with no heating on. She has worked with the owner to rectify the problem using a technical solution that required no planning permission. With no extra fees available to cover this work, the building performance was reliant on an ongoing relationship between the client and a diligent architect. A database of this information might prevent similar design errors being made in a similar commercial setting. However, more complex or costly problems may not be so straightforward to deal with.

Engineer 02 experiences similar issues as a developer, but as the design engineer feels more able to tweek the design on technical aspects. He said:

> *"some of our jobs have a got a legacy element in terms of the kind of policy and previous regulations that we have to comply with on the basis that we purchase schemes from previous developers who have obtained the permission. Sometimes the scheme in terms of design criteria, what we specify and what we can do with it, sometimes our hands are fairly well tied but that is more on the bigger picture items rather than the actual technical solutions we can put in place."*

So while he is unable to influence the larger design decisions about glazing and form that Architect 01 was dealing with, he is still able to make technical changes to the environmental systems and in some way rectify a poor design. Engineer 02 is in a position to do this as a project engineer for a developer, rather than as a designer. Facilities Manager – Developer 18 similarly has access to his own company's buildings and identifies a set of difficulties unique to this position. He describes the situation where his buildings are occupied by a number of people and as an owner with an interest in reducing the building energy consumption; he tries to find a way of attributing responsibility for end-use:

> *"there is complete haziness around who is responsible and how you make this work in a building between building management and occupiers ... yet none of this actually is very complicated…because there is so many cooks and you know there is no consensus around where responsibility lies and everything else and government hasn't really provided much direction around this ... some of their initiatives are at least encouraging reduction but they don't really understand the importance…their focus around the Green Deal has really been about installing plant and infrastructure whereas you know it is much more around management…generally across the whole piece is there is little understanding as to how to do this and what the benefits are and I think the other thing is there are there aren't market mechanisms to encourage this because of the split incentive."*

The split incentive that Facilities Manager – Developer 18 is talking about is what he sees as a range of people that can benefit from reduced energy consumption, and the ambiguity in allocating the benefits of the work that means it can be difficult to attribute the savings, benefits, profits and risks. This is a recurring theme to this chapter: attributing benefits, risks and responsibilities. The ownership of a building can create the context for building performance evaluation but changing ownership can also create obstructions to creating good design. Modern procurement processes mean that different designers work on different stages of the development process. Maintaining consistency in design intent or being able to instigate improvements can be challenging. In addition to this, buildings can be designed to be sold before construction or immediately after completion. In the former case there is no incentive to ensure a building is built to a high standard; in the latter, there is no incentive to ensure a building will work well. Both changes in design ownership and project ownership can break any coherence in the design and running of a building, exacerbating the other barriers and causes of poor performance identified in this chapter. The role of the contextual pressures with regard to compliance can 'lock in' poor design to a project. Those that do build and own buildings are better situated to establish a holistic design and management regime. However, they can struggle to apportion responsibility, costs and benefits across multiple actors, tenants, themselves and other potential beneficiaries.

7.7 Incentives

The universal incentive identified by all interviewees in the private and public sectors was money. Whether profit, capital expenditure, savings or running costs; making more and spending less was a common theme. Engineer 017 summed up the worldview of most organisations:

> *"I don't care whether you measure it in Watts or pounds or joules or kilograms of carbon, at the end of the day most companies look for the bottom line."*

The need for private practices and companies to make a profit is of course essential and is why they exist. However, the lack of value associated with POE data and subsequent lack of commercial potential means that feedback is often not carried out. Engineer 06, when asked why his organisation does not carry out more POE, asked rhetorically "is it going to bring us more fees?"

Mandatory systems can however act as a gateway to profitable activities and realising the commercial value of feedback data is key to carrying out more POE. Contractor 09 takes a pragmatic view that the less profitable activities must be undertaken to allow the more lucrative ones to be carried out:

> *"one can always take a bitter view and say that its wholly commercial and it's wholly on price; the issue is that, they are a commercial company, they*

> *need to make a profit - they do things that they don't want to do, to do the things that they make a profit from."*

Future legislation could be written to create value in feedback through mandate or reputation. Building Performance Consultant 11 identifies a potential reputational benefit that can go alongside a profit motive, as well as the cost savings associated with low energy building performance. When asked what the drivers were he said "Being seen to be green. And costs. Pure costs."

This combination of incentives could encourage more activity in POE and energy evaluation if it was made explicit: being seen to be green is a commercial positive. However, as has already been discussed, the contextual pressures do not necessarily reflect the motivations of industry. Energy Consultant 22 makes this point:

> *"…the financial implication of energy efficiency, I mean that is what big business is driven by, they can say it is carbon but, it's not really."*

The current perceived lack of value in green buildings is acknowledged by Facilities Manager - Developer 18. He has identified areas where some investment on the part of his organisation that would yield some reductions in energy consumption; however the market value of those reductions is not clear and therefore the measures are difficult to justify to the rest of his organisation and remain un-implemented:

> *"where actually we include the cost of provision of heating and cooling and things in the rent [and therefore share the savings of energy efficiency measures] and the surveyors here have all sorts of concerns that it would not necessarily be recognised in the valuation process…"*

The lack of value in the information translates as a lack of value in the buildings themselves. Facilities Manager – Developer 18 also acknowledges that there is a reputational benefit to his tenants through renting a 'green' building:

> *" [these issues] have been raised as significant reasons for taking space in our buildings and there is a whole range of occupiers through our occupier survey who have said that our BREEAM standards and sustainability standards in our new buildings are the reasons they have taken the space…I think our desire to reduce total occupancy costs for our occupiers is another reason; you know we can see that there are savings that we can make, and that the more we can reduce occupancy costs, the more possibility over time there is to increase rents [and return to] our investors."*

It seems that there is a slow change in the market for sustainable buildings and a value in being green. Although the use of BREEAM as a nationally recognised benchmark for value is raised again, this information needs to be widely disseminated. The valuation process for commercial buildings has also hindered Manufacturer 14's ability to get his low-energy natural ventilation products into property:

> *"the one difficulty for natural ventilation is that air conditioning has a premium for office space and therefore landlords prefer to put in air-conditioning because it has that perceived value to the building."*

A profit motive is a powerful force in the construction sector; so long as energy efficiency is not as valuable it will always be secondary. Engineer 02 who works for a residential developer talked about the tensions that exists between the pursuit of profit and achieving energy targets:

> *"... the biggest problem in terms of what we do is to make properties that people like in locations they like and to a reasonable quality at the right price. We are obviously looking to meet the policy targets, but trying to do that in ways that aren't harmful to us in terms of additional costs."*

A feedback platform must be capable of demonstrating whether a measure is economically 'harmful' or not. Architect 03, who designs low energy and often PassivHaus standard residential buildings and is therefore reliant on providers of small scale MVHR units and other technology, expresses her frustration with some suppliers' motivation:

> *"I think in commercial situations it's very much more cost driven in terms of capital cost…the people who are selling the kit are selling kit, they are not selling you a way to save energy."*

This again raises the issue of expertise and responsibility. Architect 05 draws a parallel between the benefits of being seen to be environmentally responsible, reputation and commercial activity:

> *"the client was interested in getting a BREEAM certificate essentially because it helps show they're kind of progressively minded and interested in green things… which is kind of important to a lot of companies above and beyond their actual ethics or morals, it's a business thing."*

Sustainability Consultant 16, however, recognises that her organisation has realised that there is value in POE and has 'invested' time in carrying out assessment, initially for free:

> *"it made sense and when the answer came out of that first building they then went on to get us to do four more buildings because at that point…I mean it was good investment on our part…They paid us full price for the four more but in three of those cases the return on their investment paid for itself in the first year."*

The initial risk taken by this firm meant that profitable POE work followed. This confirms Architect 04's earlier statement that the barriers are surmountable – if one has the resource to apply to the problem. Feedback must make the case for this initial investment in POE. On a smaller scale and on a simpler incentive mechanism, Architect 20 has been asked by profit-driven clients to install energy generation measures through a component of the contextual pressures, the FIT:

> *"they are not asking for [energy] targets… the one that wanted the solar panels he was an investment banker so he had read about the feed-in tariff and obviously at the time, before the government slashed the feed-in tariff it was an amazing deal…really good investment."*

The simplest of motivations can impact on the uptake of technology and interest in energy. Using this information as leverage to encourage more POE is essential to future policy and a feedback platform.

The profit motive is a powerful one that can help create low energy buildings but can also result in a more cynical treatment of energy measures. The current perceived lack of value in POE mean that it is not often carried out, and the disconnect between the contextual pressures and the motivations of industry means mandated energy measures can be seen as an activity that must be undertaken to 'allow' organisations to carry out profitable work. This has implications for how these energy measures are approached.

Alongside a pure profit motive sits a set of more complex relationships – there are reputational benefits and cost savings to be made when producing or working in green buildings. These other benefits are not recognised in valuations or by the market, therefore it can be difficult to implement energy efficiency measures. The practices of valuing commercial space are conservative, favouring air conditioning over unfamiliar low energy technologies. There is a suggestion that some actors are more prepared to spend money on reputational benefits rather than actual performance improvements. The need to make a profit can mean technology is sold not on the basis of improving performance but for the sake of the sale. However, it has been shown that some risks taken by an actor can lead to longer-term financial benefits and the realisation of value in energy efficiency and in POE work itself. Change in the market is possible; a role of feedback to help make this happen.

7.8 Procurement

One issue that came out of the interviews was the impact that the chosen procurement method has over actors' ability to engage properly with energy and feedback. By procurement is meant the contract 'type'; in construction this defines the actors' relationships and responsibilities, the payment structure and who 'signs off' construction work. The section on 'attributing responsibility' discussed the issue of risk and ownership over designers' ability to influence the factors that impact on energy consumption. Engineer 17 described what he saw as the problem with design and build contracts, when it comes to implementing design ideas:

> *"The problem with D and B is you have got all of the aces…the client has got an ace, the designer has got an ace, the contractor has got an ace …but if you give the builder all those aces and he employs the designers, he becomes the client as well so he's got three aces, so he is never going to be beaten in any discussion and he can manipulate price in any way he wants…So if he doesn't like an idea you can bet your bottom dollar it's going to be expensive to build. If he likes an idea it is going to be cheap."*

A contractor with so much influence means that the overriding consideration is that of his or her company. The inability of those with expertise in environmental engineering being able to influence decisions in the procurement process where the contractor is only interested in costs means feedback must frame data in cost terms. Influence over a decision also generates ownership and responsibility. Perhaps a certain amount of risk is required to engage those with responsibility for the design with the performance of the finished and occupied building.

The atomisation of the procurement process into several stages, with discontinuous work programmes and sometimes changing project teams and ownership, can also have a negative impact on the production of quality buildings. Architect 04 described a process particular to public buildings in which there is no security in the job and her practice is asked to re-tender:

> *"…a lot of times you are just hired for the first stage and then maybe the next stage.*

This constant re-competing for the same job means that a design can be passed around a number of designers through the process. The lack of continuity in personnel mean a lack of consistency in all other aspects, communication, motivation, intention etc. Local Authority Policy Maker 12 is aware of the pressures associated with commercial development that can lead to this discontinuous design process. He was preparing a piece of policy that attempted to introduce some energy targets but take into account the needs of applicants:

> *"from a developer's point of view, they get as much certainty in the process as they can to minimise the risk on their investment… they don't want to invest in all these specialists. By pushing the process forward…until they are sure they are going to get permission."*

Consultant Policy Advisor 21 describes the process of attempting to ensure that risk is passed on to the contractor in a revised piece of government procurement for public buildings:

> *"the [government department] is not keen on having any volume risk transferred to the contractor, so we are talking to them at the moment - we still think they should take some risk for their design where as what the [government department] is thinking is that we should make sure that the design is alright rather than expect the contractor to take the risk because there are so many things in volume risk I suppose."*

Both of these policy makers seemed cowed by the powerful in the construction industry. The issue with transferring risk to the contractor is the increase in costs associated with the potential liability of poor performance. However, decoupling the responsibility for poor performance from those making the decisions does not seem like an effective measure – as Surveyor 023 said, risk should be with those most able to deal with it.

As has been discussed in previous sections the procurement type can have a strong influence on how a project performs. The issue identified by interviewees included the influence that procurement has on risk and responsibility; trying to reduce risks and concentrate responsibility to one answerable organisation can place too much 'power' in the hands of one actor, resulting in one agenda being followed. Spreading risks and responsibility may mean actors work more collaboratively.

The atomised procurement process – splitting responsibilities and ownership – can reduce certainty in the process and result in delayed employment of experts; this could adversely affect the performance of a resultant building. Such is the power of the construction industry that large clients might end up retaining risks in order to try and keep costs down – this could result in poor performance from those who have responsibility for the work.

7.9 Legislation

The main component of the formal framework of contextual pressures is the legislative part. Looking at energy in buildings as an issue in isolation is difficult as it is entwined in lots of other issues; the energy consumed in a building is a result of many decisions with their own pressures. Central Government Policy Maker 13 recognises this and raises it as an issue that future policy is trying to address:

> *"our ministers believe that sustainability is about getting the energy bill down but what we were able to do was to kind of ... have a look at the whole environmental design and actually ask for [building type]s that recognise that in use - they can't consume resources and that's resources of people time, resources of money, resources of management and if you work the sort of steps backwards is what we have asked for and what we had tested it against what we are calling a base line design so we are saying that all buildings will be tested, we have now a benchmark design and the key objective of that benchmark design from an environmental perspective was focussing on ventilation, day lighting, acoustics and then how the buildings are managed, obviously energy and water."*

The acknowledgement that the existing mandated process is not as effective as it could be is indicative of the feeling across industry. The need for government to continue to apply pressure on industry legislatively is apparent in Facilities Manger – Developer 18's discussion; perhaps driven by his organisation's previous investment in creating lower energy buildings:

> *" I think that government's role in this is important and I think that there is no one single thing that actually necessarily causes it to happen but I mean certainly the introduction of CRCs created more interest from occupiers and so perhaps the interest from occupiers has in part been driven by the fact that they see the same legislative imperative that we do and certainly the message that we give government is 'don't take your foot off the gas on all of this'."*

The safety net of the knowledge that legislation means eventually Facilities Manager 18's competitors will have to make similar investment in energy efficiency measures means that he can justify investment more easily to the rest of his company. Creating the informal climate for a low energy drive is important.

A major influence in the legislative landscape is the continual change, these changes and uncertainties make it difficult for actors to keep up with necessary strategic thinking on design. Architect 05 describes his frustration at the rapidly changing definition of 'green' and the fact that his buildings might be much better than others but, publicly, have the same grade.

> *"a kind of gripe I suppose I've got is that buildings…couldn't be better in terms of grade, it's like an A-star grade, but they [often] didn't even have to prove they did it."*

The perception of a building can quickly change from being very good to being mediocre with newer buildings labelled better with no evaluation to check if performance matches the claims. In contrast, Engineer 17 expressed some frustration with the static nature of existing legislative metrics, suggesting an incentivised scale as a more effective way of effecting change:

> *"at the moment the legislation is all about compulsion and you will comply with this minimum standard and building regs: that's fine, that's a safety net but that would be, if you worked the legislation that said if you consume 100 watts a square metre it is going to cost you this much land tax, if you consume 50 watts it is going to cost you half that, if you consume ten percent we will give you ten percent back. Some sort of sliding scale."*

The idea of existing legislation as a 'safety net' with incentives to go beyond it is powerful. Engineer 02 expresses some frustration with the multi-faceted approach represented by the contextual pressures that he sees as making it difficult to meet legislation in a coherent way:

> *"You know it's like…wrestling a bag of frogs. You push one and they all jump out the other side somewhere. There are just so many variables in this, that I can see why they have so many problems in pinning down a reasonable overall strategy to go forwards, you know."*

A clear single goal rather than the existing multi-metric contextual pressures may be easier to meet but would require careful planning. Central Government Policy Maker 13 reiterated the need for legislation to reflect how buildings are actually used and to present a metric that is relevant to designers and managers:

> *"building regs are energy efficiency but not energy management or energy reduction or building physics that actually support a straightforward, easy to support, easy to manage [building type]. [Building type management] do not have money to operate a technically challenging complex ... the carbon agenda has taken our eye off of the basics and we've leapfrogged from what is appropriate for [building type]s, what is appropriate for tax payers all of*

> *those things, but for public buildings we completely took our eye off the ball on this"*

Sustainability Consultant 16 describes the conflict between what the building legislation asks her organisation to deliver and what her clients get. The implications for her organisation could be serious and articulate the fear of litigation running through the issue of feedback:

> *"I think this is a really difficult question and I think it will get more conflicted and contentious as time goes on, because I think there is a really clear break between what we can do in designing a building and what we have legally delivered as a designed building; so for example if we have designed a building and calculated that it complies with Part L… and the building doesn't perform as expected, is it because we didn't design it very well, in which case we are in legally difficult position, or is it because… they have just plugged in loads of stuff."*

The current legislative landscape seem to generate confusion in industry and ambiguity in actors' responses, Architect 01 discussed how her practice is actively encouraged to reduce the predicted energy consumption of projects through planning policy:

> *"we have to use renewables on some projects [for planning permissions]…the lower the energy figure the lower number of solar panels our client has to buy. The planners encouraged us to make it lower."*

The contextual pressures can discourage low-energy buildings, often contradicting each other; they are also frequently revised. The changing legislative landscape frustrated interviewees; Engineer 02 expressed his frustration with the legislative landscape and the need to continually revise working methods to deal with the changes:

> *"there are a lot of angles in which the agenda which has been set [and] was supposed to throw things to the market place to sort out, which was almost the religious principle of the time; it has patently failed to achieve that. They have actually stirred it up by changing the goal posts and planning to move the goal posts every three years which is a crazy situation...Part of which is the work done to get to that point by whoever it be - manufacturers, suppliers or developers - is wasted because we then have to move on in very short period of time to an alternative solution involving alternative design methods and products."*

A clear, long-term legislative goal is required; there is a range of difficulties with constantly changing targets, not least the difficulty of redeveloping solutions and standard details.

Uncertainty and constant change means re-learning regulation and developing new solutions. A feedback platform could help with a more rapid dissemination of information and solutions. Architect 05 expanded on this:

> *"[they say] the design must have a 'high quality of sustainable design'. You say well, what, how is that going to be judged and, and the… safest way seems to be at the moment to say 'oh it's a BREEAM excellent or BREEAM outstanding or good or whatever'; but again we find that they are slightly behind because in the recent BREEAM updates you didn't have 'outstanding' so you had 'excellent', which was the best you could get and an 'excellent' building on, say, 2008, I'm not too sure exactly, might only be a 'good' building now."*

The prospect of legislation addressing some of the issues explored in this thesis; linking design and actual building performance is raised by Manufacturer 14 through the prospect of future project briefing specifying an energy performance target:

> *"It's going to be interesting following in future years tender processes when clients actually specify the energy consumption… and there is a penalty clause in place. I have a feeling that that is where the industry will arrive at sooner or later. At the moment there is so much laid out in legislation to just derive how energy consumption should be achieved, it's almost missed the bigger picture because you can design a building so many different ways but the end result is just trying to achieve X amount of kilowatt hours per metre squared throughout the year."*

This approach would make explicit the grounds for litigation, perhaps overcoming some of the existing ambiguity and resulting fear. Sustainability consultant 16 expressed some reservations over the ability to legislate for energy consumption in this way:

> *"it would be very difficult to legislate to say that a building has to achieve, you know, [an energy performance] that would put everybody in quite combative positions with each other."*

Survey respondents and interviewees cited mandatory targets as the most common means of determining project energy targets. The confusion surrounding the standards indicates that the contextual pressures are perhaps not creating the best conditions for the development of low energy buildings. The feelings of interviewees about the impact of legislation on their activities was mixed and included the need for legislation to better reflect the rounded nature of sustainability and the multiple influences on energy consumption, not just building fabric. Legislation currently does not provide a suitable incentive to actors since the metrics employed are not those that industry generally uses to motivate itself or to measure performance – carbon for example is a distraction. On top of this, the multiple metrics used by the contextual pressures create a confusing atmosphere in which actors need to measure performance and show compliance in many different ways. However, despite this there is no guarantee that performance is accurately predicted or that the contextual pressures allow and encourage a fair comparison between buildings.

The changing legislative landscape means that the definition of a good building can change quickly, and with that the reputational benefits can be removed. Changes in legislation and metrics mean that actors are constantly reinventing products, processes and organisational frameworks. The uncertainty in the timetable exacerbates the problem. When the contextual pressures are changing at different rates and in different ways, negotiating the network becomes more complex. The disconnect between legislation and legal responsibility creates ambiguity and may reduce building quality. Legislation has a role to play in reducing the confusion and potential conflict in the construction industry; an ‘as-built’ target may be the way to achieve this.

7.10 Innovating

A number of interviewees, particularly those in design professions, admitted that early stage design work is based on work that has been previously proved ‘compliant’. In design practices working on similar building types, there is a degree of strategy repetition in design practice, rather than innovation. Risk-averse clients, the planning process and Part L were cited as part of a process that encouraged repetition of ideas and the avoidance of risk. This is not necessarily a bad thing, but in the context of an industry that does not test if things work as intended, it may be mean the repetition of mistakes. When asked how she knew her designs would be compliant with building regulations Architect 01 said:

> *“I suppose, at planning stage, we don’t quite simply. I mean, we have a strategy that we have used before that has previously worked and that’s more or less regurgitated.”*

This lack of design exploration is due to a number of factors, including time availability and costs, but this quick justification of a decision also means that alternatives are not sought. Statutory compliance was also frequently cited as a barrier to creating ‘good’ low energy buildings: designers felt that they were often asked to do things that they knew, either through experience or calculation, to be detrimental to building energy consumption, to their organisations' or their clients' reputation, or to the utility of a resultant building.

Engineer 02 cited examples of wind turbines and solar water heaters on the roof of a new building as a means of achieving a planning permission: he thought they would generate a net loss of electricity due to the use of power by the controls thus making him look incompetent. The architect wanted to use the roof for outdoor communal space which could not happen, making him look incompetent. The client would have higher energy bills and less external space.

> *"…I mean the lack of flexibility has been forced through policy… it wasn't difficult to work our way through the various renewable options on the table…and of course most professional engineers when they saw the tabling of wind turbines on an urban building all threw their hands in the air and went 'Woah, this is crazy' but then the planners and their clients couldn't get buildings approved without doing it. So you can't sit at a table with a client who is paying you a lot of money and stop them from getting planning permission by suggesting something different that the planners won't accept"*

The contextual pressures are aimed at lowering energy consumption and carbon emissions, but without flexibility or evidence-based decisions, tick-box solutions like the one described above will be delivered, rather than genuine good performance.

The development of innovative design solutions may be hampered by the existing contextual pressures. The combination of building regulation compliance, risk-averse clients, a lack of expertise in project teams and low fees can lead to a repetition of untested ideas rather than the development of new thinking. The contextual pressure can also force actors to specify solutions that they know do not work but are necessary to comply with statutory obligations. A feedback platform could allow for a process of evolutionary innovation to take place across industry.

Intellectual Property

One of the barriers to sharing information raised by a number of interviewees was the fact that information can form the basis of marketable knowledge, and sharing it could mean losing an organisation's competitive advantage. Developer 10 said:

> *"we have talked about whether we want to put some or all this in a big document; the problem is that we are a fairly small company in terms of head office staff in here so when I have these meetings, I have to make sure I remember what I have learned and it is there but making a document that*

> *replicates my mind or some of the other people's minds and what we have learned actually isn't worth our time and money"*

This also raises the issue of intellectual property and knowledge sharing. While Developer 10 sees the costs as a barrier, others see their expertise as a valuable asset. Energy Consultant 022 describes her organisation's attempts to create a work manual:

> *"something that I am trying to develop with one of my colleagues is this energy efficiency guide [for building type]... here is all the different kinds of projects you can do, but at present it lives in our brains, and is our intellectual property…so I think as a company at moment we are a little bit nervous about putting that all down on paper actually because, that is our strength."*

This perhaps explains some of the lack of data in the CarbonBuzz platform; despite the fact it is anonymous, organisations may feel like they are giving away their 'strength'. A feedback platform must strike a balance between organisations' competitive advantage and the collective good of industry.

7.11 The future role of feedback

The requirements and potential for a new feedback tool using empirical data were discussed with the interviewees. Architect 04 thought feedback and energy analysis should be better integrated into existing design tools:

> *"I think it would help if it was more integrated into design software.*

Linking empirical data to existing modelling software may help some of the poor assumptions and predictions illustrated in chapter 7, but without change in the legislation there is no guarantee that the output would change or be more accurate. Architect 07 said:

> *"it should allow you to eliminate a whole bunch of things…it's got to be better than SBEM as a way of just narrowing down your strategy."*

The idea of narrowing down design strategy is something that a feedback platform well stocked with data could help do through identification of environmental situations and sector-specific low energy solutions at an early stage in the process.

Local Authority Policy Maker 12 saw a role for feedback in the creation of benchmarks and to challenge assumptions in existing design models:

> *"a national platform could build up a better, a more useful average, then potentially we would be keen to try and write that into our guidance to try and say well we wouldn't accept the use of this old benchmark because our*

> *evidence shows ….you should be using this one instead. I think that would be one potential role where we would identify problems with the assumption used and it might not even be just a benchmark, I guess it might just be more just about more carefully interrogating those assumptions…"*

The creation of more robust benchmarks has been explored in chapter 7. Architect 20 describes in detail the complex nature of building systems and the kind of data that he feels would be beneficial to be able to glean from a feedback tool:

> *"it would need costing information in it, [and] standard details [and] the way that different systems interlinked, so for example a certain kind of window, how that coordinates with a certain kind of wall building-up because you can often get information about systems, you know like a cladding system or whatever, an insulation system or a window system but sometimes it's the junctions where those two meet that is the problem… there is a whole question about service, I am talking about fabric [size] because that is what I can change myself but I can't really, I don't feel like I have enough information to be able to properly question a service engineer when they are saying that they want to go this way or that …it would be really nice to be able to point to some examples 'they used that sort of, that strategy and it was x times better than the one that you are proposing so what gives. That would be really useful."*

The scope of information Architect 020 believes would be beneficial is extremely broad and beyond the remit of an energy feedback platform. However, in identifying important key details in building fabric and system design, it illustrates the range of issues that might be contained in supporting documentation to justify actors' decision-making.

Interviewees views on what a feedback tool might offer varied from feeling it was unnecessary (those who were protective of their expertise) to a comprehensive information service. Feedback could connect to existing modelling and calculation software platforms to integrate empirical data into modelled assumptions. It could also provide information about construction types and systems, construction details and compatibility of fabric types and be used to generate new benchmarks and interrogate and challenge assumptions. However, actors' intellectual property and expertise is at stake. Actors and organisations trade on their knowledge; this may make it difficult to persuade them to give it away to a feedback platform.

7.12 Summary

The semi-structured interviews have illustrated some of the findings of chapter 7 and 8 and introduced some new themes to this research. The discussion was centred on the following topics.

Aims and Targets

Mandate is the most important way of determining targets but can be a distraction from focussing on genuinely good performance. It can be used a simple tick-box exercise rather than a meaningful performance goal. At design stage, actors are much more likely to use cost as a metric rather than anything represented by the contextual pressures. There is some resentment at the focus of legislative targets, although they do oblige reluctant actors to take action. They can cause confusion in industry and greater clarity is required.

Setting project targets can be difficult with lay clients; communicating the concept of energy with clients requires the use of simpler and less abstract metrics. Consistent with the contextual pressures, the complexity of projects means that energy is a small part of a broader set of briefing targets with costs at their centre. Project targets and predictions generally carry caveats to prevent liability for failure to meet them.

Assessing Implications

Predicting energy consumption is a complex process often carried out without the input of key expertise. Assumptions are made and the uncertainties communicated to clients with some difficulty. The predictions cannot be a performance guarantee.

The multiple metrics used by the contextual pressures and legislative framework can create confusion in industry. Uncertainty in the changing legislative landscape can increase costs and hamper industry efforts to streamline their processes. Legislation does not necessarily reflect industry's motivations and therefore can become an inconvenient tick-box exercise rather than a driver of good performance.

Informing Decisions

Decisions in the design and management professions are made using assumptions and various calculation methods. Different calculation methods can impact on the way information is communicated. Rules of thumb and quick strategy development are used in the early stages of decision meaning a feedback platform can influence these.

Communication is emphasised as important to developing a design or management strategy by most interviewees. The disconnectedness of the project team means that responsibility is sometimes not matched by expertise and therefore communication of information and ideas is more important than ever. Poor information flow can hinder the process and lead to poor decision-making by the project team.

Tacit feedback loops exit in most practices but rely on individual actors remembering to pass on information. The casual nature of the loops may mean that only information significant to individuals is passed on, rather than a rounded debriefing of the project. In organisations with less complex products like component manufacturers or companies with ownership of buildings, information can be better integrated into the decision-making process.

Barriers and Disincentives

Liability and costs are the main barriers to carrying out POE. Some feel the benefits of POE are clear but cannot convince clients to pay for the information. Others can see the potential benefits of POE but these are outweighed by the risks. The barriers are also numerous and small, combining to create an overriding block to POE and feedback use.

Intellectual Property

The culture of industry can hamper innovation in design. The contextual pressures can hinder innovative thinking by forcing actors to specify solutions that they know do not work. The fear of lost competitiveness can hinder actors' willingness to share information.

Causes of Poor Performance

The lack of expertise amongst the design team or client base can mean key decisions are made without proper understanding of the implications. The contextual pressures mean that the key expertise may not be present when decisions are made or those responsible for making a decision lack the necessary knowledge. Communication between the experts and laypeople is important with a metric that all in the process can understand.

A key source of poor decision-making and subsequent building performance was in changing ownership of buildings or designs. The lack of coherence in project development means that the design intent can be lost. A lack of onward responsibility for running costs or construction quality can also remove any incentive to create a well performing building.

Incentives

A key incentive in the design, construction and management process is money; profit, costs and savings. This is not reflected in a coherent way by the contextual pressures. POE and feedback are not perceived to have value and therefore are not profitable and do not get implemented. Investment from industry is needed to demonstrate value in low-energy buildings and generate a market for this work.

Procurement

The procurement process requires careful setting up and coordination to ensure that it does not hinder the development of buildings. Risks should be apportioned to those responsible and should be reflected in the contractual set-up.

The distribution of risks in the construction industry creates a culture of blame. The need to pass risk down the supply chain may cause increased costs and poor decisions to be made. Coordination of design intent becomes more difficult, as is attributing responsibility to the appropriate actor. Risk no longer resides with the actor best positioned to deal with it.

Project team relationships

Project team relationships require trust between different actors to ensure efficient working practices. The contextual pressures and in particular the procurement set-up of a project team have a strong influence over this. The communication of information is essential for this, as are motivated individuals to push forward the energy agenda however; the atomised, often unfamiliar and frequently litigious relationships in industry teams can make this difficult. There can be conflicting aspirations between members of the design team, between the design team and the contextual pressures, and between individual components of the contextual pressures. These conflicts can lead to poor decisions being made, either through different agendas being set, misplaced intent or lack of expertise.

Like project team relationships, client relationships require trust and communication. Repeat business is dependent on good relationships that can involve informal feedback loops communicating a range of data.

The future role of feedback

Finally, interviewees discussed what the future role of feedback might be. They thought that it should be connected with existing working practices, be able to generate new benchmarks, and should provide rapid strategy clarification. Others thought it should be linked to comprehensive data about the design and makeup of a building. However, many thought that giving away intellectual property may reduce their value as professionals.

8 Discussion – What changes need to be made to the contextual pressures or actors' behaviour to implement this future role of feedback?

This chapter aims to draw together the three strands of the research, pulling together the different investigative techniques. This thesis has employed a mixed methods study to investigate the current role that energy feedback plays in the design, construction and management industries. Four sources of data have been used: participant observation in the development of the CarbonBuzz platform combined with a document review to outline the contextual pressures, described in chapter 3; an internet-based survey of industry, discussed in chapter 5; data from the CarbonBuzz platform discussed in chapter 6; and a series of semi-structured interviews, discussed in chapter 7. This chapter aims to synthesise the research carried out to answer the final research question, beginning with a recap of the work to this point. The previous four research questions generated a phased methodology. The first was aimed at understanding the context for actor decision-making in the UK design, construction and management industries. The description of contextual pressures was developed through the first two phases of the research process and describe the setting for decision-making in industry. The framework is based around the procurement process as defined by the RIBA plan of work and the CarbonBuzz defined project development stages.

The three subsequent questions were used to define the methodology for the main data collection and analysis procedures. The second question aimed to understand how industry behaviour was influenced by the contextual pressures and to uncover any variance in the intention of the pressures and the aspirations or motivations of industry. The third question focused on the relationship that the data in an information feedback platform has with the contextual pressures and actors' experience of working within them. The fourth question built on the findings of the empirical research to define the role that feedback currently and needs to play in order to offer meaningful incentives and support to actors making decisions that impact on energy consumption.

The final research question asks how the contextual pressures and actor behaviour needs to be altered to deliver this future role of feedback. The discussion is organised around these four topics and potential further work:

> 8.1 How do the 'contextual pressures' influence the [lack of] interplay between design and construction practice and energy information?
>
> 8.2 What is the potential for crowd-sourced data platforms to fulfil the role of feedback mechanisms?

8.3 What does the relationship between the contextual pressures; building energy data and actors' experience tell us about the future role of energy feedback?

8.4 What changes need to be made to the contextual pressures or actors' behaviour to implement this future role of feedback?

8.5 Further work

Each section is organised around statements of key findings.

8.1 How do the 'contextual pressures' influence the [lack of] interplay between design and construction practice and energy information?

This section is organised around the following finding statements

- The Contextual Pressures influence the interplay between design and construction practice and energy information.
- Building energy consumption reflects actors' experience of working within the contextual pressures.
- The contextual pressures represent a suite of influences that inform actor behaviour.
- Actors' relationship with the contextual pressures and therefore their data requirements varies depending on their role in the design or management process.
- Actors' willingness to engage with energy and information feedback depends on their attitude to energy and broader sustainability rather than the contextual pressures
- The performance gap exists in part because energy performance assessments do not include all of the energy uses found in buildings.
- Feedback is not habitually used in design, construction and management practice to highlight the performance gap.
- The type of information collected varies with the motivations and role of individual actors' and sector.

8.1.1 The Contextual Pressures influence the interplay between design and construction practice and energy information.

The research has shown that the contextual pressures influence the behaviour of actors in different ways. The pressures, while influencing actors' behaviour and ensuring some consideration of energy consumption, do not coordinate with the aspirations, and motivations of industry or the way that industry operates as a network of independent and mostly commercial organisations. The barriers to engaging with energy and feedback are the strongest aspect of the contextual pressures, and a rebalancing of the framework is required to ensure that feedback is a valuable and valued part of practice.

The way a project is set up – the contractual relationships between actors and how responsibility is distributed - is an important part of the contextual pressures not described in chapter 4 that can result in poor information flow, and an atmosphere of mistrust. As a result it can impede effective decision making and attribution of responsibility.

Given these relationships between clients and other project team members, the contextual pressures are conducive to casual and anecdotal feedback. Where the contextual pressures target a direct financial relationship, such as CRC intervention in the way facilities managers manage their property, the feedback used is more focussed and actions are direct and quantifiable. This was found throughout the data: those with a direct financial relationship with building performance respond the most positively to the contextual pressures and engage with energy data, whereas those with a consulting or other relationship respond to the risks involved. Those with a developmental or constructor role are motivated by compliance in order to carry out the profitable parts of their operations.

The often disconnected project team, combined with the simplified metrics of the formal framework of contextual pressures can result in decisions that do not account for the complexity of energy interactions. Within the formal framework of the pressures, the mandated part in particular is used to define project energy targets. The focus of the formal pressures on building fabric and technology places the onus on developers to finance energy efficiency through technological fixes rather than on designers to make early decisions that reduce the need for fabric and technological measures. Where the pressures are prescriptive and arguably misguided, this can lead actors to specify things they would not otherwise do.

Non-mandatory parts of the contextual pressures, for example the CIBSE TM46 benchmarks, appear to have no direct influence on actors' predictions; data in CarbonBuzz suggests these benchmarks are not used as guidance and do not reflect existing performance, which was confirmed in interviews.

The energy evaluation parts of the contextual pressures can be seen as a tick-box exercise that everybody does; those that go beyond them often run a parallel monitoring system in-house to facilitate this. However, the contextual pressures appear to influence the energy gap; they encourage a low prediction rather than a low actual performance.

The barriers to feedback use in the contextual pressures are the overriding factor influencing actor behaviour. The lack of data available in the public domain and in the CarbonBuzz database in particular makes it difficult for actors to challenge the barriers that exist in the contextual pressures. While some actors take a degree of comfort in the fact that all of industry has to engage with energy and use this to push their own agenda beyond obligations, the contextual pressures influence industry in ways that are not entirely intended. With changes in the focus of the pressures, industry activity could be positively affected. Currently the most positive aspect is the creation an atmosphere of informal pressure.

8.1.2 Building energy consumption reflects actors’ experience of working within the contextual pressures.

The energy consumption data and associated building characteristic information in the CarbonBuzz database is limited; this in itself suggests that the barriers in the contextual pressures are reflected in the data.

The formal regulated framework is contributing to the performance gap as there is no need to provide an accurate prediction. While the contextual pressures appear to influence the way energy consumption is predicted, even when actors go beyond the minimum obligations and use a rounded prediction including disaggregated end-uses, the energy gap still exists, suggesting other parts of the pressures influence the predicted values. Electricity consumption is most consistently predicted (although has a larger mean gap than heat), despite being the value least influenced by the formal contextual pressures.

Different actors appear to have different relationships to energy data. There are differences between depth of data supplied by architects and engineers. The platform is architect-led but architects’ central, or at least constant, presence in the development process may make them best positioned to gather and share building information in the future.

The energy data analysed in chapter 6 suggests that different building sectors can have a different relationship with how energy predictions are made within the contextual pressures. The energy gap varies between the Office and Education sectors. The complexity of end uses and the lack of predictability in occupancy patterns are not captured by the contextual pressures or the predictions based on them.

The simple inclusion of information in energy predictions is not a guarantee of an accurate prediction or good performance. The energy data shows that data are infrequently collected and uploaded to CarbonBuzz suggesting that the barriers in the contextual pressures are the overriding influence. The energy data that is in the database confirms the finding of question two, that the complexity of building energy consumption is not reflected in the contextual pressures and therefore in actors’ energy predictions.

8.1.3 The contextual pressures represent a suite of influences that inform actor behaviour.

The data suggests that the contextual pressures have a variable influence on actors' behaviour and decision-making, not always commensurate with the intentions of the legislative framework. Mandatory targets are important to actors when setting project goals and developing energy targets; however inconsistencies within the framework and between the framework and industry means that the relationship between actors and the pressures is complex. The contextual pressures represent a set of influences that rely on a coherent and unified project team. Some aspects of the pressures, such as the apportioning of risks and contractual set-ups used, mean that the relationships between the project team members prevent the kind of free-flowing information exchange that the design stage contextual pressures rely on. This can result in poor information exchanges and non-technical members of the design team not getting the support that they need to make evidence-based decisions.

Buildings are complex interactive energy systems: the contextual pressures necessarily simplify this into piecemeal metrics aimed at parts of buildings that fall under the responsibility of individual actors. This combined with disjointed project teams means that the complexity of buildings is not often accounted for in targets or subsequent decision-making. The simplified piecemeal approach of the contextual pressures can mean that important decisions are made by actors who do not have the expertise to make them, or that actors do not want to have the potential financial burden represented by the responsibility for taking them.

While the contextual pressures oblige all actors in industry to consider energy, at least in compliance calculations, they can also contradict each other or actors' intentions and force actors into specifying technologies that they know will not work. Actors also feel that the uncertainty created by constantly changing pressures and in particular relationships between the pressures and their own motivations mean that the pressures can become a tick-box exercise rather than an aspirational goal. This conflict of interest can mean that there is no guarantee that legislative targets have been met; actors can negotiate their way around them.

The commercial nature of the construction industry and building ownership is not reflected in a coherent manner by the contextual pressures; carbon does not drive the development or sale of buildings. Changing ownership and project teams can cause breaks in the chain of responsibility. Actors mitigating financial risks or owners capitalising on the value of design proposals prior to construction or selling recently completed buildings are not considered in the pressures.

Measures within the contextual pressures aimed at increasing industry engagement with energy, feedback and post occupancy evaluation are not great enough to outweigh the perceived financial risks posed by doing so. The contextual pressures, in this respect are not utilising industry's natural levers; the contextual pressures do not offer enough of a direct financial or reputational benefit to properly engage industry.

The pressures mandate that a certain amount of information should be available for every project – through a building regulations compliance calculation – but this information is often absent from the CarbonBuzz database, suggesting that the informal pressures create powerful barriers and disincentives even for actors who are wilfully engaging with feedback and impacting on the subsequent quality of data available to be used for feedback.

The different calculation methods stipulated by the contextual pressures have different outcomes for the energy gap. This in turn may influence how actors respond. The focus of the contextual pressures on building fabric and fixed building services for compliance calculations, as well as the introduction of renewable energy sources for planning approval, means that actors are influenced in ways that are not necessarily the best way of designing buildings but the best way of meeting regulations.

However, some parts of the framework are more successful, for example those aimed at actors with a direct financial interest in building performance rather than those aimed at designers.

8.1.4 Actors' relationship with the contextual pressures and therefore their data requirement varies depending on their role in the design or management process.

Actors' relationship with the contextual pressures varies depending on their role. The different approaches could potentially impact on how well a building is designed and developed. The clearest and perhaps most obvious relationship is between those actors with a direct financial relationship with a building and those parts of the contextual pressures that use financial incentives. The majority of actors do not have a direct financial relationship with building operation but could stand to gain from reputational benefits from well performing buildings.

Those with a financial interest in buildings are more interested in performance whereas those who provide consulting services are more interested in reputational benefits, or reputational protection. Those who own or manage buildings can access properties and data. Manufacturers of components can test and modify their products whereas members of design and construction teams have less of a unified interest, less access and more risks associated with collecting data. This becomes particularly apparent in procurement routes where responsibilities are unclear, risks are sub-contracted to others, or the ownership of a design or building changes hands part-way through a project.

While many actors would like to absolve themselves of responsibility and therefore the risk associated with decisions that they make, those that wish to make genuinely low energy buildings have difficulty overcoming the barriers in the contextual pressures. The actors' relationship with energy could be broken down into three types: first those who are engaged with building energy consumption and wish to produce well performing buildings, for whatever reason. They are able to overcome the barriers, access information and act on it; second, actors who wish to be engaged but are hampered by barriers, project set-ups or the formal framework of the contextual pressures; finally, actors who are content to meet the minimum standards and avoid unnecessary risks - for them the contextual pressures are something to comply with at minimum cost.

8.1.5 Actors' willingness to engage with energy and information feedback depends on their attitude to energy and broader sustainability rather than the contextual pressures

The avoidance of risk and lack of resource means that actors are reluctant or unable to collect and analyse data. Those that do do it by running a parallel system to the contextual pressures, such as using a specialised data monitoring consultancy - the need for motivated individuals to drive the agenda is clear. However, even those that work for organisations with stated interest in this subject can still be hampered by the over-riding barriers in the contextual pressures and project set-ups.

The reliance on mandate to determine targets and ensure that energy is given any consideration at all suggests an industry happy to be led on the issue of energy rather than setting their own agenda. The majority of data collection that does take place seems to be through casual and informal communication methods that are never formalised or collated into a sharable format. This invaluable information must be tied with quantitative data.

8.1.6 The performance gap exists in part because energy performance assessments do not include all of the energy uses found in buildings.

The relationships between design predictions and actual recorded data are more complex than simply not including all end-uses in predictions. The nature of the gap is different depending on the calculation type used, suggesting the contextual pressures have some influence on design stage prediction rather than actual performance. This variation in the gap between electricity and heat consumption suggests an under-predicting of consumption in electricity and a lack of understanding of heat consumption. The energy gap is also different between different sectors for example between Education and Office buildings.

The relationship of education projects with detailed end-use data energy consumption and CIBSE TM46 benchmarks suggests that the energy gap is driven not only by a lack of inclusion of end-uses. In projects where rounded energy predictions are made including a range of disaggregated end-use predictions including un-regulated uses, the discrepancy between design and actual records is still often over two-fold. The presence of information alone does not mean accurate predictions will be made; the interaction is more complex than this. Predictions are influenced by other pressures to keep them low and consequently regulated energy demonstrates a larger energy gap than unregulated.

8.1.7 Feedback is not habitually used in design, construction and management practice to highlight the performance gap.

The data shows that feedback is not habitually used in practice to highlight the performance gap – while the majority of survey respondents claimed to collect information from at least ‘a few’ buildings, the data in CarbonBuzz and the interviews suggest that the process is a very informal one, if it happens at all.

The feedback that does happen often relates to qualitative aspects of buildings or immediate maintenance problems with some aspects of the structure. More formal feedback does not happen because of costs, particularly in the present climate. Where data is collected, communication of the information is likely to be informal and casual rather than a systematic feedback process.

While the membership of the CarbonBuzz platform has increased year on year, suggesting growing interest in the energy gap and feedback generally, the number submitting data is still small. Feedback is not habitually used in practice.

The largest group in the membership list is architects; however there is a diverse representation of industry practitioners, most of whom have not entered data. The lack of data hampers crowd-sourced platforms like CarbonBuzz’s ability to overcome the barriers that prevent further engagement with feedback.

Formal, regular energy and building characteristic feedback is not habitually used in industry – although it is carried out by those who have a direct financial interest in building performance or are employed specifically to carry it out. Casual, anecdotal and often qualitative feedback is habitually communicated from finished buildings.

8.1.8 The type of information collected varies with the motivations and role of individual actors' and sector.

Just as different actors have different relationships with the contextual pressures, the type of data collected varies between those who have a direct access to and financial interest in buildings, those who have a specific performance monitoring role, and those who simply provide standard consulting services such as building or system design.

Those actors with direct financial interest in building performance either through paying the bills, CRC commitments, performance-related contracts or a monitoring role, by necessity collect detailed end-use energy consumption information where available. Those who provide consultancy services tend to collect anecdotal information only about aspects of their work that have performed badly or particularly well – or actively avoid collecting any other information at all. The data in CarbonBuzz comes largely from 'bills'. This is headline data that cannot identify problems or offer the insight required to provide a service improvement or detailed design advice.

8.2 What is the potential for crowd-sourced data platforms to fulfil the role of feedback mechanisms?

This section is organised around the following finding statements:

- *The relationship between the contextual pressures, building energy data and actors' experience can inform the future role of energy feedback.*
- *Feedback could be used to diagnose and resolve problems with building performance.*
- *Feedback can be used to diagnose and resolve problems with actor performance.*
- *The contextual pressures present a set of barriers that hinder effective collection, storage and dissemination of feedback data.*
- Feedback platforms can overcome the barriers inherent in the contextual pressures
- *What quality checks should a crowd sourced feedback platform carry out on uploaded data?*

8.2.1 The relationship between the contextual pressures, building energy data and actors' experience can inform the future role of energy feedback.

The data shows that the disconnected responsibilities and motivations of actors can lead to misaligned aspirations for building performance. This can be exacerbated by contractually distant relationships between actors and building projects. The subsequent inability or unwillingness of actors to collect or provide energy feedback suggests that a future role for building information is to bridge the division created by the contextual pressures. Information must overcome the current industry culture of blame and risk aversion, in a format – changeable if necessary – that different actors can engage with.

In order to do this, feedback must be able to identify where energy is used in buildings relative to a set of building, system and use characteristics. Currently this is not possible using the data in the CarbonBuzz platform. Feedback itself must be used to create conditions in which it is much easier to justify and collect feedback data.

8.2.2 Feedback could be used to diagnose and resolve problems with building performance.

The contextual pressures make it unlikely that actors are able to resolve problems with existing buildings, unless they have direct access to the projects in question. Designers and other members of the building procurement process all aim to improve future projects, illustrating the broken chain of responsibility that can result in poor decisions or poor information flow.

While it is apparent that detailed and rigorous real-time feedback is used to identify and resolve building performance issues, the value of a wider static platform like CarbonBuzz in immediate problem-solving is less clear, particularly when the contents are sparse and consist of headline data.

Where feedback is used to diagnose and resolve current problems with building performance, it is used in real time or by means of frequent half-hourly recorded data. Data in a feedback platform like CarbonBuzz which offers annual, static records is less likely to be useful in determining problems with building performance and more useful for strategic decisions and comparisons with new benchmarks. Platforms need to explore the greater amounts of data needed to assist with detail design decisions, to be more than just a benchmarking tools.

8.2.3 *Fe*edback can be used to diagnose and resolve problems with actor performance.

The ability to access information is hindered by a perceived lack of need or value in the data and the lack of expertise required to prove a need for information. Actor performance could be characterised by the decisions that they make and the way that they drive a particular agenda. The data suggests that a feedback platform could be used to support actors' decisions, help define design strategies and provide a basis for convincing others. However, there is not a sufficient amount of data currently in CarbonBuzz to provide this.

A feedback platform could be used to help improve actors’ performance by supporting decisions and providing quick justification for strategic design. This is dependent on greater levels of statistically robust data to provide evidence-based support for strategic and other decisions.

8.2.4 The contextual pressures present a set of barriers that hinder effective collection, storage and dissemination of feedback data.

The barriers represented by the contextual pressures of increased costs, fear of liability and reputational damage are evident in the data. Organisations protect their work by ensuring that design predictions made as part of reports for clients are not binding. This risk aversion stems from both not confidently being able to predict building performance due to the uncertainties inherent in the procurement process and subsequent building use, and the pervading blame culture that exists in industry.

The barriers include the project team set-up, contractual relationships and the legislative framework. They create an environment that hinders and exacerbates other barriers. There is not a briefing requirement to meet an energy target; there are as yet, no ‘as built’ regulatory checks. This means that there is no obligation for actors to check their work and no reason to risk their reputation. This lack of obligation means that POE is an unnecessary risk and as it is not going to be carried out this perhaps allows less diligence at design stage. Some actors have shown that there is economic value in low energy and green buildings but given the current cultural conditions, it would arguably be unprofessional to expose oneself to risk. The lack of information to the contrary perpetuates the idea that predicting consumption is a risk. The costs of collecting information are not built into the project contract and the lack of perceived value in the information means that it is not likely to be collected. The lack of information means that the value is never explored and the risks never understood.

There is a circular set of barriers that need to be broken which the contextual pressures support; they may only be broken by the availability of some data to show that they are not the barriers industry think they are. To produce this data will require a sea-change in how industry is set up and regulated.

8.2.5 Feedback platforms can overcome the barriers inherent in the contextual pressures

The barriers that are inherent in the contextual pressures and prevent data being collected also, by extension, prevent insights being gained that could help overcome these same barriers, however this is dependent on sufficient quantity and quality of data being available..

The limited amount of energy data available in the CarbonBuzz database suggests that the existence of a feedback platform alone cannot overcome the barriers that prevent users adding data. CarbonBuzz itself may be a barrier to the use of feedback: it is regarded as extremely onerous to use, and those actors who do carry out rigorous feedback and post occupancy evaluation do not use CarbonBuzz to organise their data and explore their buildings, rather, they use parallel in-house systems.

The focus on carbon does not encourage industry involvement in feedback. It is seen as irrelevant by many. The rigidity of the analysed platform's format means that it cannot be adapted for individual actors' needs. The quality of information in a feedback database is questionable; even those records that superficially represent a plausible energy record can be open to question on further interrogation. A feedback platform must offset the barriers inherent in the contextual pressures, not reinforce them.

While the studied feedback platform has been shown to offer the possibility of new dynamic benchmarks as an alternative to the contextual pressures, this requires a large database to provide statistically robust targets which does not yet exist.

The interviewees expressed interest in a platform that can provide quick and reliable strategy development. This would not necessarily 'overcome the barriers' of the contextual pressures but may be a starting point for a platform that can go well beyond this. At the moment CarbonBuzz is neither one thing nor the other: the data is not detailed enough to offer support for detailed design or management decisions, nor plentiful enough to offer robust benchmarks.

A platform needs more data and of better quality; in order to capture more data the barriers must be broken down. A feedback platform demonstrably cannot do this alone. There need to be changes in the culture of industry and the way the feedback is framed before a platform can begin to provide the information service it is designed for.

8.2.6 What quality checks should a crowd sourced feedback platform carry out on uploaded data?

The data in crowd sourced data platforms must be checked for completeness and integrity to ensure viable comparison and insight. This section describes a set of checks based on the sequence identified in the literature review: pre submission checks on completeness and compatibility, relational checks in the data base and boundary checks of information.

Pre-submission checks

Twenty data fields defining a minimum contribution or a 'Complete' record are described below based on the CarbonBuzz database. Each record would require an entry, whether it is a figure or acknowledgement that the data are not applicable or not yet available, in each field to be included in the data base.

Project details

1. Building Factors
    a. CIBSE benchmark category
    b. CIBSE benchmark sub-category
    c. No. of zones
    d. Cost
    e. Area
    f. Services type(s)
    g. Fuel
    h. Low and zero carbon technology
2. Occupant factors
    a. Occupancy figure
    b. Operating hours
3. Data Quality
    a. Design data source
    b. Actual Data source

Energy Data

1. Electricity
    a. Total design electricity use
    b. Total actual electricity use
2. Heat Consumption
    a. Total design heat consumption
    b. Total actual heat consumption
3. Low and zero carbon technology
    a. Design low carbon technology contribution
    b. Actual low carbon technology contribution
    c. Design zero carbon technology contribution
    d. Actual zero carbon technology contribution

The above details would allow for a minimal contribution to the comparative database. Then further checks could be applied to the data once uploaded to the data base

Relational checks

A series of in-database checks to ensure consistency within the record to make sure a meaningful comparison with the rest of the data in the database is possible. The suggested sequence of quality assessment is:

1. Error checks
   - Relational checks made between data fields (for example between benchmark category and building use)
   - Consistency checks made for categorical entries (for example between area and occupancy to determine the plausibility of occupant density figures)
2. Source of data
   - A value judgement made against the data source (for example between the quality of ‘bills’ and ‘sub-metering’)

Boundary checks

Boundary checks could be made based on the range of figures in the platform to determine the plausibility of figures.

3. Plausibility of figures
   - Boundary checks made against appropriate benchmark figures (for example for energy consumption figures)

Quality factor

Finally a quality marker or confidence figure based on the first three sections could be developed to not limit the amount of data uploaded to the platform but to allow users to determine the ‘plausibility’ or usability of the records. This could be an applicable filter in the database.

4. Quality figure a function of:
   - Percentage of entries made
   - Percentage of errors
   - Plausibility of the figures
   - Value of source

It may be appropriate for a sliding scale of quality checks to be made. Different reasons for looking at the data and different actors requirements may require or tolerate different qualities of information.

8.3 What does the relationship between the contextual pressures; building energy data and actors' experience tell us about the future role of energy feedback?

This section is broken down into the following areas:

- Increasing the collection and use of feedback data in industry
  - *Creating value*
  - *Create a reputational benefit*
  - *Overcoming risks and other barriers*
  - *Altering the contextual pressures*
- To support decisions made by the various industry actors to reduce current and future building energy consumption
  - *Engaged actors*
  - *Aspirant but hindered actors*
  - *Uninterested actors*
  - *For all actors*

8.3.1 Increasing the collection and use of feedback data in industry

This study shows that the barriers to accurate energy consumption predictions and engaging with energy consumption are more complex than simply providing a forum for information collection in the hope that this will encourage better practice.

To make effective use of feedback, statistically robust datasets that represent building sectors, system types and construction methods in sufficient detail are required. In order to compile such a dataset, industry needs to be encouraged to carry out scientifically robust and thorough Post Occupancy Evaluation and crowd sourcing platforms must perform quality checks on the submitted data.

It is therefore essential to overcome the reasons why it is not currently possible to do this. The reasons cited for not using feedback data in industry were practicality, costs, risks and lack of obligation. These individual factors can be tackled piecemeal. Alternatively feedback could be used to change the contextual pressures themselves. Primary issues that feedback needs to tackle in each area are discussed below:

Creating value

The value of post occupancy evaluation data will only be realised when actors can see what kind of impact it can have on changing a building's design or operation. A feedback platform should put forward the case for energy efficiency; show the opportunities to implement efficiency measures, and quantify the benefits using metrics that are motivating to actors.

Feedback information should itself be able to provide validation of capital expenditure on buildings and expert fees as justification for the initial investment. A platform of comprehensive data should provide information on savings achieved or available to offset the costs of POE work.

To do this the default metric should be costs; a metric that is universally used across industry. Whether capital expenditure, profitability, savings or fee generation, framing the impact of feedback on a project and the potential impact of any changes generated in these terms will create more interest in the topic and overcome one of the principal barriers.

Demonstrating the value of energy efficiency alongside the information required to take action could help industry understand where and why design techniques, systems or actors have met and exceeded expectations. The costs or savings associated with this information will encourage commercially-driven organisations to engage with energy consumption and more importantly, engage with designers who can produce cost effective buildings.

Disconnected project team members with competing commercial interests could potentially be aligned through an understanding of cost effective energy efficient design gained through a feedback platform for example. If 'architectural design' can be framed in this way by a platform, then other actors could be encouraged to appreciate its importance.

Showing industry the value inherent in understanding and being able to act on poor building performance will encourage industry to take the lead on energy matters, perhaps allowing them to try and achieve lower consumption values, rather than waiting to be led by mandate or guidance as is the case now. Demonstrating this value could in turn lead to the development of energy-related reputational benefits.

Create a reputational benefit

A feedback platform can connect design and management decisions with energy consumption, and can attribute responsibility and ownership of the elements that contribute to energy consumption. This could simultaneously overcome some of the problems with a disconnected project team and ascribe successes to actors who can use them to publicise their work.

By proving that reductions have been made in building energy consumption, providing a method of communicating these savings to the wider industry and a potential client base could allow for reputational benefits to be realised. If information on good buildings is publicly available then clients can select actors based on their performance.

The creation of a reputational benefit is of course connected to realising the associated value of low energy design or management work. A feedback platform should be able to translate the benefits into the language of the decision makers.

Overcoming risks and other barriers

The mechanism for overcoming the barriers inherent in the contextual pressures is feedback data itself. The more information there is in CarbonBuzz, the more apparent the problems and the opportunities will become.

Existing standard project set-ups, the need to pass risks down the chain of the project team, and the complexity of building energy systems requires effective coordination of expertise. A feedback platform could not only provide effective coordination of expertise but also encourage actors to assume responsibility for the impact of their decisions. Understanding the likely impact of decisions before they are committed to financially could help create a blame-free environment in which building performance can be explored for the benefit of future performance.

Demonstrating likely energy consumption could reduce the risks associated with aiming for seemingly abstract targets. Giving actors the confidence to believe that targets are achievable could reduce perceived risks and therefore costs to developers and clients.

Feedback can be used to show clients and practitioners better ways of doing things. These could be better ways of designing buildings with lower energy consumption or the way that projects are set up and procured. Each actor has different risks and different definitions of ‘better’; a feedback platform should be able to present information to accommodate them all.

A platform should make apparent the uncertainties – or lack of uncertainties – inherent in energy consumption predictions. Litigation often stems from contractual disputes where delivered services do not match those that were agreed to be delivered. A feedback platform could be used to develop reasonable briefing targets, and track where problems occur and overcome them prior to conflict. A trusting atmosphere could be created in the project team through transparent and clear goals and communication of data in metrics useful to individuals and overcoming the risk of recourse to legal action.

Altering the contextual pressures

The contextual pressures do not sufficiently reflect the complexity of the decisions that impact on building energy consumption. A feedback platform could better reflect actual building energy consumption patterns and provide a better basis for decision-making.

The interconnectivity of elements of building performance is not reflected in contextual pressures or the way that decisions are made. A feedback mechanism should provoke change in the way industry operates through understanding of the faults in the current contextual pressures by collating building performance data in order to challenge the status quo of the formal framework, and to demonstrate to policy makers where future legislation and guidance should be aimed.

A feedback mechanism should clarify the impacts that certain decisions have on the resultant energy consumption associated with a building (for example a poor planning driven decision) and therefore allow individual actors in project teams to assume responsibility for systems. The lack of continuity in existing procurement processes could be overcome by a future feedback platform.

Communicating information can show where the contextual pressures are preventing targets being met and inform policy makers where to focus their changes. Existing benchmarks have been shown to be of no real relevance to current building performance; a feedback platform could provide new benchmark targets for industry to work to.

8.3.2 To support decisions made by the various industry actors to reduce current and future building energy consumption

The atomised nature of project teams mean that information flow is often not good enough to help project teams make good decisions. Feedback has a role to play in bridging the unfamiliarity of new project relationships through the communication of clear project goals and performance targets, furnishing actors with knowledge and understanding of the in-use functioning of low energy buildings and what characterises successful buildings.

Existing procurement processes mean that actors' involvement in the process is based on the needs of the contextual pressures rather than on the needs of a well performing building. A feedback platform must show this to be the case, challenge the contextual pressures, and give clients the confidence and impetus to employ expert involvement at the most important points in the procurement process. In line with this, a feedback platform could be used to ensure that early choices are made that follow, best practice strategies, by making actors aware of the likely impact of their decisions, good and bad.

This can reduce iterative design procedures and in the absence of expertise, help non-technical actors make evidence-based judgements about aspects of the building that impact on energy consumption.

The existing contractual relationships established by the contextual pressures mean that information flow is often very informal and anecdotal or limited to very specific aspects of compliance calculations or finished buildings. A feedback platform could build on these existing flow paths and embellish the information with the kind of in-depth scientifically robust data that will offer actors the necessary insights to improve building performance.

Communication between the range of expertise and technical understanding in a project team could be supported by a feedback platform that can be referred to by all team members using common values, converting information into discipline-specific metrics.

Actors can be classified in three groups: those uninterested in energy or carbon but obliged to make some effort to reduce the energy consumption associated with their buildings or projects; those for whom energy and carbon is of interest to them personally or to their organisation but who feel they are hampered in implementing meaningful projects; and those who are interested in energy and have found a means of implementing what they feel are meaningful energy reduction measures. These groups are discussed below.

Engaged actors

The engaged actors tend to have developed their own organisation-specific feedback mechanisms; however this insular system can result in the repetition of similar ideas. Engaging with a broader industry-wide feedback platform could highlight other successful designs and management strategies and promote innovative thinking to drive industry forward. There is however a boundary between sharing data and retaining a competitive advantage.

A wider feedback platform could allow engaged actors to push forward a low energy agenda to wider industry by demonstrating where the value in energy efficiency lies with respect to other motivations and metrics.

Aspirant but hindered actors

The contextual pressures, while requiring actors to engage with energy, do not support the development of innovative low energy buildings. A feedback platform must provide aspirant actors with supporting data to show other members of the project team that their aims are achievable, that the barriers currently preventing action are surmountable and aligning ambition with technological feasibility and costs by providing a robust evidence base for decision making.

Using contextual pressure obligations to determine energy consumption targets reduces industry risks but will not necessarily result in an accurate understanding of how buildings will be used. Aspirant actors' decisions need to be supported by providing a solid evidence base for consultant interactions with each other and their clients. They need to be able to convince others that feedback is worth using and that a low energy building is a valuable asset.

Uninterested actors

Uninterested actors need to be engaged by the advocacy of engaged actors, using a feedback platform that presents information in a format that appeals to their motivations.

Feedback is most used in industry when it is causal, anecdotal and informal. This feedback loop relies on individuals passing on information that they deem important without a comprehensive set of information that can render insights more actionable. A feedback platform could enable this to happen by providing a natural forum to embellish existing discussions with greater understanding of the issues.

Assigning responsibility for particular aspects of energy consumption could engage uninterested actors with POE and energy consumption. A competitive market in low energy buildings will mean they will have to engage.

For all actors

A feedback platform must be accessible to all actors, from large-scale consultancies to small single practitioners. The presentation format must be capable of communicating clear and understandable information to laypeople involved in the development of buildings as well as those with expert knowledge.

Feedback should be able to demonstrate for a given set of project characteristics a range of potential design or management strategies with associated energy and cost implications. This should be used to eliminate unlikely strategies as well as provide direction or the starting point for detailed design, and should connect information with existing prediction methodologies.

A feedback platform should be able to embellish existing feedback loops with concrete evidence to improve discussions, problem diagnosis and development of remedial action, providing a platform for communication of information in a format that appeals to all actors. Actors should be able to share information without feeling that they have given away their professional expertise and therefore their livelihood.

8.4 What changes need to be made to the contextual pressures or actors' behaviour to implement this future role of feedback?

This section describes changes to the following sections of the contextual pressures:

- *Benchmarks*
- *Legislation and regulation*
- *Planning Policy*
- *Certification*
- *Incentives*
- *Procurement Process*

While commercial value is clearly a driver of activity in the construction industry, many of the financial benefits that can be realised through engaging with POE and utilising feedback already exist but most are not taken up by industry. This thesis has shown that market forces can drive energy efficiency with sufficient supporting information, but also, as with the use of CRCs, punitive measures have a role to play in forcing organisations to act.

There are weaknesses in the current pressures that have a bearing on both the quantum and quality of available feedback data and this section suggests ways in which the formal parts of the contextual pressures could be adjusted to address these weaknesses. As the data has suggested, the formal portion of the contextual pressures has a role to play in shaping the informal, therefore this section only addresses the formal in the expectation that the informal – which is created from actors' perception – will follow suit.

The commercial nature of construction needs to be taken into account in the contextual pressures and the chain of responsibility needs to be maintained throughout commercial transactions. The balance of the contextual pressures should be shifted away from risk and liability to financial benefit (whether reduced expenditure or increased profits) and reputational gain. The contextual pressures must use the factors that motivate industry rather than the relatively abstract notion of carbon dioxide emissions. The discrepancy in motivations between designers (aiming at carbon) and owners (aiming at financial savings) creates a disconnect in their decision-making. The barriers need to be overcome through the greater use of feedback data.

The major role of feedback in a proposed revision of the contextual pressures is to provide the underlying figures for all policy and targets. Using actual energy consumption records as the basis for energy targets, legislation, and policy and subsequent performance will allow for a constant comparable metric across all industry activity which can be monitored against CCA commitments.

Benchmarks

Feedback-derived benchmarks should form the basis for regulatory and statutory targets, providing an ambitious but achievable goal for performance improvement to consistently improve the mean energy consumption of the building. This requires a dataset that includes the full range of energy end-uses.

Existing benchmarks first need to be substantially revised. Data analysed in chapter 6 showed that the current TM46 benchmarks do not reflect either design predictions or actual records. Future benchmarks should be tied to actual building performance and in turn be connected to regulatory and statutory targets. Basing the entire formal framework of contextual pressures on actual recorded total building energy performance will make meeting carbon reduction obligations clearer, enable easier cost analysis and help designers engage with end-users in a more meaningful way through use of conversion factors to whichever metric is most suitable. An improvement factor can be applied by other policies or organisations and by other certification schemes, to increase the stringency of targets.

Legislation and regulation

The legislative framework has been shown to form the basis of the majority of actors' target setting as well as creating confusion, uncertainty and an array of targets that do not necessarily match with individual actors' or main project goals. Due to the limited nature of calculation methodologies, there is no guarantee that designed performance will be achieved in finished and occupied buildings.

The regulatory framework therefore should be adjusted to use a benchmark-derived targets presented in a metric that meets actors' motivations (via a conversion rate from energy consumed per unit of area), encourage calculation of a total energy consumption at design stage by reference to actual disaggregated records, track potential changes to this throughout the procurement process, and finally mandate and regulate POE.

Connecting building regulations to in-use incentives would help engagement across industry. Predictions that are compared to actual benchmark values accompanied by verification POE will help to ascribe responsibility to designers, not builders.

Planning Policy

Planning policy has been shown to sometimes contradict regulation and oblige actors to carry out work against their judgement. Local development control is essential; however in its current form the planning process often means critical decisions about buildings are made at an early stage in the design process and procurement set-ups mean that not all of the necessary expertise is involved in the project. This means that actors without expertise take decisions they are not qualified to take.

Coordinating planning energy policy with an overarching industry metric would help streamline the procurement process and mean that a project could be aimed towards a single goal. Using the same metric for planning, building control and operation certification would encourage changes in procurement.

Using a benchmark derived from actual records, local authorities could ask for a greater improvement on the value than current regulations, so allowing local flexibility. The stipulation that certain technology is used should be replaced with a freedom to innovate and meet the target in any way, removing the prescriptive elements of current policy and encouraging innovation from industry.

Certification

Certification should become a genuine reputation maker (or breaker). Organisations who achieve low energy buildings should be rewarded by positive publicity and marketing opportunities. The use of a feedback-derived benchmark as a certification guide will allow for easy comparison across all policy and buildings. Using a metric that appeals to potential clients will help turn good performance into reputation and market advantage. A clearer, flexible metric – of an actor's choosing and calculated through conversion factors – rather than the current operational and asset ratings will help create this cross-industry legibility.

The use of certification as a means of generating reputation relies on other aspects of the contextual pressures and good building performance itself becoming a valuable commodity. This will only happen by changing the metrics to meaningful figures.

Incentives

The data analysed in this thesis suggests that financial incentives (or punitive measures) genuinely help actors to engage with feedback and reduce energy consumption. Extending this to those working earlier in the design process would help to engage the entire industry in project energy consumption and design aspirations.

Tying the benefits of in-use energy reductions to design stage predictions somehow – through shared rebates or avoided penalties – would engage the design industries with actual performance. However to avoid the creation of an additional barrier the primary incentive must come from the reputational benefits, cost savings and further work that are associated with demonstrably delivering good building performance.

Procurement Process

Adjusting the formal framework of contextual pressures, mostly through the mandated parts, will create the necessity for greater actor involvement across the procurement process. When the benefits (and disbenefits) of using feedback are made explicit, developers, clients, owners and managers may realise the need to employ expertise throughout the process.

Incentivising the project team by tying them to the reputational benefits of good energy performance of finished buildings may provoke change in how the team is set up, how they operate and how responsibility is attributed.

8.5 Further work

This thesis has described a future role for energy information feedback in the design, construction and management industries, and developed a range of propositions as to how this could change the contextual pressures and the way that the design, construction and management industries currently operate. Further work stemming from this would be to test the ability of information and a feedback platform to fulfil these roles.

Many of the identified potential roles for feedback rely on the delivery of comprehensive information. Delivering this to actors involved in live, real world projects whilst recording their activities could offer some validation of the findings of this thesis.

Short term points of interest in the process would be:

- Has data quality improved
- How project teams are set up following the introduction of building performance information.
    - Are responsibilities attributed to those best able to meet them?
    - Are the risks associated with the uncertainties in making energy predictions lessened by knowledge of what is a realistic energy target?
- How the contextual pressures are dealt with.
    - Do project teams go beyond the limitations of current mandated targets?
    - Are the limitations of the current calculation methods exposed?
- Do actors feel better equipped to push a low energy agenda?
    - How do they use feedback data to support this?
- Are actors able to challenge current prescriptive guidance?

Longer term studies could look at:

- Changes to the contextual pressures following the introduction of comprehensive information source.
- Is the resultant energy gap lower?
- Is resultant building energy consumption lower?
- Are actors more likely to share information?

The nature of the construction industry makes the above study a long-term project; this could be split into smaller protocol studies.

However this further work is carried out, the key is to investigate the ability of the proposed roles of feedback in the design, construction and management industries to deliver real year-on-year energy consumption reductions in the built environment.

[BLANK PAGE]

References

Adams, S.A., 2011. Sourcing the crowd for health services improvement: The reflexive patient and “share-your-experience” websites. *Social Science & Medicine*, 72(7), pp.1069–1076.

Anderson, B., 2006. *Energy Performance of Buildings Directive*, BRE.

Andreu, I.C. & Oreszczyn, T., 2004. Architects need environmental feedback. *Building Research & Information*, 32(4), pp.313–328.

Anon, CarbonBuzz. Available at: http://www.carbonbuzz.org/ [Accessed July 28, 2013].

Bartlett, E. & Howard, N., 2000. Informing the decision makers on the cost and value of green building. *Building Research & Information*, 28(5-6), pp.315–324.

Beamish, T. & Biggart, N., 2010. *Social Heuristics: Decision Making and Innovation in a Networked Production Market*, Rochester, NY: Social Science Research Network. Available at: http://papers.ssrn.com/abstract=1533429 [Accessed February 11, 2013].

Bordass, B., BUNN, R. & Ruyssevelt, P., 1995. PROBE: Post-occupancy review of building engineering. *Building Services Journal*, (July), pp.14–16.

Bordass, B., Cohen, R. & Field, J., 2010. Energy Performance of Non-Domestic Buildings: Closing the Credibility Gap. In *Building Performance Congress*.

Bordass, B. & Leaman, A., 2013. A new professionalism: remedy or fantasy? *Building Research & Information*, 41(1), pp.1–7.

Bordass, B. & Leaman, A., 2005. Making feedback and post-occupancy evaluation routine 3: Case studies of the use of techniques in the feedback portfolio. *Building Research & Information*, 33(4), pp.361–375.

Bordass, B., Leaman, A. & Ruyssevelt, P., 2001. Assessing building performance in use 5: conclusions and implications. *Building Research & Information*, 29(2), pp.144–157.

Brabham, D.C., 2008. Crowdsourcing as a model for problem solving an introduction and cases. *Convergence: the international journal of research into new media technologies*, 14(1), pp.75–90.

Brambilla, M., Ceri, S. & Halevy, A., 2013. Special issue on structured and crowd-sourced data on the Web. *The VLDB Journal*, 22(5), pp.587–588.

BRE, 2010. *The Government’s Standard Assessment Procedure fo Energy rating of Dwellings*, Watford: DECC.

BRESCU, 2003. *Energy Consumption Guide 19 (“ECON 19”), Energy Use in Offices*, Watford.

Bruhns, H., Jones, P. & Cohen, R., 2011. CIBSE REVIEW OF ENERGY BENCHMARKS FOR DISPLAY ENERGY CERTIFICATES. In CIBSE Technical Symposium. DeMonfort University, Leicester: CIBSE.

Brundtland Comission, 1987. *Our Common Future*, Oxford: Oxford University Press.

BSRIA, 2009. *Soft Landings Framework*, Bracknell: BSRIA. Available at: http://www.usablebuildings.co.uk/Pages/UBPublications/UBPubsSoftLandings.html.

Building Research Establishment, 2013a. BRE Group: SBEM: Simplified Building Energy Model. Available at: http://www.bre.co.uk/page.jsp?id=706 [Accessed August 1, 2013].

Building Research Establishment, 2013b. BREEAM: What is BREEAM? Available at: http://www.breeam.org/about.jsp?id=66 [Accessed August 1, 2013].

Building Research Establishment, 2009. NCM: National Calculation Method. Available at: http://www.ncm.bre.co.uk/ [Accessed August 1, 2013].

Bull, R., Chang, N. & Fleming, P., 2012. The use of building energy certificates to reduce energy consumption in European public buildings. *Energy and Buildings*, 50(0), pp.103–110.

Carbon Trust, 2003. Energy Consumption Guide 19.

Charmaz, K., 2006. *Constructing Grounded Theory: A Practical Guide Through Qualitative Analysis*, London: Sage.

CIBSE, 2008. *TM 46 Energy Benchmarks*, London: CIBSE.

CIBSE, 2006. *TM22 Energy assessment and reporting method*, London: CIBSE.

CIBSE, 2009. *TM47 Operational Ratings and Display Energy Certificates*, London: CIBSE.

Clery, D., 2011. Galaxy zoo volunteers share pain and glory of research. *Science*, 333(6039), pp.173–175.

Climate Change Act, 2008. *Climate Change Act*, London: Her Majesty's Stationary Office (HMSO). Available at: http://www.legislation.gov.uk/ukpga/2008/27/contents.

Cohen, R. et al., 2001. Assessing building performance in use 1: the Probe process. *Building Research & Information*, 29(2), pp.85–102.

Cohen, R. et al., 1999. *PROBE Strategic Review 1999 Report 1: Review of the Probe process Final report to DETR*, The Probe Team.

Cole, R.J. & Brown, Z., 2009. Reconciling human and automated intelligence in the provision of occupant comfort. *Intelligent Buildings International*, 1(1), pp.39–55.

Committee on Climate Change, 2013. *Fourth Carbon Budget Review – part 1 – Assessment of climate risk and the international response*, London. Available at: http://www.theccc.org.uk/wp-content/uploads/2013/11/1784-CCC_SI-Report_Exec-Summ_1.pdf.

Construction Industry Council, 2005. *Survey of UK Construction Professional Services 2005/6*, London.

Cooper, I., 2001. Post-occupancy evaluation - where are you? *Building Research & Information*, 29(2), pp.158–163.

Corbin, J.M. & Strauss, A., 1990. Grounded theory research: Procedures, canons, and evaluative criteria. *Qualitative sociology*, 13(1), pp.3–21.

Corbin, J.M., Strauss, A.L. & Strauss, A.L., 2008. *Basics of Qualitative Research: Techniques and Procedures for Developing Grounded Theory* 3rd ed., Los Angeles: Sage.

Cross, N., 2001. Design cognition: Results from protocol and other empirical studies of design activity. *Design knowing and learning: Cognition in design education*, pp.79–103.

Dammann, S. & Elle, M., 2006. Environmental indicators: establishing a common language for green building. *Building research and information*, 34(4), p.387.

Darby, S., 2008. Energy feedback in buildings: improving the infrastructure for demand reduction. *Building research and information*, 36(5), p.499.

Day, T., Jones, P. & Ogumka, P., 2007. *Review of the impact of the energy policies in the London Plan on Applications referred to the Mayor (Phase 2) Final Report*, London: South Bank University.

DECC, 2010. Carbon dioxide emissions within the scope of influence of local authorities - Department of Energy and Climate Change. Available at: http://webarchive.nationalarchives.gov.uk/20121217150421/http://www.decc.gov.uk/en/content/cms/statistics/local_auth/co2_las/co2_las.aspx [Accessed August 1, 2013].

Department for Communities and Local Government, 2008. *A Guide to Display Energy Certificates*, Available at: http://www.communities.gov.uk/publications/planningandbuilding/displayenergycertificates.

Department for Communities and Local Government, 2013. Energy measures to save £200 annually in fuel bills for a new home - Press releases - GOV.UK. Available at: https://www.gov.uk/government/news/energy-measures-to-save-200-in-fuel-bills-for-a-new-home [Accessed August 1, 2013].

Department for Communities and Local Government, 2012. *Proposed changes to Part L (Conservation of fuel and power) of the Building Regulations 2012/13 in England, Consultation stage impact assessment*, London: Department for Communities and Local Government.

Department for Communities and Local Government & Local, 2009. *Explanatory memorandum to the energy performance of buildings (Certificates and Inspections) (England and Wales) egulations 2009*, The Department for Communities and Local Government.

Department for Energy and Climate Change, 2013a. 2012 UK Greenhouse Gas Emissions, Provisional Figures and 2011 Greenhouse Gas emissions, Final Figures by Fuel Type and End User.

Department for Energy and Climate Change, 2012a. Carbon Emissions Reduction Target (CERT) - Department of Energy and Climate Change. Available at: http://webarchive.nationalarchives.gov.uk/20121217150421/http://www.decc.gov.uk/en/content/cms/funding/funding_ops/cert/cert.aspx [Accessed August 1, 2013].

Department for Energy and Climate Change, 2012b. CRC Energy Efficiency Scheme - Reducing demand for energy from industry, businesses and the public sector -

Policies - Inside Government - GOV.UK. Available at: https://www.gov.uk/government/policies/reducing-demand-for-energy-from-industry-businesses-and-the-public-sector--2/supporting-pages/crc-energy-efficiency-scheme [Accessed February 24, 2013].

Department for Energy and Climate Change, 2012c. Enhanced Capital Allowances (ECAs) - Reducing demand for energy from industry, businesses and the public sector - Policies - Inside Government - GOV.UK. Available at: https://www.gov.uk/government/policies/reducing-demand-for-energy-from-industry-businesses-and-the-public-sector--2/supporting-pages/enhanced-capital-allowances-ecas [Accessed February 24, 2013].

Department for Energy and Climate Change, 2013b. Feed-in Tariffs: get money for generating your own electricity - GOV.UK. Available at: https://www.gov.uk/feed-in-tariffs [Accessed February 24, 2013].

Department for Energy and Climate Change, 2013c. Green Deal: energy saving for your home or business - GOV.UK. Available at: https://www.gov.uk/green-deal-energy-saving-measures [Accessed February 24, 2013].

Department for Energy and Climate Change, 2013d. Renewable Heat Incentive (RHI) - Increasing the use of low-carbon technologies - Policies - GOV.UK. Available at: https://www.gov.uk/government/policies/increasing-the-use-of-low-carbon-technologies/supporting-pages/renewable-heat-incentive-rhi [Accessed August 1, 2013].

Department for Energy and Climate Change, 2013e. UK Greenhouse Gas Emissions: Performance Against Emissions Targets - 2012 Provisional Figures.

Department of Trade and Industry (DTI), 2007. *Meeting the Energy Challenge. A White Paper on Energy*, London: The Stationery Office. Available at: http://www.berr.gov.uk/files/file39387.pdf [Accessed July 2, 2013].

DeWalt, K.M. & DeWalt, B.R., 2010. *Participant Observation: A Guide for Fieldworkers* 2nd Revised edition., AltaMira Press,U.S.

Dickinson, J.L., Zuckerberg, B. & Bonter, D.N., 2010. Citizen science as an ecological research tool: challenges and benefits. *Annual review of ecology, evolution, and systematics*, 41, pp.149–172.

Dillman, D.A., 2007. *Mail and Internet Surveys: The Tailored Design Method* 2nd ed., Hoboken, N.J: Wiley.

Duffy, F. & Rabeneck, A., 2013. Professionalism and architects in the 21st century. *Building Research & Information*, 41(1), pp.115–122.

Edwards, B. & Hyett, P., 2005. *Rough guide to sustainability*, Riba Enterprises. Available at: http://www.lavoisier.fr/livre/notice.asp?id=RSKW6LARR6LOWV [Accessed March 20, 2013].

EnergyIQ, *EnergyIQ Rules: Reduce Decision Risk through Enhanced Data Quality*, Energy IQ. Available at: http://www.energyiq.info/wp-content/uploads/2013/11/EnergyIQ-EIQ-Rules.pdf [Accessed June 22, 2014].

European Commission - Joint Research Centre, 2011. *The 2011 EU Industrial R&D Investment*

Scoreboard;jsessionid=FQqBR11bmwn6hClV7zRjm22VyL1ZJXt5NvvYgZfR1PPhL7T9WmnG!1097651567!1375027099365.pdf, European Union. Available at: http://iri.jrc.ec.europa.eu/documents/10180/11456/The%202011%20EU%20Industrial%20R%26D%20Investment%20Scoreboard;jsessionid=FQqBR11bmwn6hClV7zRjm22VyL1ZJXt5NvvYgZfR1PPhL7T9WmnG!1097651567!1375027099365 [Accessed July 28, 2013].

Faridani, S., Buscher, G. & Ferguson, J., 2013. Mentor: A Visualization and Quality Assurance Framework for Crowd-Sourced Data Generation. Available at: http://www.ieor.berkeley.edu/~faridani/papers/Mentor-v15.pdf [Accessed June 1, 2014].

Faruqui, A., Sergici, S. & Sharif, A., 2010. The impact of informational feedback on energy consumption—A survey of the experimental evidence. *Energy*, 35(4), pp.1598–1608.

Field, A.P., 2013. *Discovering statistics using IBM SPSS statistics and sex and drugs and rock "n" roll*, London: SAGE.

Friedmann, A., Zimring, C. & Zube, E.H., 1978. *Environmental design evaluation*, Plenum Press.

Fulcher, M. & Mark, L., 2012. RIBA scraps Plan of Work: say goodbye to stages A-L. *http://www.architectsjournal.co.uk*. Available at: http://www.architectsjournal.co.uk/news/daily-news/riba-scraps-plan-of-work-say-goodbye-to-stages-a-l/8637663.article [Accessed July 30, 2013].

Furniss, D., Blandford, A. & Curzon, P., 2011. Confessions from a grounded theory PhD: experiences and lessons learnt. In *Proceedings of the 2011 annual conference on Human factors in computing systems*. CHI '11. New York, NY, USA: ACM, pp. 113–122. Available at: http://doi.acm.org/10.1145/1978942.1978960.

Gething, B. ed., 2011. *Green Overlay to the RIBA Plan of Work*,

Godoy-Shimizu, D. et al., 2011. Using Display Energy Certificates to quantify schools' energy consumption. *Building Research & Information*, 39(6), pp.535–552.

Greater London Authority, 2011. The London Plan.

Gupta, R. & Chandiwala, S., 2010. Understanding occupants: feedback techniques for large-scale low-carbon domestic refurbishments. *Building Research & Information*, 38(5), pp.530–548.

Håkansson, H. & Ingemansson, M., 2013. Industrial renewal within the construction network. *Construction Management and Economics*, 31(1), pp.40–61.

Hamza, N. & Greenwood, D., 2009. Energy conservation regulations: Impacts on design and procurement of low energy buildings. *Building and environment*, 44(5), pp.929–936.

Hawkins, D. et al., 2012. Determinants of energy use in UK higher education buildings using statistical and artificial neural network methods. *International Journal of Sustainable Built Environment*, 1(1), pp.50–63.

Hong, S.-M. et al., 0. Improved benchmarking comparability for energy consumption in schools. *Building Research & Information*, 0(0), pp.1–15.

Howe, J., 2006. The Rise of Crowdsourcing. *Wired*, (14.06).

http://energyiq.lbl.gov/EnergyIQ/index.jsp, EnergyIQ | Action-Oriented Energy Benchmarking. *EnergyIQ*. Available at: http://energyiq.lbl.gov/EnergyIQ/index.jsp [Accessed February 9, 2014].

http://www.cibse-sdg.org/, School Design Group UK | CIBSE School Design Group. Available at: http://www.cibse-sdg.org/ [Accessed February 9, 2014].

http://www.co2estates.com/, Carbon Estates | Home. Available at: http://www.co2estates.com/ [Accessed February 9, 2014].

http://www.estidama.org/, Estidama. Available at: http://www.estidama.org/ [Accessed February 9, 2014].

http://www.gbca.org.au/green-star/green-star-overview/, Green Star overview - Green Building Council Australia (GBCA). Available at: http://www.gbca.org.au/green-star/green-star-overview/ [Accessed February 9, 2014].

http://www.iservcmb.info/, Front Page | iSERV cmb. Available at: http://www.iservcmb.info/ [Accessed February 9, 2014].

http://www.rics.org/uk/knowledge/more-services/professional-services/ska-rating-/about-ska-rating/, SKA Rating. Available at: http://www.rics.org/uk/knowledge/more-services/professional-services/ska-rating-/about-ska-rating/ [Accessed February 9, 2014].

https://new.usgbc.org/leed/certification/, USGBC.org. Available at: https://new.usgbc.org/leed/certification/). [Accessed February 9, 2014].

International Energy Agency, 2010. *Energy Technology Perspective 2010*, Available at: http://www.iea.org/W/bookshop/add.aspx?id=401.

International Energy Agency, 2013. *World Energy Outlook 2013*, Paris.

IPCC, 2013. *Climate Change 2013 The Physical Science Basis Working Group I Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change Summary for Policymakers*, Switzerland: Intergovernmental Panel on Climate Change.

Janda, K.B. & Parag, Y., 2013. A middle-out approach for improving energy performance in buildings. *Building Research & Information*, 41(1), pp.39–50.

Jaunzens, D. et al., 2003. *Building Performance Feedback: getting Started*, London: BRE Bookshop.

Johnson, R.B. & Onwuegbuzie, A.J., 2004. Mixed Methods Research: A Research Paradigm Whose Time Has Come. *Educational Researcher*, 33(7), pp.14 –26.

Joint Contracts Tribunal, 2009. *Standard building contract: with quantities: revision 2, 2009* 3rd ed., London: Sweet & Maxwell.

Khatib, F. et al., 2011. Crystal structure of a monomeric retroviral protease solved by protein folding game players. *Nature structural & molecular biology*, 18(10), pp.1175–1177.

Knight, I., 2012a. Assessing electrical energy use in HVAC systems. *REHVA Journal (European Journal of Heating, Ventilating and Air Conditioning Technology)*, 49(1). Available at: http://eprints.cf.ac.uk/14965/1/Knight_2012_Assessing_electrical_energy_use_in_HVAC_systems_rj1201.pdf [Accessed June 1, 2014].

Knight, I., 2012b. Assessing electrical energy use in HVAC systems. *REHVA Journal (European Journal of Heating, Ventilating and Air Conditioning Technology)*, 49(1). Available at: http://eprints.cf.ac.uk/14965/1/Knight_2012_Assessing_electrical_energy_use_in_HVAC_systems_rj1201.pdf [Accessed June 1, 2014].

Koskela, L. & Vrijhoef, R., 2001. Is the current theory of construction a hindrance to innovation? *Building Research & Information*, 29(3), pp.197–207.

Landmark Information Group, 2013. Landmark | Environmental Reports & Digital Mapping. Available at: http://www.landmark.co.uk/solutions/registers/nondomestic/cip/ http://www.landmark.co.uk/ [Accessed August 18, 2013].

Leaman, A., 2009. The Great Escape. *Ecolibrium*, 8(5), pp.18 – 20.

Leaman, A. & Bordass, B., 2004. An Intellegant Approach to Occupant Satisfaction Using Feedback. *Building Services Journal*.

Leaman, A., Stevenson, F. & Bordass, B., 2010. Building evaluation: practice and principles. *Building Research & Information*, 38(5), pp.564–577.

Leech, N.L. & Onwuegbuzie, A.J., 2007b. A typology of mixed methods research designs. *Quality & Quantity*, 43(2), pp.265–275.

Leech, N.L. & Onwuegbuzie, A.J., 2007a. A typology of mixed methods research designs. *Quality & Quantity*, 43(2), pp.265–275.

Leeuw, E.D. de et al., 2008. *International Handbook of Survey Methodology*, New York: Psychology Press.

Lutzenhiser, L., 1994. Innovation and organizational networks Barriers to energy efficiency in the US housing industry. *Energy Policy*, 22(10), pp.867–876.

Mathew, P. et al., 2008. Action-Oriented Benchmarking: Using the CEUS Database to Benchmark Commercial Buildings in California. *Energy Engineering*, 105(5), pp.6–18.

McMullan, R. & Seeley, I.H., 2007. *Environmental science in building*, Basingstoke: Palgrave Macmillan.

Mertens, D.M., 2012. What Comes First? The Paradigm or the Approach? *Journal of Mixed Methods Research*, 6(4), pp.255–257.

Merton Council, 2013. The Merton Rule. *The Merton Rule*. Available at: www.merton.gov.uk/environment/planning/planningpolicy/mertonrule.htm [Accessed February 21, 2013].

Miles, M.B. & Huberman, A.M., 1994. *Qualitative data analysis: an expanded sourcebook*, Thousand Oaks: Sage Publications.

Mozafari, B. et al., 2012. Active learning for crowd-sourced databases. *arXiv preprint arXiv:1209.3686*. Available at: http://arxiv.org/abs/1209.3686 [Accessed June 1, 2014].

Mumovic, D. & Santamouris, M., 2009. *A Handbook of Sustainable Building Design and Engineering: An Integrated Approach to Energy, Health and Operational Performance*, Earthscan.

Office for Budget Responsibility, 2013. Autumn Statement 2013 - GOV.UK. Available at: https://www.gov.uk/government/topical-events/autumn-statement-2013 [Accessed June 11, 2014].

Pahl, G. & Beitz, W., 1984. *Engineering Design*, London: Design Council.

Palmer, J., 2009. Post Occupancy Evaluation of Buildings. In *A Handbook of Sustainable Building Design and Engineering, An integrated Approach to Energy, Health and Operational Performance,*. London: Earthscan, pp. 349–357.

Pawlowicz, S. et al., 2011. Dynamic Surveying Adjustments for Crowd-sourced Data Observations. In EnviroInfo 2011 Conference Proceedings. Available at: http://enviroinfo.eu/sites/default/files/pdfs/vol6919/0510.pdf [Accessed June 1, 2014].

Peirce, C.S. & Menand, L., 1997. *Pragmatism: A Reader*, Vintage New York. Available at: http://202.120.227.5/havard/links500/hf0038.doc [Accessed April 9, 2013].

Peters, G.P. et al., 2013. The challenge to keep global warming below 2 °C. *Nature Climate Change*, 3(1), pp.4–6.

Preiser, W.F. & Vischer, J.C., 2005. *Assessing building performance*, Routledge. Available at: http://books.google.co.uk/books?hl=en&lr=&id=M3tateQmE-sC&oi=fnd&pg=PP2&dq=PRIESER+W.+and+VISCHER+J.+(eds).+Assessing+Building+Performance.+Elsevier,+Oxford,+2005,+p.+8.&ots=Rv3mCvLsOI&sig=h3EiW0a8KntBxNncxgl4BhygK7c [Accessed July 28, 2013].

RIBA, 2007. RIBA Outline Plan of Work 2007.

RIBA, 2013. RIBA Plan of Work 2013. Available at: http://www.architecture.com/TheRIBA/AboutUs/Professionalsupport/RIBAOutlinePlanofWork2013.aspx#.UdlwvqwkyTY [Accessed July 7, 2013].

Riley, M., Moody, C. & Pitt, M., 2009. A review of the evolution of post-occupancy evaluation asa a viable performance measurement tool. In *4 th Annual Conference Liverpool BEAN*. p. 129. Available at: https://www.livjm.ac.uk/BLT/BUE_Docs/BEAN_Conference_2009_GH.pdf#page=135 [Accessed July 28, 2013].

Roaf, S., Horsley, A. & Gupta, R., 2004. *Closing the loop: benchmarks for sustainable buildings*, RIBA. Available at: http://books.google.co.uk/books?id=oa1zQgAACAAJ.

Roberts, P., 2001. Who is post-occupancy evaluation for? *Building Research & Information*, 29(6), pp.463–465.

Rosenow, J., 2012. Energy savings obligations in the UK—A history of change. *Energy Policy*, 49, pp.373–382.

See, L. et al., 2013. Comparing the Quality of Crowdsourced Data Contributed by Expert and Non-Experts. *PloS one*, 8(7), p.e69958.

Seidman, I., 2006. *Interviewing as qualitative research: a guide for researchers in education and the social sciences* 3rd ed., New York: Teachers College Press.

Short, C.A., Cook, M. & Lomas, K., 2009. Delivery and performance of a low-energy ventilation and cooling strategy. *Building Research & Information*, 37(1), pp.1–30.

Short, C.A., Lomas, K.J. & Woods, A., 2004. Design strategy for low-energy ventilation and cooling within an urban heat island. *Building Research & Information*, 32(3), pp.187–206.

Sinclair, D., 2013. *Guide to Using the RIBA Plan of Work 2013*,

Soanes, C. & Stevenson, A. eds., 2008. *Concise Oxford English dictionary* 11th ed., rev. [2008]., Oxford: Oxford University Press.

Steemers, K. & Manchanda, S., 2010. Energy efficient design and occupant well-being: Case studies in the UK and India. *Building and Environment*, 45(2), pp.270–278.

Stern, N., 2007. *The economics of climate change: the Stern review*, Cambridge University Press. Available at: http://books.google.co.uk/books?hl=en&lr=&id=U-VmIrGGZgAC&oi=fnd&pg=PA1&dq=economics+of+climate+change&ots=9csU2qlvob&sig=TKzjrZvqKYT8cIk0HIFAUmtNbaE [Accessed February 7, 2013].

Stevenson, F., 2009. Post-occupancy Evaluation and Sustainability: A Review. *Institution of Civil Engineers Urban Design and Planning*, 162(DP3), pp.123–130.

Surowiecki, J., 2005. *The Wisdom of Crowds* Reprint edition., New York: Anchor.

Swan, M., 2012a. Crowdsourced Health Research Studies: An Important Emerging Complement to Clinical Trials in the Public Health Research Ecosystem. *Journal of Medical Internet Research*, 14(2). Available at: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3376509/ [Accessed June 8, 2014].

Swan, M., 2012b. Scaling crowdsourced health studies: the emergence of a new form of contract research organization. *Personalized Medicine*, 9(2), pp.223–234.

Szigeti, F. & Davis, G., 2002. The turning point for linking briefing and POE? *Building Research & Information*, 30(1), pp.47–53.

Talan, J., 2011. Can a Web-Based Recruitment Tool for Genomic Analysis be Valid? *Neurology Today*, 11(16), pp.38–40.

Tashakkori, A. & Teddlie, C., 2003. *Handbook of Mixed Methods in Social & Behavioral Research*, SAGE.

Tashakkori, A. & Teddlie, C., 1998. *Mixed Methodology: Combining Qualitative and Quantitative Approaches*, SAGE.

Technology Strategy Board, 2010. *Building Performance Evaluation*, Swindon.

The European Parliament & The Council of the European Union, 2010. DIRECTIVE 2010/31/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCILof 19

May 2010on the energy performance of buildings (recast). *Official Journal of the European Union*, L(153), pp.13–35.

The Observer, 2013. Nicholas Stern: “I got it wrong on climate change – it”s far, far worse’ | Environment | The Observer. Available at: http://www.guardian.co.uk/environment/2013/jan/27/nicholas-stern-climate-change-davos [Accessed February 6, 2013].

Torrance, H., 2012a. Triangulation, respondent validation, and democratic participation in mixed methods research. *Journal of Mixed Methods Research*, 6(2), pp.111–123.

Torrance, H., 2012b. Triangulation, Respondent Validation, and Democratic Participation in Mixed Methods Research. *Journal of Mixed Methods Research*, 6(2), pp.111–123.

Tunstall, G., 2012. *Managing the Building Design Process*, London: Routledge.

UNCCS, 2013. *UN Climate Change Conference in Warsaw keeps governments on a track towards 2015 climate agreement*, Warsaw: United Nations Framework Convention on Climate Change (UNFCCC).

Vaughan, A. & Harvey, F., 2013. No UK households have completed green deal process, figures show | Environment | theguardian.com. *The Guardian*. Available at: http://www.theguardian.com/environment/2013/jun/27/green-deal-energy-efficiency [Accessed August 1, 2013].

Vessey, I., 1991. Cognitive Fit: A Theory-Based Analysis of the Graphs Versus Tables Literature*. *Decision Sciences*, 22(2), pp.219–240.

Vischer, J.C., 2009. Applying knowledge on building performance: from evidence to intelligence. *Intelligent Buildings International*, 1(4), p.239.

Way, M. & Bordass, B., 2005. Making feedback and post-occupancy evaluation routine 2: Soft landings – involving design and building teams in improving performance. *Building Research & Information*, 33(4), pp.353–360.

Weidema, B.P. et al., 2013. *Overview and methodology: Data quality guideline for the ecoinvent database version 3*, Swiss Centre for Life Cycle Inventories. Available at: http://vbn.aau.dk/ws/files/176769045/Overview_and_methodology.pdf [Accessed June 1, 2014].

Wicks, P. et al., 2010. Sharing Health Data for Better Outcomes on PatientsLikeMe. *Journal of Medical Internet Research*, 12(2), p.e19.

www.carbonbuzz.org, CarbonBuzz. Available at: http://www.carbonbuzz.org/ [Accessed February 9, 2014].

www.carbontruststandard.com, Certification - Carbon Trust. Available at: http://www.carbontrust.com/client-services/footprinting/footprint-certification [Accessed February 9, 2014].

www.dreamassess.com, MOD DREAM. Available at: https://www.dreamassess.com/ [Accessed February 9, 2014].

www.ecoinvent.org, www.ecoinvent.org. *www.ecoinvent.org*. Available at: http://www.ecoinvent.org/database/ [Accessed June 21, 2014].

www.nabers.gov.au/public/WebPages/Home.aspx, Available at: http://www.nabers.gov.au/public/WebPages/Home.aspx [Accessed February 9, 2014].

www.passivhaus.org.uk/standard.jsp?id=122, Passivhaus: The Passivhaus Standard. Available at: http://www.passivhaus.org.uk/standard.jsp?id=122 [Accessed February 9, 2014].

Yun, G.W. & Trumbo, C.W., 2000. Comparative Response to a Survey Executed by Post, E-mail, & Web Form. *Journal of Computer-Mediated Communication*, 6(1), pp.0–0.