Life in the gap: how does a construction company respond to the challenge of targets for energy and carbon in-use?

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A dissertation submitted in partial fulfilment of the requirements for the degree of Doctor of Philosophy of UCL

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Declaration

I, Catherine M Willan, 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.
Abstract

Operational energy targets have been suggested as a solution to the “gap” between buildings' energy performance in design and use. Although construction professionals will play a crucial role in the implementation of these targets, their response is under-examined. This research presents a case study of how a construction company reacts to energy and carbon performance targets in a large, non-domestic project, employing qualitative data from interviews, observation, and documents. It reveals how high-level problems in industry collaboration and communication around energy play out in day-to-day life amongst construction actors “inside the gap”.

Three strands of argument are developed, inspired by different, but complementary, concepts from Science and Technology Studies. Firstly, it is argued that construction actors’ practices create multiple versions of the targets. Aligning these poses many practical difficulties, and raises questions about the nature of an energy efficient building. Using discourse analysis, the construction team’s talk around the targets is shown to perpetuate the gap between the theory and reality of building performance, and impede collaborative discussion of the uncertainties inherent in energy performance. Finally, the concept of boundary objects reveals how current systems of information management do not support construction actors in translating the targets’ aspirations into action, and fail to prioritise energy.

The findings suggest that operational energy targets have the potential to drive improvements in the building stock, but encounter unforeseen difficulties when imposed on established relationships and ways of working. Adjusting commercial relationships is key to energy targets’ eventual success. However, the energy performance of a building is a mutable product, made and mediated by many actors. Care must be taken
in the setting and enforcement of performance targets. The research demonstrates the value of a situated understanding of how new policy mechanisms play out amongst the actors charged with their implementation.
Impact Statement

The intent behind this thesis is to engage with means to improve the energy efficiency of, and reduce carbon emissions from, the built environment. This is an inherently applied area of research. It has at its heart the aim to join academic insight with industry and policy goals to tackle climate change. As such its impact should be threefold, providing benefits to academia, policy, and industry.

The thesis examines an area of growing policy interest, namely the potential impact of performance-based assessment for buildings' energy use and carbon emissions. It also feeds into Government’s aspirations to increase business energy efficiency, cut emissions from new buildings, and transform the industry through the Construction Sector Deal. However, if Government wishes to move towards more output-based systems of building energy control, and to make good on its aspirations to cut energy and carbon, then it is vital that learnings are gathered from the deployment of incentives such as energy targets. This thesis provides a very timely contribution to this policy development. The researcher has participated in policy workshops to feed in ideas to government and civil service, and has presented the work at multi-stakeholder forums.

The thesis offers two contributions to the research community. Firstly, it works at the intersection between building energy research and Science and Technology Studies (STS). Although these disciplines have many potential synergies, they have not been fully exploited. The thesis also offers a situated analysis of construction’s response to new energy policy incentives. This has been an area of comparative neglect in energy research, despite the huge potential influence of these professionals on building energy outcomes. The findings have been presented at a number of national and international
academic conferences. Additionally, the researcher has been able to feed in experience from it to other research projects dealing with construction and energy at UCL. One article has so far been submitted to a peer-reviewed journal, and it is anticipated that further publications will be produced once the thesis is complete.

The PhD represents a partnership with a UK construction company. This sort of collaboration is vital for increasing the transfer of knowledge between academia and industry, which is so important if significant change is to be achieved in the building stock. The aim has been to investigate a topic of mutual interest to the company and to UCL, and to develop the relationship. Therefore, the academic findings have been translated into formats that are more accessible to industry. For instance, the research has been presented to the company at team meetings, in commercial reports, formal and informal meetings, and, in one instance, an international webinar. As the company has operations both in the UK and abroad, the reach of insights is potentially international. In addition, findings from working with a commercial sponsor, and its benefits and challenges, have been fed back into UCL and the student cohort to benefit future interactions.
Acknowledgements

Thanks above all to my supervisors, Paul Ruyssevelt, Michelle Shipworth and Russell Hitchings, who have bravely read through many drafts, asked pertinent questions, challenged me, and offered so much support and expertise throughout the PhD.

I would also like to thank my principal contact in the sponsoring company. He has been interested, helpful, and ready to offer suggestions for contacts, information, and his own perspectives on energy, carbon, and buildings. Additionally, the many participants who took time out to participate in my research were welcoming, interesting, and honest. This research is, of course, composed of what they have told me, and I am grateful to them.

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I also need to thank my family for dealing with the intrusion of my PhD into their life: my husband Joe for his patience and willingness to step in and help whenever I needed it, and for my children, who have been very forgiving of my spending so much time writing.
Publications arising from this thesis

Material from Chapter 5 draws on work that has been submitted to a peer-reviewed journal for publication with my co-authors Russell Hitchings, Paul Ruyssevelt and Michelle Shipworth.
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<tr>
<td>Air-tightness testing</td>
<td>n/a</td>
<td>Method of measuring how much air is lost through leaks in the building fabric. Required by Building Regulations.</td>
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<td>BIM</td>
<td>Building Information Modelling</td>
<td>Process for gathering, and sharing digital information about built assets. Umbrella term for a wide variety of software and techniques.</td>
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<td>BMS</td>
<td>Building Management System</td>
<td>Hardware and software used to monitor and control building systems, including energy use.</td>
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<tr>
<td>BRUKL</td>
<td>Building Regulations UK Part L report</td>
<td>Reports produced by Part L modelling in order to demonstrate regulatory compliance in energy/carbon.</td>
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<td>BSRIA</td>
<td>Building Services Research and Information Association</td>
<td>Non-profit building research body.</td>
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<tr>
<td>CAT A / CAT B fit outs</td>
<td>n/a</td>
<td>Refers to level of finishing in building fit out. CAT A tends to include only basic services and fittings; CAT B will include final finishes, such as partitions, internal lighting, and equipment.</td>
</tr>
<tr>
<td>CfD</td>
<td>Computational Fluid Dynamics</td>
<td>Branch of fluid mechanics that can be applied to building design.</td>
</tr>
<tr>
<td>CIBSE</td>
<td>Chartered Institution of Building Services Engineers</td>
<td>Professional body for building services engineers. Also publishes best practice guidance and tools.</td>
</tr>
<tr>
<td>COBie</td>
<td>Construction Operations Building Information Exchange</td>
<td>Subset of BIM (q.v.) that captures project data to help in the asset's maintenance and operation.</td>
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<tr>
<td>Commissioning</td>
<td>n/a</td>
<td>Process of calibrating, adjusting and testing the effective operating of installed building systems prior to completion of the project.</td>
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<tr>
<td>COP</td>
<td>Coefficient of Performance</td>
<td>Denotes efficiency by comparing energy input to output.</td>
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<tr>
<td>CRC Scheme</td>
<td>CRC Energy Efficiency Scheme (formerly known as the Carbon Reduction Commitment)</td>
<td>Carbon trading scheme intended to reduce emissions from large, non-energy intensive organisations. Now scheduled for closure.</td>
</tr>
<tr>
<td>D&amp;B</td>
<td>Design and Build</td>
<td>Contract in which the main (construction) contractor is responsible for the design as well as the construction of the project.</td>
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<td>DEC</td>
<td>Display Energy Certificate</td>
<td>Shows the energy performance of large, public buildings, using rating from A to G. Displays both energy</td>
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<tr>
<td>DSM</td>
<td>Dynamic Simulation Modelling</td>
<td>Software for modelling building performance, including energy and internal conditions, in greater detail than modelling techniques used for regulatory compliance.</td>
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<td>EnCO2de</td>
<td>Health Technical Memorandum (HTM) 07-02</td>
<td>Document produced by Department of Health to provide guidance on managing energy use in NHS facilities, including new build and existing buildings.</td>
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<td>EPC</td>
<td>Energy Performance Certificate</td>
<td>Rates the energy efficiency of a building from A to G. Required when a building is built, sold, or rented. Energy use is based on design figures, and does not include all sources of energy that will be used within the building in operation.</td>
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<td>ERIC</td>
<td>Estates Return Information Collection</td>
<td>This government system collects information on the costs of the NHS estate, including energy use.</td>
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<tr>
<td>FC</td>
<td>Financial Close</td>
<td>The point at which procurement is complete and contracts for delivery and finance are signed off.</td>
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<tr>
<td>FM/FS</td>
<td>Facilities Management or Facilities Services</td>
<td>Facilities teams are responsible for the management of a building in operation.</td>
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<tr>
<td>Hard FM</td>
<td>n/a</td>
<td>Building management of physical services, such as energy, but also general physical maintenance, fire systems, and water.</td>
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<tr>
<td>HBNs</td>
<td>Health Building Notes</td>
<td>Produced by Department of Health to offer guidance on design and planning for new-build or extensions to/refurbishment of health sector buildings.</td>
</tr>
<tr>
<td>HTMs</td>
<td>Health Technical Memoranda</td>
<td>Produced by Department of Health to provide guidance on the design, installation and operation of specialised building and engineering technologies in NHS estate.</td>
</tr>
<tr>
<td>IES</td>
<td>Integrated Environmental Solutions</td>
<td>One brand of commercially produced software for design and modelling of building performance, (including energy use).</td>
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<tr>
<td>IP</td>
<td>Intellectual Property</td>
<td>Intangible assets such as designs, professional knowledge, trademarks, copyright etc..</td>
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<tr>
<td>JV</td>
<td>Joint Venture</td>
<td>Legal entity created by two or more parties, sometimes with different expertise, in which ownership, risks and returns are shared. Often used by businesses to undertake a specific project.</td>
</tr>
<tr>
<td>KPI</td>
<td>Key Performance Indicator</td>
<td>Measure used to evaluate an important aspect of person, project, or organisation’s performance.</td>
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<tr>
<td>LED</td>
<td>Light-emitting Diode</td>
<td>Form of energy efficient lighting technology.</td>
</tr>
<tr>
<td>M&amp;E</td>
<td>Mechanical and Electrical</td>
<td>Often used as shorthand to describe either the internal or external engineers who work on mechanical and electrical systems, or the systems themselves.</td>
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<tr>
<td>Merton Rule</td>
<td>n/a</td>
<td>Planning policy, originally developed by Merton Council, requiring new developments to generate at least 10% of their energy needs from on site renewable energy.</td>
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<tr>
<td>NABERS</td>
<td>National Australian Built Environment Rating System</td>
<td>Australian scheme that provides a star rating for buildings based on operational performance, including energy data. The rating reflects a building's performance relative to its peers. Principally used for non-domestic buildings.</td>
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<tr>
<td>NHS</td>
<td>National Health Service</td>
<td>UK public healthcare system.</td>
</tr>
<tr>
<td>O&amp;M</td>
<td>Operating and Maintenance</td>
<td>Activities involved in ongoing operation and maintenance of the completed building, including energy and other aspects.</td>
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<tr>
<td>PC</td>
<td>Practical Completion</td>
<td>The point at which all the works in the contract have been carried out. Represents the formal end of construction and commissioning.</td>
</tr>
<tr>
<td>PFI</td>
<td>Private Finance Initiative</td>
<td>Government policy designed to increase private sector involvement and investment in the provision of public services.</td>
</tr>
<tr>
<td>PFU</td>
<td>Private Finance Unit</td>
<td>Responsible for developing and promoting PFI (q.v.) policy for public bodies.</td>
</tr>
<tr>
<td>PI</td>
<td>Professional Indemnity</td>
<td>Type of insurance covering claims against poor commercial advice or work provided to a client.</td>
</tr>
<tr>
<td>POE</td>
<td>Post-Occupancy Evaluation</td>
<td>A review of the completed building to assess its success, identify areas for improvement and learn lessons for future projects, including energy use.</td>
</tr>
<tr>
<td>Pressure testing</td>
<td>n/a</td>
<td>See air-tightness testing.</td>
</tr>
<tr>
<td>Project Co.</td>
<td>n/a</td>
<td>Special Purpose Vehicle (q.v.) in form of limited company, which delivers a PFI (q.v.) construction project.</td>
</tr>
<tr>
<td>RIBA stages</td>
<td>n/a</td>
<td>The Royal Institute of British Architects (RIBA) produces a Plan of Work that describes the stages of a building project from conception to use, and which are numbered 0-7.</td>
</tr>
<tr>
<td>Snags(snagging)</td>
<td>n/a</td>
<td>Process of finding and correcting minor defects in a building project.</td>
</tr>
<tr>
<td>Abbreviation</td>
<td>Term</td>
<td>Definition</td>
</tr>
<tr>
<td>--------------</td>
<td>-------------------------------------------</td>
<td>------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Soft FM</td>
<td>n/a</td>
<td>Building management of internal services, such as cleaning, catering, or waste management.</td>
</tr>
<tr>
<td>STS</td>
<td>Science and Technology Studies</td>
<td>Academic discipline concerned with the nature, practices and implications of science and technology.</td>
</tr>
<tr>
<td>TM54</td>
<td>TM54: Evaluating Operational Energy</td>
<td>Technical Memorandum from CIBSE (q.v.), aimed at the performance gap, and intended to improve understanding of how to evaluate energy performance in buildings by designers and modellers.</td>
</tr>
<tr>
<td></td>
<td>Performance of Buildings at the Design</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Stage</td>
<td></td>
</tr>
<tr>
<td>Soft Landings</td>
<td>n/a</td>
<td>Originally formulated by BSRIA (q.v.) and the UBT (Usable Buildings Trust). Its aim is to provide a framework to smooth transition between the stages of design, construction and operation, and so prevent problems in building performance emerging in-use.</td>
</tr>
<tr>
<td>Tier 1</td>
<td>Tier 1 contractor</td>
<td>Organisation at the top of the construction procurement tree, which is directly contracted to the client.</td>
</tr>
<tr>
<td>Abbreviation</td>
<td>Term</td>
<td>Definition</td>
</tr>
<tr>
<td>--------------</td>
<td>-----------------------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>VE</td>
<td>Value engineering</td>
<td>A technique to improve cost-effectiveness, by establishing whether the same product or material can be obtained at a lower price without compromising performance. However, often used colloquially to denote cost-cutting at the expense of quality.</td>
</tr>
</tbody>
</table>
Note on sponsorship

The research for this PhD has been carried out in partnership with a large, UK construction company who provided both funding and, significantly, staff time, data, and attention to this project. In order to protect the identity of this company, it will be referred to as “Construction Co.” throughout, and the names of its employees, subcontractors and projects are also anonymised.
1. Introduction

1.1. Overview

Buildings designed to be energy efficient or low carbon do not always turn out to be so once in-use. This failure to meet expectations is termed the “energy performance gap”. Making construction companies more accountable for the operational energy performance of the buildings that they build has been proposed as one solution to help correct this phenomenon. In response, there has been a recent upswing of interest amongst some in the research, industry, and policy communities around the need for new incentives, such as energy targets, that promote this accountability for operational energy performance. It is, therefore, opportune to step back and consider the nature of energy targets, their relationship to the diverse stakeholders of construction projects on whom they are intended to act, and whether they can be expected to produce more reliably energy efficient, or low carbon, buildings.

In particular, consideration of how construction professionals might react to such targets has been comparatively neglected. This is unfortunate, given these stakeholders’ significant role in implementing, and hence shaping, any such new incentive. This thesis presents a qualitative study of a construction project with contractual targets for energy and carbon emissions in-use. It therefore provides an opportunity to explore what construction’s response to energy targets might be, and, in so doing, allows us to reflect on what “life in the gap” is like for these crucial actors who may find themselves on the sharp end of new energy policies.
The thesis focuses in the majority on one non-domestic project. This is a hospital in the midst of construction. Access to the project has been facilitated through a partnership with the main contractor, “Construction Co.”. Data has been gathered from the construction company’s own staff and its subcontractors, using interviews, observation, and documents. Three different concepts, drawn from Science and Technology Studies (STS), have been used to examine what the construction team members do, say, and share in response to the unfamiliar incentive of operational energy targets.

Firstly, Mol’s contention that reality is “enacted” through day-to-day practices (2002) is used to show how different, ontologically-distinct versions of an apparently singular object, in this case an energy target, may be brought into being. Secondly, Gilbert and Mulkay’s approach to discourse analysis and interpretative repertoires (1984) is applied to explore how members of the construction team may create different accounts of the energy targets. Finally, the boundary object concept is taken from Star and Griesemer (1989). The concept explores how diverse social groups may collaborate to produce coherent work, despite their differences. All three provide distinct findings, demonstrating how these concepts from STS may be very aptly applied to energy and buildings, and offer fresh insight. However, they also complement each other, in revealing how apparently singular and straightforward energy targets may become multiple amongst the diverse members of the construction team, in different ways.

The use of these theory-driven concepts from STS is intended to highlight how the energy performance gap, and the targets intended to address it, may be mutable concepts. They are intended to help take apart some of the assumptions about how buildings “perform”, and how energy efficiency or carbon emissions are reported, that are inherent in some of the policy discussions around low carbon buildings (discussed
later in the Literature Review in Chapter 2). This has potential implications for the political expectations of new incentives and for the industry actors that they may affect. In response, the thesis will attempt to employ these theory-driven insights to reflect on their practical implications, outside the bounds of STS. It was felt that this shift between theory and implication was important, as this thesis is at its heart a project of applied research. Indeed some in STS have famously argued that theoretical “daring” must not come at the expense of retreating from useful engagement with the “realist” world (Collins and Yearley, 1992:309-10). As such, these findings are intended to engage with communities of policy and industry, and energy and buildings researchers from other disciplines, as well as specialists within the STS community.

The case study of the hospital and its construction will therefore show how actors take up the policy intent of energy targets, and remake it through their own actions and words. It will reveal how aspirations for energy efficiency may conflict with established processes and practices, how the targets can rub up against, or be shaped by, other powerful commercial incentives and project demands, and how actors may lack experience, information, and confidence in dealing with these new requirements. It is therefore fundamentally about how energy policy in buildings is mediated “on the ground” (Schweber, 2017:302), by construction actors who operate within the “gap” itself, and must deal with the targets in their everyday working lives. The potential contribution of the thesis is discussed in more detail in the sections that follow.

1.2. Contribution of the research

The thesis is intended to contribute to a number of areas. Firstly, it aims to add to conversations around energy policy in buildings, as the public sector energy targets for this particular case study are currently an unusual mechanism, but one which might be
pursued further by local or national policy. Secondly, the thesis hopes to offer a critical perspective, derived from its STS grounding, on how the often-discussed difficulties of collaboration and communication in the construction industry may contribute to the “gap” between energy in design and use. Thirdly, the research engages directly with industry, through its sponsorship by Construction Co., and hence its opportunity to exchange ideas between academia and construction. These are all important issues for this research that will be outlined here, and returned to later in the thesis.

1.2.1. The policy context: why research energy targets?

Through its case study of energy targets, this thesis focusses on energy use and carbon emissions in non-domestic buildings. Reducing, or controlling, the carbon emissions from this sector is difficult. If energy use in domestic properties is problematic to manage and predict due to the interaction of the physical and the social (Chiu et al., 2014; Shipworth and Ucci, 2015), then these issues are even more acute in non-domestic buildings, which are many times more complex, and varied in form and use (Evans et al., 2017). Such is the diversity of organisational types and behaviours in non-domestic buildings that it is indeed arguable whether the “sector” can properly be described as such (Department of Energy and Climate Change, 2012:43). In addition, data on energy use in non-domestic buildings is hard to come by, and sometimes inconsistent when it is available (Pérez-Lombard et al., 2008). Unfortunately, the sector has also frequently been a neglected counterpart to research in the domestic sphere (Engineering and Physical Sciences Research Council, 2013). Therefore if the energy use and carbon emissions from non-domestic buildings are to be reduced, there is a need for much more detailed work to understand these complex challenges.

Despite the many “cans of worms” (Moezzi and Janda, 2014:35) inherent in non-domestic buildings, the significance of carbon emissions from them makes addressing
them worthwhile. Non-domestic buildings represent around 10% of the UK’s total emissions, if taking account of direct and indirect CO₂ emissions (Committee on Climate Change, 2017). This may represent only about half the amount of emissions from domestic buildings, but it is still a very significant value. Moreover, the Committee on Climate Change also observes that emissions from buildings in general are now rising, and that a “major overhaul of policy” is required to tackle this trend (Committee on Climate Change 2017:8). In particular, they identify a significant policy gap around additional standards for the construction of new buildings. Therefore new instruments such as energy targets are a valuable focus of research, as they could play a significant role in extending building energy policy.

Incentives for controlling the energy use of new non-domestic buildings are principally vested in: mandatory building regulations and related certification requirements; and the non-regulatory Building Research Establishment’s Environmental Assessment Method (BREEAM). The details of these are set out in Table 1.1 overleaf, and in the context of other government and construction initiatives relevant to energy targets in Appendix A. Within Building Regulations, the “Conservation of fuel and power: Approved Document L” relates directly to energy and carbon (HM Government, 2016), and is often referred to simply as “Part L”. The requirements for new non-domestic buildings are a sub-set of Part L.

As can be seen from Table 1.1, Part L focusses on particular aspects of a building’s construction and its anticipated energy use, and require a calculation of the carbon emissions that will arise from that eventual energy use. The legislative requirements of Part L have been driven by the European Union’s Energy Performance of Buildings Directive of 2002, and its later amendments (The European Parliament and the Council
of the European Union, 2010). The Directive is, for instance, responsible for the introduction of Energy Performance Certificates (EPCs) that assess a building’s design performance, and Display Energy Certificates (DECs) that assess a building’s operational performance, but are limited to certain types of building. However, the UK government’s commitment to implementation of the Directive has faltered in recent years, including the requirement for nearly zero-energy buildings (HM Treasury, 2015). Indeed the Government has sometimes appeared to be rowing back on progress already made, such as in its suggestion that DECs might be “gold-plated” (Department for Communities and Local Government (DCLG), 2015:6).

By contrast, BREEAM is a voluntary standard. It rewards engagement with a number of sustainability issues in a building’s design. These include energy and carbon, but also encompass water, waste, and other factors. As shown in Table 1.1, BREEAM credits are awarded for a number of sustainable design elements, which when accrued will result in a relative rating. Credits for energy and carbon are awarded for exceeding the requirements of building regulations, and for particular low carbon design features (BRE, 2018). Although it is still only used in a minority of construction projects, the reach of BREEAM is growing through its adoption by local planning authorities and commercial developers (Cass, 2018). Critically, whilst both Part L and BREEAM can incentivise construction project stakeholders to minimise energy use and carbon emissions, they stop short of comprehensive enforcement of performance during a building’s occupation and operation.
<table>
<thead>
<tr>
<th>Instrument</th>
<th>Principal features</th>
<th>Details of requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Building Regulations, Approved Document L2A. Conservation of fuel and power in new buildings other than dwellings, 2016. (Part L).</strong></td>
<td>Calculation of new building’s target emissions rate, using approved methodology</td>
<td>Models carbon emissions from new building Includes only energy use associated with building fabric and fixed services (i.e.: excludes loads such as computers and printers). This effectively distinguishes between “regulated” and “unregulated” energy use. Assesses the project by comparing it to the emissions from a “notional” building of a similar type</td>
</tr>
<tr>
<td>Other requirements relating to particular elements of design and construction</td>
<td>Limiting thermal efficiency values for building fabric and components. Provide information and controls to help occupants manage building efficiently. Limitation of solar gains, and fabric heat loss. Energy sub-metering to cover 90% of annual energy use. As-built pressure testing of building fabric.</td>
<td></td>
</tr>
<tr>
<td>Display Energy Certificate (DEC)</td>
<td>Rates building in operation from A-G based on actual carbon emissions. Based on meter readings in occupied building over 12 months. Includes all sources of energy (not just “regulated”). Required only for large, public buildings.</td>
<td></td>
</tr>
</tbody>
</table>
Table 1.1 Energy and carbon requirements of the Energy Performance of Buildings Directive, Building Regulations, and the BREEAM Standard


It has been suggested that policy to address carbon emissions from non-domestic buildings beyond these two instruments has stalled (Committee on Climate Change, 2017; UK Green Building Council, 2018). Indeed, Mallaburn and Eyre have argued that there is also a danger of the gains of previous policy successes “unravelling” entirely (2014:39), with cost-effective solutions being “ignored” by policy (Committee on Climate Change, 2018:85). Recently, there has been some indication of movement in Government’s Clean Growth Strategy (Department for Business, Energy & Industrial Strategy, 2017b), and the related Grand Challenge to halve the energy use of new buildings by 2030 (Department for Business, Energy & Industrial Strategy, 2018b), which point to political ambitions around the dual benefit of driving down carbon
emissions and the costs of construction. However, the exact policy measures that will deliver these aspirations remain to be determined.

It is therefore particularly timely to consider how new instruments such as operational energy targets could contribute to reducing carbon emissions from new non-domestic construction. Targets have been recommended by some as an attractive addition to policy, by providing an incentive to tackle the well-documented “performance gap” between a building’s energy use as predicted at design and the actual energy used in operation. Indeed as will be explained in section 2.2 of this Literature Review, some commentators are already proposing mechanisms in this mould to control the operational energy use of non-domestic buildings in the UK. However, as will also be explained later, using targets to set aspirations for, and assess outcomes of, energy efficiency in buildings is not an uncomplicated endeavour for policy to undertake. It is therefore very important that we consider what can be learnt from the deployment of energy targets to date.

1.2.2. The research context: investigating the role of construction in building energy performance

The challenges of collaboration are a recurring theme of construction research in general, often attributed to the sheer variety and number of professionals and organisations involved in the lifecycle of a project. Working relationships are characterised by multiplicity and change, with many inter-connections, iterative information flows, and daily decision-making (Pryke et al., 2017). Moreover, these relationships are tied to the project lifecycle, and so are inherently temporary, making it difficult to establish “a culture of cooperation that integrates the diverse skills” of the team (Hietajärvi and Aaltonen, 2018:1). Each of the different professional disciplines may operate within its own “knowledge base and language”. As a result, they lack a
“shared system of meaning for understanding, accepting or deploying” knowledge (Bresnen et al., 2003:158). These challenges also bear on construction teams’ ability to produce low carbon buildings. The situation is exacerbated by the current failure of construction contracts, regulations, and voluntary standards to enforce the energy performance of buildings in operation (Visscher et al., 2016). Aligning construction actors’ tasks and communications and creating a shared body of knowledge around energy performance in buildings is therefore likely to be difficult, to say the least.

Because of these difficulties, construction teams are often implicated as a major component of any failure in low carbon buildings. The industry has been variously accused of: a lack of professionalism; a failure to innovate, whilst clinging to embedded ways of working; and a lack of skills or interest in providing a quality product that performs to plan (Wingfield et al., 2008; Bordass and Leaman, 2013; Zero Carbon Hub, 2014; Morrell, 2015). The suggestion is that construction companies are simply not equipped, or even eager, to produce lower carbon buildings. It has been suggested that energy targets could help counter this, acting as "a single indicator" that “provides a common language for building performance that can span the whole supply chain” and "is straightforward to understand" (UK Green Building Council, 2016:12). However, models or policy ideals of how change in construction should happen may not fit with the way that the industry actually approaches its work (Whyte and Sexton, 2011; Loosemore, 2015). A solution that imposes a new incentive, such as an energy target, onto construction companies and expects change to follow might not be realistic. There is a need to look in detail at what happens inside construction teams when they are made responsible for energy in-use, from their perspective. Rather than focussing on systemic problems with the construction industry, this PhD will consider how these larger issues play out in a particular team.
The thesis engages with existing research in a number of ways. As just suggested, the work aims to contribute to academic research on the daily lives of construction professionals working on energy efficiency in buildings. Much valuable work in building energy research has dealt with the people and processes of design and occupation. Comparatively little qualitative work is done on what lies in the middle, despite recent attention to the influence and agency of “middle actors” such as construction professionals (Janda and Parag, 2013; Parag and Janda, 2014). The thesis is titled “life in the gap” partly to draw attention to the importance of examining this part of bringing a building to life. Understanding what happens “inside the gap” itself is critical to understanding construction’s influence on building energy outcomes.

Leading on from this point, and most obviously of all, the research contributes to the debate on the energy performance gap, and on new incentives for low carbon non-domestic buildings. There has been recent criticism of the failure of government to provide policy leadership in this area (Committee on Climate Change, 2017), and non-domestic buildings still remain the under-researched counterpart of the domestic sector (Engineering and Physical Sciences Research Council, 2013). Government now seems to have ambitions to reduce emissions from business and buildings further (Department for Business, Energy & Industrial Strategy, 2017b; 2018b). Suggestions have been made as to how international models and voluntary initiatives that focus on disclosing buildings’ energy and carbon emissions in-use could be used as leverage to improve performance (Bordass et al., 2016; Mallaburn, 2016). However, buildings policy does not always turn out as expected when it encounters local stakeholders (Foxell and Cooper, 2015), and indeed, research into the limited number of projects that have employed energy targets to date supports this (Dasgupta et al., 2012; Jain et
This PhD can help explain why this might be, by using the insights gained from its chosen STS concepts to reveal the difficulties and complexities behind ambitions to control the carbon emissions from non-domestic buildings.

Lastly therefore, this thesis also adds to the pool of research that overlaps the domain of energy and buildings and the STS research community. One of the central concerns of STS is the co-constitutive relationship between people and technology, and it offers many tools to unpack the entanglements that result. It is also capable of revealing insights of broad political or societal relevance from the smallest of empirical case studies. As such, it seems highly suited to exploring the complexities of the energy in buildings. Yet despite this, STS work done so far has tended to cluster around certain areas of the discipline (Sovacool, 2014). The three works used in the thesis aim to emphasise the value that a diversity of approaches from the field of STS could offer to how we think about buildings and energy.

1.2.3. The industry context: working with the construction company

This PhD has had a valuable opportunity to work with a construction industry partner, giving academia and industry a chance to exchange data and learning. This sort of opportunity is important, as academic findings can sometimes appear impenetrable to the industry they describe, due to the style in which research is written, the sheer number of articles produced, and a lack of access to the journals that carry it (Conaghan, 2015). Thus, as Oreszczyn and Lowe observe, it is:

“essential for the research community to engage, to a much greater extent than hitherto, with stakeholders in that industry and to accept that the meaning and validity of research cannot be determined by the research community alone, but must be negotiated in partnership with stakeholders.” (2010:118)
‘Non-technical’, interpretivist research that pulls on strands from industry, theory, energy and construction work can be of particular value in this respect (Schweber and Leiringer, 2012). As some in the construction industry itself acknowledge, more qualitative, rather than technological, research into the details and practicalities of “how collaboration happens” around low carbon buildings is needed (Chartered Institution of Building Services Engineers, 2016). Working directly with construction companies and their contractors is one crucial way in which this research can engage directly with some of the industry issues highlighted in the previous sections.

1.3. Research questions

The primary research question addressed by this PhD is: “what can we learn about the origins of the performance gap from the practices and communications around energy targets in a construction team?” This has been broken down into three subsidiary questions for the hospital case study, each addressed by one of the empirical chapters. These are:

1. What do actors in the construction team do in response to energy targets?
2. What do actors in the construction team say in response to energy targets?
3. How do actors in the construction team share information about energy targets?

These three subsidiary questions each draw on one of the specific works that have been taken from STS, and that were briefly introduced earlier. The final section below shows how these questions will be addressed through each part of the thesis.
1.4. Structure of the thesis

The thesis contains seven chapters, of which this Introduction is the first. It is followed by the Literature Review (Chapter 2), and the Methodology (Chapter 3). There are three empirical chapters, setting out the findings, each, as explained, drawing on one of the three concepts from STS (Chapters 4, 5 and 6). The final chapter, Chapter 7, summarises the findings, draws together implications, and provides overall conclusions. Appendices contain further supporting material.

The thesis therefore opens with a review of the current literature relevant to the primary research question. This covers three main areas of interest: firstly, the existing discussion around the energy performance gap in non-domestic buildings; secondly, the smaller body of literature that deals directly with energy targets; and thirdly, the work done so far within STS on energy and non-domestic buildings. In exploring these different bodies of work, the chapter will make clear the case for this research in understanding the role of construction teams in the implementation of energy targets, and in the further drawing together of links between STS and energy and buildings research.

The Methodology (Chapter 3) will provide an introduction to Construction Co., and explain my early work in getting to know it better. I will show how I came to select my research approach through early explorations, and ultimately the hospital case study project itself. The chapter will provide more information on the project, and its energy and carbon targets. Chapter 3 also covers the many important considerations of selecting a case study, the theoretical or analytical approaches, and the challenges of research in the “real world” environment of a construction business. Given the size and complexity of a large construction project, and the need to gather data for different STS
works, the data gathering process, and any inherent limitations, are described in some detail. The chapter closes with some pragmatic, and some more reflective, considerations on my research practice.

Chapter 4 considers what actors in the case study construction team do in response to the case study energy targets. Using concepts from Mol (2002), it shows how energy targets are brought into being (or “enacted”) by the construction team’s day-to-day practices, and how this leads to multiple versions of the targets. It discusses to what extent these multiple targets are brought together and aligned (“coordinated”) by the team, any gaps in coordination, and the reasons behind these. In doing so, it leverages questions about the ontology of an “energy efficient” building to draw out why it is necessary to pay attention to how building energy targets are assessed, and by whom, when considering their effectiveness in incentivising more low carbon buildings.

Chapter 5 addresses what construction actors say about the energy targets, using Gilbert and Mulkay’s approach to discourse analysis (1984). This uncovers the “interpretative repertoires” through which actors discuss the targets in their own terms. It focuses on two examples: one in which actors rationalise the differences between the “theory” and “reality” of building energy performance; and a second in which formal and informal accounts of the uncertainties of energy use are contrasted. The repertoires reveal the anxieties that targets create amongst construction professionals, and the strategies that they use to cope. These illustrate some of the difficulties and unexpected responses associated with introducing targets into established relationships and ways of working.
The final empirical chapter, Chapter 6, examines how actors share information relating to the energy targets. Drawing on the concept of a boundary object (Star and Griesemer, 1989; Star, 2010), it considers how effectively the targets engender collaboration between the different professionals (or “social worlds”) in the construction team around a common aim of operational energy performance. In particular, it explores how energy information is captured and “traded” (circulated) around the construction team, the company, and its contractors. In doing so, it reveals what “residual” energy information might remain un-captured, and why. This allows the Chapter to discuss the implications for the construction company if it were to enhance its experience and expertise around energy targets, and the operational energy use of the buildings that it produces.

Due to their differing epistemological and ontological perspectives, and the particular findings that are derived from these, each of the three empirical chapters will contain its own brief literature review, findings, discussion, and reflections on the works employed. For this reason, Chapter 7 (Discussion and Conclusions) will be slightly briefer. It will focus firstly on summarising the findings of each empirical chapter, and then on drawing together the insights across all three. The latter approach is important as, not only were the concepts selected to offer complementary insights, but, critically, they are also all intended to produce a coherent set of findings that are helpful for stakeholders in industry and policy. Implications for construction, policymakers, and suggestions for further research arising from across the thesis are therefore presented. This is followed by some final thoughts on what can be learnt from the research approach, and the limitations of what it has not been able to cover. Overall conclusions complete Chapter 7, and the thesis.
2. Literature Review

This chapter lays out the existing research landscape within which this PhD is located. In doing so, it will also make the case for why this particular study is necessary. I will explore in turn three areas of scholarship that are relevant to my work. Firstly, section 2.1 considers research that examines the energy performance gap in non-domestic buildings, as this directly relates to industry and policy efforts to improve energy efficiency in buildings with which this work wishes to engage. However, another task is to explore how the energy performance gap has many definitions, and thus is not necessarily singular. Secondly, section 2.2 deals with the small body of literature focussing directly on energy and carbon targets, as it is the response to this incentive mechanism that is the topic of the thesis. Thirdly, in section 2.3, I will consider how STS thinking has already been applied to problematise energy use in buildings, and hence to place this thesis in context. Each of these three bodies of research is discussed in a separate section and forms the majority of this chapter. Lastly, in section 2.4, I will provide an overview of the three concepts used in this PhD. As previously noted, this is a brief introduction only, as they are set out in more detail at the beginning of each empirical chapter.

2.1. The energy performance gap in non-domestic buildings

Buildings do not always perform as planned. There is often, therefore, a “gap” between what a building’s design intends, and what happens during occupation. In terms of energy use, the “energy performance gap” is a topic that has engaged academics from technical and social backgrounds, as its challenges cross the boundaries of traditional
disciplines (Love and Cooper, 2015). However, each of these disciplines approach the “gap” with their own set of analytical tools and traditions. The “gap” that they discover is not, therefore, the same. As Law and Ruppert have observed, research findings depend on “our own questions, and our own agendas” (2013:233). The energy performance “gap”, as this section will show, may therefore be conceived in a variety of ways by different strands of research. This is important to appreciate, given that energy targets are proposed as a solution to “the gap”, and thus if it, or energy use, may be multiple, this affects the impact and expectations of such targets.

The first step is to understand how the energy performance gap came to be identified. I will begin by considering studies that take a wide-angle lens to the issue of the energy performance gap in buildings from the top-down, and explain how it became part of a reform agenda for British construction, and linked to policy targets for carbon reduction. This sets the scene within which the public sector targets for this case study have emerged. Flipping the viewpoint, I will then review the work done in detailed building case studies from the bottom-up, which also primarily addresses the energy performance gap as the result of failures in the design and construction process. Using detailed analysis of individual building’s energy data, these bottom-up studies seek to understand the practical means by which technical design and measured operational energy use could be brought together, and working processes improved. However, their recommendations focus on what is not working and how it can be corrected, rather than asking why actors act as they do, or what a “good” design is trying to achieve.

Another body of research has used qualitative lenses to consider some of these questions. Communities of designers and occupiers, of various sorts, have been
considered in particular. However, the focus on the two points of design and operation neglects the role of construction teams, “inside the gap” itself. An important strand of research is therefore that which considers the influence of “middle actors”, and their professional roles, on building energy outcomes throughout the whole project lifecycle. Finally, research into construction actors’ communications and collaborations, the form of, or indeed the lack of which, is often held to be responsible for problems in realising energy efficiency in-use.

Together, this forms a landscape within which actors in the construction industry are clearly a present influence on building energy use, appearing either in researchers’ observations about poor relationships, communications and collaboration, or in their very absence between other more heavily-researched stakeholders. I will conclude that as a result we still do not know enough about this influential group of construction actors, who reside within the “gap” itself. Moreover, if the gap itself is variable in nature then understanding how construction actors conceptualise it amongst themselves is important.

2.1.1. From the top-down: the energy performance gap as a symptom of industry failings

It has been suggested that the energy performance gap is partly a product of deep-seated, systemic issues in the building industry. Major reviews of the construction industry dating back over twenty years have identified issues that could affect building performance, including: adversarial relationships rather than collaboration; a lack of innovation, research, and skills development; the prioritisation of short-term cost minimisation over long-term performance; and fragmented construction teams (Latham, 1994; Egan, 1998). The link between these problems and carbon emissions was made
explicit in the later Wolstenholme Review, in which the authors note a "huge missed opportunity" on the part of construction to engage with the environmental performance of its buildings (Wolstenholme et al., 2009:25). A year later, the government itself suggested that the construction industry should stop viewing carbon emissions in-use as “someone else's problem” (Department for Business Innovation and Skills, 2010:23), and that building legislation and incentives needed to be geared more towards outcomes. However, the report also highlighted a number of significant challenges, including: a lack of energy data in practice; construction industry silos and fragmented supply chains hampering innovation; a confusing landscape of competing initiatives; and uncertain customer demand for low carbon buildings. However, whilst raising important challenges, these industry scale reports fail to land on the specifics that they think could help reorient construction towards better building outcomes.

These reports also suggest that there has been little progress in the intervening time to change the cultural character of the industry (Farmer, 2016). The recent investigation into the Grenfell Tower disaster also raised fundamental issues about the construction industry, such as: the potential for misinterpretation of complex regulations; a lack of clear responsibilities to “make things happen”; a lack of effective sanctions to drive behaviour change; and a conclusion that what is missing is a “golden thread” running through projects, to connect what is designed with what is built (Ministry of Housing, Communities and Local Government, 2017:9-10). From an academic perspective, Smyth’s recent work on the structure and market of UK-based construction companies (2018) likewise highlighted little progress in addressing collaboration, fragmentation, or the focus on short-term costs. This connection between the industry, its priorities and the energy performance gap is important, as it underscores the usefulness of gaining a better research understanding of construction professionals.
Third sector research has also considered the difficulties in getting low carbon buildings to perform as promised. The Carbon Trust produced a short guide to the performance gap (2011), primarily aimed at an industry audience, but which raised interesting issues around the limited capture of energy sources by Part L, leading to poor, or no, design consideration of unregulated, and primarily electrical, loads. It also covered key problems such as variations in occupational use, poor practice in commissioning or operation, and failure to include functions such as information technology and catering. Another body sitting between industry and the public sector is the Zero Carbon Hub, which, although focused on the energy performance gap in domestic construction, does raise crosscutting industry challenges (2014). Once again these include a plethora of problems, including: a failure to integrate professionals across different building stages; procurement, installation, and commissioning work that does not attend to energy standards; design variations and substitutions of less energy efficient alternatives during construction; and a lack of attention to and knowledge of the effects of actions on energy efficiency in construction teams.

The problem that working relationships in construction might pose for energy performance was further illustrated by the Edge Commission, which identified the performance gap as one of the consequences of a failure in “professionalism”. The report emphasised an urgent need for action:

“there can hardly be a cause more deserving of cross-industry collective contemplation and action than the constant failure of its product.” (Morrell, 2015: 82)

The UK Green Building Council has also grappled with building performance, with carbon as one of their main focus areas. Their key recommendations included better
communications and knowledge sharing, throughout the supply chain and with the client. They also expressly recommended performance targets as a way to facilitate understanding in a construction project:

“setting a simple target – at the very least for energy use (kWh/m²) – should help create a common language and shared aspirations across the delivery process.” (2016:29)

Unfortunately, the Council does not outline the potential difficulties inherent in this, nor the means by which such a target might be embedded into established ways of working.

Alongside these industry studies, academic research has also provided high-level perspectives on problems that arise from construction stakeholders’ priorities, knowledge, or skills. Studies have highlighted many issues of cultural adaptation for the construction industry in moving towards more sustainable buildings (Pitt et al., 2009; Häkkinen and Belloni, 2011). Matar et al. (2008) additionally drew attention to a lack of processes and project delivery structures that could help construction make such a transition. Sorrell (2003) addressed himself directly to the Egan and Latham agendas, and urged for “making the link” that at the time was crucially lacking between climate policy and the drive for construction reform. The list of problems he highlighted in construction mirrored those of Egan and Latham. However, Sorrell’s proposed solutions were economic, recommending better-structured incentives and contracts to draw parties together, and iron out inconsistencies and inefficiencies.

These strategic positioning pieces present a broad spectrum of problems in the construction industry and its professions that have been gradually linked by high-level policy to the particular “performance failures” of low carbon buildings. The evidence
they present therefore strongly suggests that many of the difficulties of producing low carbon buildings relate to the actions of construction teams themselves. Yet the very scale of these high-level studies means that they cannot provide detail on how these systemic issues play out in specific circumstances, and hence how such performance failures emerge. As a result, it is hard to get a grip on how the challenge of improving building energy performance might be tackled in specific, practical ways through consideration of individual building projects and their stakeholders. Moreover, collectively they paint a broad policy background from which energy targets can emerge as a solution to controlling an apparently unruly and recalcitrant construction industry, of which the energy performance gap is one symptom.

2.1.2. From the bottom-up: using building-based data to diagnose the gap

At the other end of the spectrum are building-based case studies that focus on the details of particular projects. These studies form some of the original work that ‘discovered’ the energy performance gap, beginning with the early building analyses of the 1970s (Socolow, 1978; Markus, 2001). For UK non-domestic buildings, one of the landmark, and still highly-cited, studies were the PROBE building analyses (Bordass et al., 2001a, 2001b, 2001c; Cohen et al., 2001; Leaman and Bordass, 2001). PROBE’s post-occupancy evaluations raised a large number of practical issues for designers and contractors to consider. Their aim was to render buildings more responsive to occupants’ needs, as well as more energy efficient. The PROBE authors espoused simpler buildings, better feedback both before and after occupation, and meaningful benchmarks for performance appraisal. On the latter they raise important questions around what is included, the complexity that may underlie umbrella metrics, and the overriding importance of considering empirical bases rather than theoretical generalisations. Overall, PROBE positions non-domestic buildings as bespoke products, more akin to “ships” than mass-produced technological artefacts like cars.
(Bordass et al., 2001c:150), and hence requiring consideration both to the technologies they use, and to the people who make, manage, and use them.

Supporting the PROBE findings, Cooper (2001:161) reflected on “decades of neglect” of post-occupation review of buildings, due to a mutual lack of interest from clients, who may fail to appreciate its potential value, and builders, who are reluctant to risk liability for any failings exposed. Cooper sought a new agenda for assessing buildings’ success, driven by more feedback of operational information into design, a method of measuring success that fitted with the occupiers’ own management interests, and the creation of benchmarks for sustainable buildings. One of the other pioneers of building performance, Markus, agreed with Cooper on the need for the building industry to learn from experience, rather than persist in what he likened to a “collective amnesia” when approaching new projects (2001). These studies set an impetus, and an investigative framework to diagnose relative energy efficiency, that has subsequently been picked up by others studying the energy performance gap.

A further development was Way and Bordass’s concept of Soft Landings (2005), which envisioned how post-occupancy evaluation might be worked into the procurement process from the very beginning of a project. The logic was that this would make feedback routine, so that designers and builders were required to engage with building performance as a matter of course, rather than as an exception. In particular, Way and Bordass recommended: measurable performance targets (for energy and other performance issues); clear decision points, roles and responsibilities; and more sustained involvement with users and building managers, especially in the initial years of occupation. Soft Landings continues to develop (Agha-Hossein, 2018), and is now
accompanied by other performance evaluation methods (Guerra-Santin and Tweed, 2015).

In terms of individual buildings, one approach to performance analysis has been to compare variances between modelled and measured energy use. Demanuele et al. (2010) investigated factors that determined energy use in a group of case study schools. They explored the sensitivity of various energy modelling inputs, finding that “occupant behaviour is highly variable and unpredictable”, concluding that the concept of a “prediction” was not “meaningful” (ibid:6). Using a similar approach in a very different sector, Menezes et al. (2012) undertook a post-occupancy evaluation of a single office building, also focussing on the divergences between modelling assumptions and in-use performance. They likewise argued for more attention to variability in occupier activities, especially in a building with many different uses such as a multi-tenanted office, but also for an understanding of the influence of building managers’ actions on energy use. They concluded that more detailed models and better benchmarks were needed in design. Whilst these studies do engage with the difficulties of predicting energy use, they also risk conceptualising this as a failure in the energy modelling process that can be fixed by more “realistic” inputs (ibid:140).

One of the largest recent exercises in evaluating the performance gap in non-domestic buildings was undertaken by Innovate UK’s Building Performance Evaluation (BPE) Programme (Palmer et al., 2016). This study covered 56 buildings, taken from a variety of sectors, but all sharing high aspirations for energy efficiency under different guises, from Energy Performance Certificate (EPC) ratings, to BREEAM, and targets for renewable energy. The work concentrated on the building fabric and energy systems, combined with occupant feedback. It uncovered a wealth of detail around the kinds of
practical things that can go wrong with design, installation, and operation. It also indicated that projections of energy use made by BREEAM, EPCs, or Part L did not correlate well with eventual energy in operation, suggesting that existing regulations and standards were not functioning effectively.

Behind the details of the issues that were explicitly raised by BPE, the influence of people on a project’s outcome can be discerned. So, for instance, the report suggests that designers frequently underestimate occupants’ energy use outside standard working hours. However, the high level of this study means it is unable to consider the actors themselves and why they might make these apparent omissions. They also illustrate, but do not pursue the implications of, the multiple processes and forms in which energy efficiency is measured, and hence the various ways in which an energy performance gap may be found.

Post-occupancy reviews have also been taken up by some in industry. For instance, professionals may submit building data anonymously to the CarbonBuzz platform, which also makes use of CIBSE benchmarks (CarbonBuzz, 2019). Commercial organisations have also carried out their own investigations, such as that of over 200 of its portfolio buildings by Jones Lang LaSalle and the Better Buildings Partnership. Mirroring the BPE, this revealed “little or no correlation between EPC ratings and actual energy performance” (Jones Lang LaSalle, 2012:4). The report also drew attention to the particular problems of split incentives and lack of data in the commercial office rental sector in which they operate. Thus these industry initiatives also reveal the multitude of stakeholder motivations behind the performance gap, and the variety of data used to quantify it.
These detailed case studies of non-domestic buildings therefore shed valuable light on the reasons why there might be a gap between design and operation. Drawing on specific buildings, they highlight the influence of each project’s individual circumstances and players. They work analogously to detective work, drawing together data from various sources to create a narrative from which an energy performance gap may be discovered, and the culprits identified. However, this research approach, based as it is on technical data gathering, occupant surveys, and practical suggestions for improvements, does not explain in detail the social contexts or relationships that might be affecting energy performance. More specifically, it cannot consider the impacts of professions and organisations on why, for example, designers make the assumptions they do, or occupiers do not behave in the ways that energy models expect. Finally, they do not follow up a suspicion that the energy performance gap, being by definition the result of a comparison of two separate points, may itself may be variably constructed depending on the data used for that comparison.

2.1.3. Regulating and modelling expectations of energy use

As noted in the introduction, instruments to control building energy use are currently embodied in the form of EPCs, DECs, Part L and BREEAM. These therefore play a key role in creating expectations of what an energy efficient or low carbon building should be, and how compliance with these expectations should be demonstrated. Voluntary standards, such as BREEAM, or indeed the original incarnation of the Australian NABERs scheme (discussed later in 2.2.1), are underpinned by the logic of using market demand to drive sustainability efforts. This is used to justify their impact. For example, using statistical data from buildings in the United States, Eichholtz et al. (2010) produced a highly-cited paper suggesting that building ratings schemes, such as Energy Star and LEED, attract a financial premium for the buildings they accredit. Newer market instruments, such as green leases, which incentivise stakeholders to
cooperate around operation, are another market mechanism. However, they are still evolving, and questions remain around their fit with commercial circumstances and their approach to operational enforcement (Janda et al., 2016).

BREEAM itself may act as an “anchor” for sustainability in a project, and provide an incentive for teamwork around sustainability issues that might otherwise be neglected. However, its market focus also tends to bureaucratic standardisation and an elision of individual projects’ variations under a single rating (Schweber, 2013). Moreover, initiatives such as BREEAM may increase awareness of sustainability issues in buildings, but fail to produce measurable reductions in carbon emissions (Lorch, 2017). As Lowe et al. (2017) noted, the BREEAM standard assumes that the inclusion of a certain number of design features will result in a well-performing building, which is not necessarily the case. Moreover, Pérez-Lombard et al., (2009:272) have identified a “multiplicity of terms and concepts” amongst different building certification and labelling schemes that renders their definition and implementation open to different interpretations by stakeholders. The implementation of BREEAM itself may also depend on the individuals in each construction team who engage with it, and their experience, relationships, and other project priorities (Schweber and Haroglu, 2014).

As for building regulations, and Part L, Hamza and Greenwood (2009) studied the introduction of the new Target Emissions Rate, focussing on buildings’ carbon emissions, after the 2006 amendments to Part L. They found not only that the new requirements did produce a more focussed attention to a building’s carbon emissions, but also that the new energy modelling required encouraged collaborative working. However, as an incentive to operational, rather than design, efficiency, Part L still fell short. Burman et al. (2014:156) observed that design energy projections, although
modelled in a way that is entirely compliant with the requirements of Building Regulations, “are not directly comparable with actual performance”. They went on to observe that Part L is formulated around compliance at the design stage of a project, with very limited follow up of performance of a project once built, exacerbated by simplified modelling templates, and a failure to cover “unregulated” energy use. Thus existing regulations and standards may encourage stakeholders to create energy efficiency through design alone.

Problems with design, the first side of the gap, have been attributed to the way that it is assessed. Central to this is the process of energy modelling. Modelling is used variously: to assess compliance with Part L, or BREEAM credits; to predict a building’s potential to meet an energy-related target; or to help negotiate the level of a target in the first place. Dasgupta et al.’s work on schools (2012) indicated that modelling predictions may be static, and hence fail to take account of: changes in the way a building is used; occupiers’ or building managers’ influence; and interactions with system controls and the building infrastructure. Others have also problematised occupants as a modelling difficulty (Hoes et al., 2009; Clevenger et al., 2014), and indeed the International Energy Agency’s Annex 66 research programme has been dedicated to an examination of how building modelling might better reflect “occupant behaviour” (Yan et al., 2015). These studies therefore suggest that the energy performance gap may be reduced by more sophisticated methods of prediction, such as improved algorithms, or at least better incentives for stakeholders to use them.

Another suggestion made by the literature is that there need to be better linkage between design, on one side of the gap, and operation, on the other. Modellers, in particular, often lack data (Low Carbon Innovation Coordination Group, 2012),
especially from the non-domestic stock, that leaves them struggling to find inputs that represent the diversity of activities within these sorts of buildings (Tian and Choudhary, 2012). There is a resulting danger that benchmarks used to represent certain generic types of non-domestic building will not fit the individual project at hand. Bordass et al. (2014) point out that generic expectations of what a pre-conceived type of building might produce in a particular sector are often inappropriate, and it would be better to look at the particular activities and services applicable to that individual building. Hong et al. (2013) have also pointed out that the DEC benchmark categories into which non-domestic buildings are placed for comparison are not always meaningful. These difficulties with benchmarks are compounded by the effects of varying form and function in the individual buildings, and by technological change, which can render benchmarks obsolete (Hong et al., 2018). Setting the expectations against which the energy use of a non-domestic building is to be judged is therefore a tricky process of balancing the need for comparison against a recognition of its individual circumstances.

However, the assessment of energy predictions against operation is affected by other, more subtle, variables besides the availability of reliable data or benchmarks. These variables reveal the unstable construction of design predictions. Different brands of modelling software, for instance, have been shown to produce different results (Raslan and Davies, 2009). This, Schwartz and Raslan noted elsewhere, “raises questions concerning the ability to rate ‘sustainability’ in a consistent manner” (2013:350). This is especially true when the bewildering plethora in means of predicting and evaluating building performance is considered (Borgstein et al., 2016). Rees (2017) recently likened energy modelling to a weather forecast, arguing that actors may take as gospel something that is inherently uncertain, and that a more open discussion is required on modelling’s inherent limitations. CIBSE itself has attempted to engage with this need
through its TM54 standard, “Evaluating Operational Energy Performance of Buildings at the Design Stage”, (Chartered Institution of Building Services Engineers, 2013). These findings collectively raise questions about what a modelling prediction is, or can reasonably be expected to be, and how actors engage and talk about energy performance aims (Moncaster, 2015).

Many (although not all) of the studies quoted so far have had a ‘technical’ slant. In the main, they have dealt with the actions and motivations of people in relation to energy through surveys, mixed methods, and the giving of practical recommendations. In this, they offer a very valuable contribution to the research on the energy performance gap in their own disciplines. They also raise interesting questions for qualitative researchers, as they all grapple with issues caused by people, whether these be the activities of office workers, the decisions of modelling software designers, or the priorities of government regulators. There is of course a body of work that does look at the effect of people on the energy use of non-domestic buildings through social theory. This has also often clustered around the two points that the performance gap fails to unite: design and operation.

2.1.4. Considering designers and occupiers

Social scientists have considered how demands for energy efficient or low carbon buildings can impact design stakeholders. The overall impact of introducing carbon requirements into the Building Regulations has been found to be affected by designers’ established routines, and conflicting stakeholder interests (Zapata-Lancaster and Tweed, 2014). Although communities of design professionals may be keen to lay claim to certain parts of the low carbon agenda in buildings, they may shy away from responsibility for other aspects (Janda, 2011). Murtagh et al. (2016) found that professional motivations and sustainability could work in concert amongst building
professionals, but often did not. Their recommendation was that better professional education in sustainable construction could help “join” parallel conversations about professional identity and sustainability. Professional routines and identities may thus be disrupted by new requirements to make a building lower carbon (Janda, 1998).

Sometimes drivers that might be expected to encourage energy efficient building designs can actually produce the opposite effect. Cass and Shove (2018) have recently considered the effect of “market-driven” standards, such as BREEAM, on designers. They suggested that the effect might be to perpetuate energy inefficiency, through over-specification for compliance thresholds, and lock-in of energy using normative assumptions. In an earlier example, Fischer and Guy looked at the evolving requirements of building regulations. They found that increased complexity lead to increased reliance on specialised processes in design to comply with them. As a result, architects’ and engineers’ processes became obscure to each other, illustrated by one participant dismissing energy modelling as “black magic” (2009:2589). The consequence is that the new regulations intended to control energy or carbon may paradoxically lead to poorer results, professional conflict, and less understanding between actors in design.

In addition to design professionals, occupiers of non-domestic buildings have also received research interest. Their interaction with the physical environment of the building, and its energy systems, has been one focus. A lack of engagement with energy systems, and consideration of how, or to what extent, to link occupiers and building operation have figured in the findings (Karjalainen and Koistinen, 2007; Brown et al., 2009; Morgenstern et al., 2015). Cutting out occupiers’ choice through automation can be a solution to the troubles of predicting how they will behave, but
may bring the corollary of dissatisfaction with it (Day and O’Brien, 2017). Coleman et al. (2013) considered whether the provision of personalised energy information could motivate workers to reduce their energy use in offices. This study similarly emphasised the importance of whether control over energy was vested in individual workers, or was centralised. It also indicated that empowering individuals through information was not enough: the information needed to be relevant and understandable to those who received it.

Into this equation, we also need to introduce facilities managers, who can be critical in influencing energy use in non-domestic buildings (Min et al., 2016). It is likely that facilities managers will employ their own interpretations of “green” or “sustainable” in the context of the buildings they work in, and their own goals and priorities (Lewis et al., 2010). Their actions can also be constrained by practical issues. For instance, their interaction with workers may be hampered by lack of time and appreciation for the critical part that this relationship plays in the energy use of buildings (Pettersen et al., 2017). This stream of work on occupiers, of various sorts, therefore complements the literature cited earlier on “unpredictable” occupiers, by indicating the complex dynamics of engaging them in operating energy systems in the workplace.

However, there is more to occupiers than individuals. Attention has been drawn to the importance of group behaviours in organisations (Deline, 2015; Dixon et al., 2015). Behaviour within businesses, such as their structure, routines, and priorities, can affect energy-saving decisions (Wong et al., 2013; Andrews and Johnson, 2016). Organisations will take decisions in the context of their own strategic identity, which may not flex to include energy concerns (Zimmerman, 2011). They also sit within complex webs of commercial and legal relationships, such as those in tenanted office.
buildings, which could act as networks for spreading environmental change, but also make them hard to tackle (Axon et al., 2012). In addition to the role of professionals as individuals and groups, there are the pressures that act on them from outside their group. Clients and investors may not understand the opportunities of energy efficiency investments or innovations, and continue to be risk averse and reluctant to pay for innovation as a result (Ivory, 2005; Mills et al., 2006; Loosemore, 2015). Therefore, there exists an opportunity to explore this relationship between energy, organisations, their networks, and individuals at work much further (Janda, 2014; Andrews and Johnson, 2016).

2.1.5. Construction, professionalism, and middle actors

Pertinent to this thesis is the need to consider how the combination of organisational context and individual work plays out in construction companies. Hoffman and Henn (2008) considered the social and psychological barriers to green building, running through individuals, organisations, and institutions across the building industry. They identified problems with information flows in temporary teams, and team structures that did not coordinate or reward energy considerations, compounded by inertia or fear of change. Boyd and Schweber (2012) have likewise considered the “mainstreaming” of sustainability in construction companies. They addressed the challenges of moving from a few, client-led demonstration case studies, towards the embedding of sustainability into a firm’s culture. These sort of challenges within construction companies remind us that these are organisations with dynamics and motivations, just like the designers and occupiers who influence building energy use.

Despite the crucial role they play in producing the buildings that are the central concern of the energy performance gap, the influence of construction actors have been less often investigated than the other sides of the “gap”. Qualitative research has more
frequently opted to pursue designers and, in particular, occupiers of low carbon buildings (Schweber and Leiringer, 2012; Gram-Hanssen and Georg, 2018). Indeed it has been observed that:

“when we are interested in ‘behaviour’ we have tended to be interested in the behaviour of those who occupy buildings and less in the complex social interactions which together produce the buildings we end up with.” (Schiellerup and Gwilliam, 2009:803)

However, this has now begun to change, even during the progress of this PhD, with an emerging focus on the “missing middlemen” of energy performance (Wade et al., 2016), and the role that these professions might play in construction and energy.

Change in the energy efficiency of buildings comes not just from the top-down or the bottom-up, but also from the middle-out, amongst those who might not directly “produce nor consume” the energy of a building, but nevertheless “shape and can alter the ways in which it is used” (Janda and Parag, 2013:42). Work on these “middle actors”, such as professionals in construction, local authorities, or technology suppliers, suggests that their agency has been underestimated. Previous research had already identified that new requirements to reduce carbon emissions can give rise to a corresponding need for professional intermediaries, such as architects, to translate them into practice (Fischer and Guy, 2009). However, Janda and Parag’s conceptualisation of “middle actors” is, as the name suggests, more active, recognising the influence of these professionals beyond being passive conduits for change. In addition, middle actors are also likely to be hedged around by the constraints of their particular knowledge and networks (Parag and Janda 2014), and by market forces within their sectors (Janda and Parag, 2013). This indicates that more attention is required to the potential influence of these professionals in the “middle” of energy transitions.
A focus on middle actors also raises questions of how professional identities and their associated tasks adapt to the new demands of low carbon issues in the building sector (Janda et al., 2014). Abbott’s system of professions (1988) has proved one useful lens to analyse some of these impacts (Janda, 1998). As hinted earlier, the integration of energy concerns into building professions is not always smooth. Wade et al. (2018) recently explored the interplay between energy and professional identity as managed through routine working practices, and found that existing professional jurisdictions restricted advocacy for energy-saving opportunities. The existing structures of the industry, which foster the fragmentation of professional roles in projects, may not fit well with coalescing around a single goal of energy efficiency (Killip et al., 2013). Indeed, this may link to concerns over a professional “crisis” raised earlier (section 1.2.1), which prevents its members responding to energy demand. The circulation and development of professional knowledge that could help improve the quality of buildings may therefore not occur.

The issue of professional integration can loom large. Non-domestic projects have complex layers of supply chains (Department for Business, Innovation and Skills, 2013), which have little commercial incentive to cooperate with each other beyond the bounds of their individual tasks, but which will nevertheless produce work that does interact with others’, leading to contradictory pulls to both collaborate and act independently (Kesidou and Sorrell, 2018). Those who are required to collaborate on energy issues may fail to trust each other, hampering the effectiveness of tools that could promote cooperation (Alsaadani and Bleil De Souza, 2016). Internal structures may not help either. Middle actors in construction organisations who could be in a position to mediate may find themselves pulled by conflicting demands from internal
stakeholders, and with inadequate organisational support, as Goulden and Spence’s study of facilities managers illustrated (2015). Furthermore, there may be divisions within professional groups (Brown and Phua, 2011), driven by individuals’ decisions and day-to-day working practices (Phua, 2013). Middle actors such as construction professionals therefore have huge potential to influence the energy outcomes of buildings, and enable or disable energy policy targets, but existing industry structures and incentives may present significant barriers to channelling this influence in positive directions.

2.1.6. Research on communication and collaboration in construction requires more detail on energy

Research is often in agreement that communications in construction hamper building energy performance. However, whilst it is easy to agree with the case made by Cole (2011) that better buildings may require more stakeholder engagement and greater communication and dialogue, the these general exhortations are not always accompanied by details of exactly how to achieve this:

“it is difficult to trace the root cause and detail of communication problems which bridge across multiple professions and teams.” (Zero Carbon Hub, 2014:7).

Unfortunately, buildings policy has sometimes neglected to explore disconnects between national policy and local implementation, meaning that the challenges of changing industry ways of working, and the unexpected consequences and hiccups of implementation, are not recognised (Foxell and Cooper, 2015). Interpretative studies can play an important role in this context, in revealing exactly these sorts of localised difficulties in the communities that policies affect (Wesselink et al. 2013). However, in the case of construction, whilst research into the “lived experiences and practices” of
Construction workers is growing, it is still small in volume (Shipton et al., 2014:788), and in the case of energy in construction it is even smaller.

Conversely, however, it seems that somehow the professions do manage to collaborate effectively enough to get the building built (Harty, 2005). This suggests that research is needed to uncover more about the nature of the problem in communications or collaboration around energy in particular. Construction management research, outside the scope of the energy performance gap, has already helped to conceptualise some of the problems with collaboration and knowledge sharing (Bresnen et al., 2003; Robinson et al., 2005; Carrillo et al., 2013), including considering new qualitative methods to explore relationships amongst construction actors (Fellows and Liu, 2017; Pryke et al., 2017). Attention has also been paid to the everyday practices, roles, and interactions of design and construction teams (Kabiri et al., 2012; Boudeau, 2013). What is needed is more work around how those in construction organisations deal with the challenge of energy efficiency or sustainability, that goes beyond the identification of factors to highlight what “conditions render them effective”, or not (Boyd and Schweber, 2012:1352). This would help uncover more about the situated details that lie behind the cultural barriers to change in construction (Hartmann, 2006), and the myriad of other long-standing issues, which persist because of the way the are structured into the system via contracts and incentives (Sorrell, 2003). Qualitative research designed to “collect insights on how easy it might be for different professions to incorporate energy saving into their everyday working practices” (Wade et al., 2018:51) could be valuable.

There are some qualitative studies that have already dealt with the issue of energy efficiency on the ground in construction teams, in detail. They have highlighted the
importance of the ways in which information is captured, circulated, and interpreted (Fedoruk et al., 2015). Some very recent case studies also suggest that knowledge and learning around building energy performance is particular problematic in construction, both within the industry, and in feedback links to government and research (Shrubsole et al., 2019). Environmental issues in construction may compete with other priorities, and individuals may not have the power to prevent them being abandoned, especially in the project environment where decisions are reactive, experience-based and urgent, and environmental concerns can seem like so much bureaucracy (Gluch, 2009).

Additionally, the implementation of energy knowledge must work with the existing interrelationships between people in construction teams, rather than sticking rigidly to an idealised view of how the community should be listening or reacting to energy concerns (Gluch et al., 2013). Sustainable construction is therefore still faced with decentralised decision-making, in which uneven rewards, many players, local decision making, and failures to understand each other, fight against the importance of getting everyone aligned (Bueren and Priemus, 2002).

Drawing together the implications of this section, it appears that the issues facing the implementation of energy efficiency or carbon reduction incentives in construction teams are likely to be many and complex. It is hard to understand the potential of new energy incentives without a detailed understanding of how these challenges are manifested in the situated responses of construction actors. Yet, in the case of energy targets, this situated response of construction teams has yet to be studied. Research into the performance gap has too often concentrated on the two opposing sides of design and operation. The practices, decisions, and conversations that are likely to form part of “life in the gap” have therefore been comparatively neglected, despite growing interest in middle actors. Policy may moreover hope to skate over the
problematic no man’s land of construction with incentives that devolve accountability for drawing together the apparently two opposing sides of the gap. This thesis aims to address this omission by exploring what happens to energy targets “inside the gap”. With this in mind, the next section will explore existing research into energy targets.

2.2. Energy targets

2.2.1. What are the expectations of energy targets?

The concept of setting targets that measure operational energy use and carbon emissions, as opposed to those that only focus on energy predictions in design, is that they could provide a powerful lever to reduce the performance gap in public and commercial buildings. They are a solution that has been recommended by some of the literature quoted earlier in this chapter, such as the UK Green Building Council (2016:4). Work from the Building Performance Evaluation Programme also suggested that “successful [energy efficient] operation relies on having a clear end-to-end strategy for the building’s performance which all parties should be signed up to”, and which should be based on “setting clear sustainability goals at the outset” (Faithful-Gould, 2014:62). The Committee on Climate Change has also noted the importance of aligning policy to “real-world performance”, and the potential contribution of schemes that focus on either enforcing, guaranteeing, or disclosing actual energy and carbon performance through financial and reputational incentives (2018:86). Thus energy targets are portrayed as a way for the disparate professionals of the construction team to rally around a common aim, spurred by accountability for the end result. Note that the targets themselves do not come with a process, nor a means by which they are to achieve this bringing together of professionals. They are therefore very far from introducing a model intended to transform the relationships between construction stakeholders, such as the concept of integrated design (Owen et al., 2010).
Policy interest in targets for in-use energy or carbon has fluctuated. Mitigating climate change, and the role that lower carbon buildings could play, rose high on the UK political agenda at the end of the 2000s (House of Commons Education and Skills Committee, 2007). During this period, contractual energy- and carbon-related targets were introduced into procurement contracts for some public buildings, such as hospitals and schools (Education Funding Agency, 2013; Department of Health, 2015). Interest then faded with the change in government, but has shown some small signs of revival recently. For instance, operational metrics have recently been raised in various forms by local and national government consultation and strategy publications (Greater London Authority, 2017; Department for Business, Energy & Industrial Strategy, 2018a; Department for Business, Energy & Industrial Strategy, 2018b). In addition, other public sector or commercial organisations have sometimes chosen to pursue targets voluntarily (Faithful+Gould, 2014; Palm and Reindl, 2016; Jain et al., 2017), but they have remained exceptional.

Recently, the Australian NABERS rating scheme has been suggested as a model for UK commercial buildings (Mallaburn, 2016). NABERs discloses in-use energy, and classifies buildings on their performance, which in turn should drive a market for better-performing buildings. As such, supporters of a NABERs style scheme, suggest that it could rather neatly to tackle a number of issues around the feedback, communication, and incentive problems discussed in the previous section. Indeed, it has been claimed that a NABERs-style system could present a “transformational” opportunity in building performance if applied in this country (Cohen et al., 2017). If information about buildings’ actual performance were readily available, then this would not only enable learning about what works, but also foster “a collective understanding that better
energy performance in-use was everybody’s goal” (ibid:535). The applicability of a NABERs-style scheme for the UK is currently being trialled through the Design for Performance initiative in a number of commercial buildings (Bordass et al., 2016; Better Buildings Partnership, 2018). This renders further investigation of these sorts of operational incentive, and a consideration of these high expectations for them, opportune.

2.2.2. How operational energy targets can help bridge “the gap”

The most obvious argument for energy targets is therefore that they focus on performance in operation. As Tuohy and Murphy (2014) have observed, if policy and regulation are focussed on predicted rather than actual energy use, then it is little surprise if the construction industry aims to deliver buildings with design promises of energy efficiency, rather those that are reliably low energy in operation. This is what has been termed the “design for compliance culture” (Cohen et al., 2017:720), based on the presumption by designers and builders that their work is done once the building is physically complete (Way and Bordass, 2005). This lack of accountability has formed a major problem for energy performance:

“ordinary people might reasonably expect designers and builders to be experts on the performance of the buildings they create. This is not normally so: ...By and large, the providers do not stay around long enough to get much of an idea about how well the buildings they have produced actually work…” (Bordass et al. 2001b:13)

Re-orientating accountability to performance in-use could help correct this major structural failing in the industry.

Additionally, operational energy targets have been suggested as a means to bridge the separation between the actors involved in the design and construction of the building,
and those who own or use it. Not only are designers and builders usually not there during occupation, they may actively avoid being so, as fear of liability can prevent them investigating completed buildings further (Robertson and Mumovic, 2013). The building sector has frequently been criticised for operating in a dysfunctional “circle of inertia”, where incentives work against each other and groups of actors fail to work together (Carbon Trust, 2009:11). Bringing stakeholders together via an operational target could help overcome this. It should also focus the design and construction team on gathering more post-occupancy data. This could create a virtuous circle of feedback to enhance subsequent designs, as called for earlier by Cooper (section 2.1.2). The case for energy targets, as set out in these sections, therefore rests on their ability to correct perceived malfunctions in the process of design, construction, and operation.

2.2.3. **The case for targets is strong, but experience is less inspiring**

On the basis described above, the case for operational energy targets appears strong. Yet there are a number of practical case studies illustrating that where energy targets for operation have been imposed, and should be providing the incentive for collaboration that was missing, they have not had the effect anticipated. The Private Finance Initiative (PFI) funding model was originally hailed as a means to tackle the “build and disappear” tendencies of construction (Winch 2000), and was in some cases accompanied by the setting of specific energy and carbon targets. However, public sector building procurement was in general often marked by a focus on architectural design, a lack of focus on outcomes, and a “tick box” approach to sustainability (Bordass and Leaman, 2015). Evidence from introducing targets over and above legislative minimums to domestic construction has had similar findings, indicating that fundamental changes in underlying ways of working need to accompany the introduction of new low carbon incentives (Wingfield et al., 2008). This is supported by recent work on integrated design, which indicates that it does not necessarily overcome
the design and construction actors’ predisposition to concentrate on short-term issues, and hence does not necessarily produce sustainable buildings (Leoto and Lizarralde, 2019).

The performance of projects under the Building Schools for the Future programme is a key example from the non-domestic sector. The programme has been heavily researched, and findings from its schools suggest that the presence of a target does not necessarily guarantee an efficient building (Demanuele et al., 2010; Dasgupta et al., 2012). Pegg (2007), for example, found substantial differences between design and actual energy use in newly-built case study schools, in which some actually performed worse than the existing stock. Badi (2017) has more recently suggested that half-hearted enforcement of targets by schools and local authorities, combined with lack of budgetary support, has undermined their carbon targets. A similar, though less often-researched, situation has been noted in hospitals failing to perform as designed, despite ambitious carbon targets for the NHS (see section 3.5.1). This could perhaps be a problem in the means of deployment, rather than the concept of targets itself. As Bordass and Leaman remind us, pushing down accountability to groups of stakeholders is not necessarily the best way to create collaborative relationships of trust and foster expertise (2013). Before deploying new forms of energy targets, it is therefore important to learn more from the limited number of cases in which they have been used to date.

2.2.4. The relationship between the nature of “the gap” and the aims of energy targets

The previous sections have shown how some strands of research have discussed targets for energy in-use as a solution to the energy performance gap. However, a gap is inherently a relative term, requiring the definition of two points between which it can
emerge. A difficulty with some of the research calling for targets is the lack of reflection around how the problem of the gap has been formulated in the first place. In some studies of the performance gap, a mutability of its definition can be apparent, but is not discussed. Van Dronkelaar et al. (2016), for example, described three different “performance gaps” depending on the type of modelling used. De Wilde (2014) had a slightly different set of three different energy performance gaps, depending on the origin of the design and operation figures being compared. Pettersen et al. (2017) suggested that the performance gap came in two forms: one a mismatch between methods of modelling and measuring; and the other relating to physical and technical variations during the building process. Thus deciding whether a building has an energy performance “gap” is clearly determined by what we choose to compare.

Additionally, the processes of setting targets and the motivations that they engender are inherently tricky. The introduction of performance-based goals for buildings brings with it a whole host of difficulties around setting the goal in the first place, and then managing the stakeholders and systems to assess it, and considering the intrusion of external effects (Meacham et al., 2005). Furthermore, whilst performance indicators can clearly be useful, metrics may “bring with them the danger of over-representing the easy-to-quantify” (Gann and Whyte, 2003:4). So, for example, it might appear relatively easy to specify the total expected energy use of a building in kWh or GJ/m², as this can be read off the completed building’s meters and floor plans. Whereas specifying and measuring something less easily conveyed in numbers, such as occupiers’ thermal comfort or long-term satisfaction with the building’s environment, could be more problematic (Bunn and Marjanovic-Halburd, 2017). Thus the nature of the target set is likely to shape the solutions offered by actors. Several of Innovate UK’s case study buildings, for example, had biomass boilers installed to produce a “low carbon”
building, with little thought as to the skills needed to install and operate them, nor the availability or price of fuel supplies (Palmer et al., 2016).

Time is also a critical component of the performance gap. A building’s form and use will evolve from its early design conception through construction and long-term operation (Bunn and Burman, 2015; Boyd and Schweber, 2018), meaning that the selection of particular points within this state of flux will affect the size of the “gap” detected. De Wilde et al. (2011) recognised that building performance is affected over time by, for instance, physical decay to the building components, variances in external conditions such as weather, and occupancy changes. However, in addition to the boundaries of time, those of energy sources and technology are also important. Godoy-Shimizu et al.’s (2011) work on schools observed how carbon emissions from the sector have risen due to increasing “unregulated” electricity use. They suggested that greater attention should be paid to the sources and types of energy that are covered by building regulations, and highlight the difficulty of setting sensible expectations for energy use and carbon emissions amongst the shifting sands of technological development. Encapsulating this variability in energy use in a single number to represent an entire building is therefore problematic, especially for non-domestic projects, given their size and the scale of activities that take place within them (Bordass et al., 2014; Morgenstern et al., 2016).

Indeed, the selection of numbers can make a gap disappear, as well as appear (Janda and Topouzi, 2015). Targets and operational figures can be gamed, with actors adapting to meet the targets themselves, not to the underlying issue they were supposed to address (Bevan and Hood, 2006). Recent analysis of design air-permeability testing under UK Building Regulations (Love et al., 2017) suggests that
construction professionals are able to exploit the meaning, if not the spirit, of regulatory provisions, relying on remedial sealing to pass the immediate test, rather than making more long-lasting improvements to the building fabric. The result determines whether a building is considered adequately energy efficient, and buildings that pass can therefore be hailed as a policy success. This suggests a potential risk to energy targets, if we fail to consider that they may be both mutable and negotiable.

Energy targets therefore appear from the literature to be simultaneously very promising and rather slippery concepts. They provide a much-needed incentive for collaboration, and for directing attention and accountability to operational energy use, but research also suggests that things do not always go to plan. More thought is needed before further implementation of targets, ratings, or benchmarks in one format or another is pursued. The literature raises some ambiguities in what is being assessed when we talk about targets, or a “gap”. The choice of points to compare, and what these constitute, is important, as it determines the judgement of the ultimate success or failure of the incentive.

This thesis aims to offer a counterpoint to the research advocating energy targets as the ideal solution to the vagaries of operational energy performance, by offering a more reflective perspective on how these targets may play out amongst stakeholders in construction. As such, it also contributes to the growing literature around middle actors’ influence on energy use in buildings. In order to do this, the thesis requires concepts that can allow for the influence of stakeholders on technology outcomes, explore the mutability of assessment, and reveal the social processes underlying technological decisions. STS is well suited to this need, and this is where the final section of the Literature Review will now turn.
2.3. Applying Science and Technology Studies (STS) to energy and buildings

2.3.1. Why STS?

The origins of STS lie in the suggestion that science is social (Sismondo, 2010). As such, knowledge does not grow purely out of objective processes, as scientists might contend, but is “constitutively social” (Shapin, 1995:289). STS has now grown beyond the boundaries of scientific knowledge, to occupy itself with the relationships between science, technology, knowledge, expertise, society, and politics. As a discipline, STS is sometimes philosophical, and sometimes focused on the mundane, but often most effective when it draws the former from the latter in surprising ways. So for example, ontologies of sustainability can be found in bin bags (Woolgar and Lezaun, 2013), or an allergy to onions can provoke reflections on power and marginalisation (Star, 1991). Given that energy research shares so many of the overarching concerns of STS, around socio-technological change in high-level policy and in day-to-day engagements, it is very well-suited to investigate energy use in buildings.

Calls have been made over a number of years for greater appreciation of the contribution of social sciences in general to energy and buildings research and policy, but even recent studies indicate that more could still be done (Wilhite, 2005; Shove, 2010; Whyte and Sexton, 2011; Schweber and Leiringer, 2012; Sovacool et al., 2015). Sovacool’s review of energy research by discipline (2014) noted the potential for STS to consider social groups involved in energy systems and decisions, and the dynamics of closing energy questions down through consensus and negotiation. However, the principal theories that he highlighted were some of the more familiar aspects of STS that deal with systems, meaning-making, and technology stabilisation, such as the
Social Construction of Technology (SCOT) (Bijker, 1992), and Actor-Network Theory (ANT) (Callon, 1986; Latour and Woolgar, 1986; Latour, 2005). Both SCOT and ANT will be discussed below, but there is potentially much more for STS to provide in helping us understand energy use in buildings.

Sovacool is, however, not alone in seeing the untapped potential of STS. Rohracher had already made a strong case for more STS work to be done some years ago (2001), specifically in the area of sustainable construction. He argued that detailed examination of the actors involved, through perspectives, relationships, and discourse, is vital to help transition to a more sustainable building stock. More generally, Bijker has argued that STS scholars need to engage beyond the specialised audience of academia, and to “dirty their hands” in practical case studies (2003:446). STS also sits well with the need for a “contextually sensitive” approach to energy transitions, which examines the apparently banal, and surprisingly variable, energy practices of actors in their own environments, which uncover their individual subtleties (Hitchings, 2009; Hitchings, 2014). Beneath its unifying themes though, STS is a broad umbrella of theories and tools, of which the choice needs to reflect the purpose of this research.

This section will therefore examine some of the theoretical strands of STS that have been used to examine energy and buildings so far, and which have influenced the development of my thesis. As far as possible, I have focussed on energy and buildings research, rather than work that has employed STS in relation to energy transitions, or to construction in general. Additionally, I have concentrated my review on the non-domestic sector, as I did when considering the performance gap earlier, on the grounds that the social dynamics, and the complexities of the buildings and technologies, are very different between domestic and non-domestic buildings. However, in certain
cases, I will also discuss papers that are relevant despite this: for example STS as applied to the definition of zero carbon homes, knowledge in construction, or social norms.

2.3.2. Socio-technical perspectives on new technologies and innovation

Branches of STS with particular relevance to energy and buildings are the Social Shaping of Technology (SST) and the Social Construction of Technology (SCOT). Both are concerned with social influences on technological development. SST argues that technological development does not exist independently of society, but emerges from a variety of social “factors”, whether economic, political, or cultural (MacKenzie and Wajcman, 1999). The implication is that the best, most efficient technology will not automatically appear and succeed, but will be buffeted by complex social and commercial considerations (for example, Cowan, 1985). SCOT develops this further, and has famously been used to explore how everyday technological artefacts, such as bicycles (Pinch and Bijker, 1987), or light bulbs (Bijker, 1992), emerge as products of negotiations between different stakeholder groups. One of the most important aspects of SCOT, as described by Pinch and Bijker, is “interpretative flexibility”, whereby the purpose and meaning of an artefact may vary between social groups. So, for instance, a bicycle may be defined by its qualities of safety, or of speed. Hence, a technology does not objectively “work”: it works because stakeholders agree that it does.

These framings can be very relevant to the uptake of new technologies in construction (Rohracher and Ornetzeder, 2002; Schweber and Harty, 2010). Stenberg and Räisänen (2006) used interpretative flexibility to show how ideas of “green buildings” are socially constructed, and hence subject to change, and the competing interests of the actors who interpret them. Boyd et al. (2015) used SCOT to examine photovoltaic installations, and so uncover the interests and tensions between social groups that
more technical studies have ignored. They found that standard processes and contracts did not fit well with the need for the new technology to cross construction’s ‘packaging’ of works, leading to misunderstandings or omissions. Recently, this work with SCOT was extended to explore renewable energy installations in commercial projects (Boyd and Schweber, 2018), working on what the authors note as the under-explored role of construction professionals in energy outcomes. This revealed how the division or acceptance of responsibilities, and the unintended consequences of a myriad of decisions relating to other building priorities such as aesthetics, schedules, and contracts, caused energy’s “visibility” on the construction agenda to fluctuate. Interestingly, the research also argued for the role of a target in keeping energy performance on the agenda, citing the example of the Merton Rule in one of the case studies.

In case studies of sustainability policy in schools, Moncaster and Simmons (2015) followed ideas of socio-technical entanglement to investigate policy discourses around “sustainable schools”. They observed the unpredictability of stakeholder responses to new requirements. They argued that assessing whether policy has been implemented as designed or not, and therefore looking for a “gap” between the two, fails to recognise that policy is a “process: a negotiation of multiple perspectives, values, interests and actions” (463), in which local context may well drive change, but through a diversity of situated responses. Therefore, the effects of a nascent policy must be assessed locally and with an open mind, beyond a narrow view of whether the numerical target was reached, considering instead how actors responded to it. These varying views of socio-technical change, and whether a technological outcome, or policy, has “worked” have already helped frame the consideration of how sustainability and energy-related targets might be enacted, and assessed.
The concept of interpretative flexibility, although this time derived from Latour, was also used by Ryghaug and Sørensen to examine why energy efficiency innovation “fails” in construction in Norway. This allowed them to reveal how general government policy relied on the industry to innovate and come forward with their own solutions to each project, rather than imposing specific standards or regulations. This, they showed, resulted in “heterogeneous and idiosyncratic local practices” that did not produce the energy efficient buildings anticipated (2009:9). Harty (2005) also considered innovation in construction, in which changes required the cooperation of many firms, arguing that too much research had been focussed on innovation where only a single innovator was at work. Focussing on heterogeneous engineering and systems building, he suggested that construction research or policy, whether based around innovation or process efficiency, often run into issues of collaboration, due to the many interactions and particular ways of working in the industry. He argued that STS is ideally suited to examining the inter-relationships of multiple actors and objects that underlie “barriers” to change.

These studies have all engaged effectively with the socio-technical aspects of change in low buildings or construction. They have used concepts from STS that emphasise the interpretative flexibility of technologies, and the complex negotiations of stakeholders in realising change. This is relevant in many ways to the case study of energy targets in this thesis, where many stakeholders must grapple with new and innovative technologies that are planned to reduce carbon emissions from the building, and hence contribute to the energy targets. However, this thesis wishes to consider stakeholders’ responses and interpretations of the targets overall, rather than any particular technological solution to them. Moreover, a focus on innovation in particular,
although relevant, is not necessarily the only aspect of energy targets that requires investigation.

2.3.3. Considering the arrangement of actors and artefacts in construction

In addition to the development of new technologies, STS thinking has been used to understand how arrangements of actors, both human and non-human, are made and maintained in the built environment. Of this, Actor-Network Theory (ANT) is a strand of STS that has proved particularly suited to explore the practical connections and networks of actors, both human and non-human, in energy and buildings (Berker, 2006). The construction process, with its diverse actors and artefacts, can be viewed as a classic actor-network (Sage et al., 2010; London and Pablo, 2017). ANT can also help deconstruct what lies behind the ordered outputs of construction work. Mirroring some of the work quoted in the preceding section on energy targets, Latour and Yaneva question the “static” conceptualisation of buildings in drawings and plans that fail to catch the fluidity and dynamism of “the environment in which buildings are built—and even less the world in which they are lived” (2008:82). Yaneva’s own work on architectural design shares this concern of a mismatch between documented design processes and the messier experience of the team:

"from a distance it is a linear process, but during the design it is really hard to say where exactly we are going." (Yaneva, 2009a:14)

This suggests it is necessary to look from the inside out at the experience of bringing a building into being, which can help explain why it might have so many unpredictabilities in its ultimate realisation (Yaneva, 2009b).

Some of ANT’s principal themes are around power and the translation of information between stakeholders. These have been used to examine aspects of the building
process, including the negotiation of interests and ambitions in design (Tryggestad et al., 2010; Kurokawa et al., 2014). Rydin deployed ANT to explore decision-making in the planning process for a new low carbon office building. Her work raised interesting questions about what evidence is marshalled to embody compliance with low carbon standards, and who, or what, is obscured or “glossed over” (2013:40). Additionally, she also highlighted the impact of the wording of sustainability regulations on what is delivered. Eidenskog (2017) has examined energy modelling through an ANT lens. She found that the specialist nature of modelling lead to it being “black-boxed”. This encouraged either trust or tension, depending on the relationship between the modeller and the rest of the team. Similarly to Rydin, Eidenskog emphasised the importance of what is revealed or hidden about the model, such as its uncertainties or the parameters used, and the impact of this on the wider team’s decisions. These papers use ANT to reveal some of the complex power dynamics of information management in sustainable buildings.

However, ANT has some limitations in studying energy in buildings. Firstly, whilst it is useful to look back at stories that end in stabilisation, the market for, and delivery of, reliably-performing, energy efficient buildings has not yet finished evolving. Moreover ANT has, with some notable exceptions (Latour, 1996), been focussed not just on stabilisation, but also on success (Sismondo, 2010). Although Law and Lien have set out to challenge ANT’s attendance "to the flowers rather than the weeds", and to look at what is not done, as well as what is (2013:372), it is perhaps not the best tool to investigate the performance gap, in which translations may fail and actors may not be connected successfully. Secondly, ANT focuses on the recruitment (the “interessement”) of allies into a network (Callon, 1986). However, in considering how a team responds to energy targets, we are not looking for the particular relationship
between people and specific technologies, such as the interactions between installers and the technologies installed (Wade, 2015). Therefore, if assessing the development of energy targets and “life in the gap” before a building outcome is determined, the ANT approach is less suitable.

Indeed other STS research shows that buildings are highly unstable. Gieryn (2002) pointed out the contradiction of buildings both stabilising social practices through materialising them, but simultaneously being unstable as they may be changed, either physically or in the meanings ascribed to them. His application of heterogeneous design is particularly interesting, commenting on how the outcome of the building is a negotiation between peoples’ aims and technology possibilities, influenced by power structures as to whose vision and priorities win out in the final implementation of the construction, as illustrated by the final configuration of the university laboratory that he studies. Gieryn makes the case that buildings shape us, just as we shape them, and that this process is ongoing.

Similar insights about the instability of buildings and construction have been revealed by other authors. Walter and Styhre (2013) used a case study of bridge construction in Sweden, employing the concepts of material agency and “organisational objects” that have the agency to mobilise actors in construction management. Moving away from the end product itself, Ewenstein and Whyte (2009) explored visual representations in construction, such as architectural drawings, as epistemic objects, which are subject to shifting meaning, layers of interpretation, and ambiguity. In doing so, they showed how the drawings were not stable nor without agency, but required interpretation by different stakeholders, and raised questions that helped evolve the design. Drawing directly on Ewenstein and Whyte, and working on a hospital case study, Harty et al. have argued
further that visual representations produced during design are mobilised to negotiate spaces in the planned building and in so doing “constrain and enable” different practices, and innovation (2015:876). These studies that capture the fluctuating reality of buildings raise interesting questions for the analysis of energy targets, predicated as they are on the assessment of a building around static points in its lifecycle.

2.3.4. Standards, norms, and overcoming “barriers” to energy efficiency

Standards and standardisations are a preoccupation of STS, and also applicable to energy in buildings. Shaw and Ozaki (2016) combined STS work on standardisation with practice theory to see how the Code for Sustainable Homes was “materialised” by local actors. Looking also at standards for homes, Schweber et al. (2015) used Bowker and Star’s work on classification to examine the definition of zero carbon homes. General policy aspirations for more “low carbon” or “zero carbon” buildings were found to negotiate the practical boundaries of what this included, or excluded, within its definition. This reflects the findings of others who have noted the many “contingencies” such as time, energy sources, and modelling assumptions around norms in the definition of what a zero carbon building might be (Walker et al., 2015). Also combining STS frameworks of standardisation with other theories, Schweben examined BREEAM to assess the extent to which it travels across and becomes embedded within different social groups. She argued that the standard itself is not enough to spread sustainable building, but must be accompanied by other practices and institutions that “lead in the same direction” (2017:302).

Shove, and those working alongside her, have interwoven practice theory with STS concerns of the interconnection of people and technologies. Shove argues against the position, sometimes taken by policy and technical research, that inconvenient social “barriers” stand in the way of technological progress (1998). Her alternative is to study
energy use as locked-into the ways that we do everyday things, through social norms and infrastructures (Shove and Southerton, 2000). This indicates that transformations in the way that we use energy are not best achieved by pressurising individuals into action, but by looking at the overriding structures and norms of interlinked practice (Shove, 2010). Recently, and very pertinently to building energy targets, she has drawn attention to how the formulation of generalised energy efficiency policies strips away the localised contingencies of energy use. This allows policy impact to be aggregated and compared, but in doing so creates the false impression that energy use is the same everywhere, when it is not (Shove, 2018).

Shove’s concepts have been translated into practical instances in non-domestic construction. So, for example, Walker et al. (2014) explored decisions around the installation of air-conditioning in a hospital project, in which energy-using technologies became design necessities due to their interlinkage with other issues, such as standards of care, or the performance of other equipment in the hospital. In this light, energy efficient solutions cannot be considered in isolation, as many other influences, which do not appear at first sight to be energy-related, weigh on the decision-making. In an agenda-setting paper, Guy (2006) set out a vision of energy research that supported Shove’s urging to escape the building energy research paradigm of technical determinism and economic rationality. Drawing on a wide range of STS authors of the time, he used this to make the overall point that technical innovation is a contested thing, being a contingent product of social interests. This, he suggested:

"means attempting to peer over the shoulder of the actors making energy-related decisions by following actors through their professional and personal routines."

(Guy, 2006:651)
The implications of this strand of research for this thesis is that standardising the assessment of energy efficiency, or incentives intended to encourage it, is far from the straightforward process assumed by policies that may recommend it.

2.3.5. How energy use is materialised

Another idea taken from a less well-known piece of work by Shove (1997), is her illustration of how “energy knowledges” emerge, considering the ways in which this elusive substance was captured via a variety of proxies, such as kWhs, U-values, or cost. She showed how different professions might draw on varying terms to make others “believe” in their version of energy. It was not the case, she argued, that these represented different perspectives on the same underlying object; rather that the means of measurement gave rise to different types of knowledge “and hence construct what are, in effect, different forms of energy” (ibid:2). This affected the course of action chosen. For example, if energy was represented as cost, then recommendations were more likely to be monetary.

Other research has considered how actors may materialise energy. Janda (1999) has also shown how engineers and architects may literally “see” things differently, respectively seeing a building composed of physical things and the numbers associated with them, or a building of aesthetic abstractions. Suchman’s case study of infrastructure design (2000) reflects on how engineers talk amongst themselves and how they “materialise” courses of action, arguing for a situated understanding of organisational actions. This consideration of how we “know” energy raises very important questions for how energy incentives are framed by the stakeholders involved.

This theme also touches on a further difficulty of energy relevant to target setting, which is its intangible nature. If energy, or carbon, is to be made visible by certain
measurements or in certain circumstances, as already suggested in several places in this chapter, then this is a necessarily selective, and potentially manipulable process (Haslam et al., 2014). The representation of an energy source may encompass not only its material aspects, such as fuel and infrastructures, but also the associated technical knowledge and economic conditions needed to exploit it, so that the meaning of the resource becomes entangled with other objects, understandings and assumptions about the future (Barry, 2013).

The concept of domestication is another angle that may be used to understand the process of mutual adaptation between people and technologies, indicating how energy becomes part of daily routines. It is clearly relevant to the introduction of new technologies in homes (Hargreaves et al., 2018). However, it can also be used to effect in non-domestic settings. Berker (2011) considered the application of scripting and domestication to case study college buildings in Norway. Here both theories allowed him to uncover mutual adaptation between building and occupier. He also noted that this process can be eased by mediators, such as building managers. This built on previous work by Bye et al. (2009), which had considered the theme of domestication and the mediating potential of energy managers in non-domestic buildings. In that study, the facilities actors were found to have an ability to “see” energy, which allowed them to act as mediators to render it visible to occupiers and designers.

Selecting to measure or see something in a particular way can also bring with it “collateral realities” (Law and Ruppert, 2013). So, for instance as the introduction of security cameras may shift crime to new places, so assessing energy through one means could shift it to places where it is less easily measurable. The visibility of energy will also be a product of the organisational context in which it is observed. Returning
back to the earlier issues raised by Walker and Shove around the influence of non-energy influences, Royston’s study of energy in higher education (2016), explores the “visibility” of energy use, and finds it is restricted to certain roles and certain activities, and that more generally it may be over-shadowed by other organisational priorities. These ideas all expose the protean nature of energy, and are a further inspiration for this research.

The use of STS theory in energy and buildings research has therefore provided valuable context to the practical issues raised around target setting, the nature of the performance gap, and communication difficulties between construction stakeholders raised earlier in this chapter. This thesis will use theoretical concepts from STS to examine construction actors’ relationship with energy efficiency and low carbon buildings. To do so, it employs three concepts that have also been either under-used, or used only in particular ways, to explore energy in construction and buildings, but which appear extremely relevant to its issues and concerns. These three theoretical and analytical concepts are set out in the next section.

2.4. The theoretical and analytical bases for the research

Three different concepts have been selected to approach the research findings. They each enable the exploration of the construction team’s response to the energy and carbon targets in the case study project, through asking:

1. What actors do (actors’ practices);
2. What actors say (actors’ discourse); and
3. What information they share (actors’ information sharing processes).
Mol (2002) is used to approach actors’ practices. Mol is an influential figure in the “ontological turn” in STS, which contends that reality is made (or “enacted”) through practices. Using a case study of the treatment of atherosclerosis in a hospital, Mol revealed how the disease was enacted in different ways by different medical professionals. She showed how, if practices were not coordinated, this could lead to multiple, and potentially incompatible, realities of the disease being generated. These multiple realities had important implications for how medical outcomes were reported and interpreted, in the hospital, and in health policy in general. Mol’s work will be used to examine whether multiple versions of the energy targets are being enacted, whether these are coordinated, and what this means for the assessment of the case study building’s eventual outcome.

Gilbert and Mulkay’s work (1984) is used to analyse actors’ discourse around the energy targets. This particular approach to discourse analysis revolves around the identification of “interpretative repertoires”, or recurring patterns by which actors represent their work depending on the context in which they find themselves. Based on a case study of scientists discussing a biochemical controversy, Gilbert and Mulkay showed how the interpretative repertories were used to make a distinction between good and bad professional practice, and to “account for errors”. This indicated how actors carefully positioned work around areas of controversy, and used talk to construct professional boundaries. As such, this work provides an interesting analogy to how a construction community might talk about the challenge of energy performance targets, position professional boundaries or accountability for them, and the influence of context on their discussions.
Finally, the concept of boundary objects (Star and Griesemer, 1989; Star, 2010) has been used to explore actors’ sharing of information. Star and Griesemer’s work considered how diverse professionals managed to collaborate effectively, using a common aim or system (a “boundary object”), whilst still maintaining their distinct professional identities and motivations. Although developed from an historic case study, the boundary object has a clear relevance to exploring professional collaboration, and has been widely used for this reason in organisational studies. In this PhD, some of the particular aspects of the boundary object concept around the collection and trading of information are used, to consider how it is gathered and transmitted between professionals in the construction team.

Each of the three works covers an important aspect of the construction team’s response to energy targets, and so provides individual insights arising from its own particular approach. The works are therefore valuable in their own right. However, they are also intended to complement each other. Not only do all three originate in STS, they also share a concern with multiplicity, as played out in professional environments. For Mol, this is explicitly addressed by her contention that reality is multiple, illustrated by the differing professional engagements with a particular disease. For Gilbert and Mulkay, it lies in the suggestion that there is no one single account of events offered by a scientific community. Finally, for Star and Griesemer, it is in a diverse set of actors who manage to collaborate successfully on a joint venture whilst maintaining their own individual interests. If literature tells us that the definitions of energy efficiency, low carbon buildings, or the performance gap have multiple meanings in different hands, then the targets may have too. Thus the theories to examine it must have the ambition to allow us to explore the epistemology and ontology of what an energy target might be for different construction professionals. However, as this question remains one of
applied research, and one with the aim to provide useful and intelligible feedback to industry, then it is important that the theories chosen also facilitate practical findings, such as what people do, say, and share in response to new energy incentives.

In order that the reader may move more easily from theory to findings, the theories, their background, and the work they have inspired will be described in more detail in their individual empirical chapters. The choice of three works, rather than a single in-depth focus, is intended to offer a varied perspective on the challenges of operational energy targets. Practices, discourse, and information sharing are all manifestations of communication and collaboration, which will allow the research to explore how effectively the case study construction team attempts to make the building more energy efficient and lower carbon in operation. Each of the three sets of findings are therefore intended to provide different insights by examining different facets of the construction team’s response, and any implications for the building’s eventual performance. Each, however, draws on a different epistemological and ontological standpoint, and hence raises different requirements for data analysis and collection (see section 3.6.3 in the Methodology). It is also worth noting that the actors who make up the “construction team” in this case study are a diverse and fluid group, around which it is often hard to draw definitive boundaries. This, and the background to the construction company and project in which they work, will also be discussed in the Methodology that follows.

2.5. Summary

This chapter has both situated my work within existing conversations around energy use in buildings, and suggested how it will provide new insights to the debate. I began by stressing the importance of examining new policy incentives to reduce carbon emissions from non-domestic buildings, such as targets for energy in-use. I then set
this in the context of the performance gap in non-domestic buildings, to which these sorts of targets are suggested as a solution. Research into the performance gap has revealed the entanglement of multiple technical and social issues behind it, played out at many levels, from industry to individuals. It also raises questions around multiplicity in the construction of “the gap” itself, which this thesis aims to explore further in the context of its particular case. Moreover, despite growing attention to influence of professional “middle actors” on building energy outcomes, much research still focuses on design and operation. What happens “inside the gap” amongst construction teams is less well understood, meaning that a crucial link in our understanding of the energy performance gap, and how it comes into being, is not being made. This is in spite of the critical role that construction teams are likely to play in the outcomes of the buildings that they build.

A deeper understanding of construction stakeholders’ interpretations and response to mechanisms such as energy targets is therefore urgently required, especially if policymakers and other industry stakeholders are to consider introducing operational incentives more widely. In the final section of this chapter, I argued that STS’s interest in people’s relationship with technology makes it ideal to unravel some of the socio-technical complexity of construction’s response to energy performance in buildings. Previous research using STS in energy and non-domestic buildings has already shown how it can enrich our understanding of the challenges of carbon reduction, and the synergies between the two fields. This research has taken three works from STS, as yet little-used in, but highly relevant to, the analysis of contractual energy targets in construction, to analyse what actors do, say, and share in response to them. These address three critical aspects of construction’s response to the incentive of operational energy targets, and so enable the thesis to inform research, policy,’ and industry
stakeholders. However, before moving to the findings in which these insights are offered, I will explain the process of how I came to settle on these three concepts, the background to the case study project itself, and how I engaged with the challenges of data gathering, analysis, and my own research practice.
3. Methodology

3.1. Introduction

This methodological chapter has several tasks. As shown in Figure 3.1, it explains how I determined an appropriate research strategy to answer the research questions set in Chapter 1. My choices were informed by the Literature Review in Chapter 2, and taken with the aim of underpinning the findings presented in Chapters 4-6 with appropriate and considered methods. As can be seen in the diagram, the chapter will therefore cover what I did, why I chose to do it, and the background to the company and project that shaped these choices, as well as my reflections on them.

Following this route, section 3.2 will introduce the sponsoring company, Construction Co., and its business. Section 3.3 will explain my early work in getting to know the company, and, in particular, how I selected the hospital project, as the majority of the findings in this PhD are derived from this single case study. In section 3.4 I will explain why I chose a qualitative case study, in combination with a “short-term” approach to ethnography in construction, as the most suitable research method. The selection of the three theoretical and analytical concepts from STS will also be explained.

I will then provide details of the hospital project itself, the health sector context, its procurement, and, of course, its energy targets (section 3.5.) I will then turn to the specifics of researching energy targets through data sampling, collection, and analysis, and consider any areas of limitation (sections 3.6 and 3.7). I will summarise issues of confidentiality, data protection, and ethics, before concluding with some reflections on
my research practice and my experiences working in a partnership with industry (sections 3.8 and 3.9).

Figure 3.1 How methodological considerations link the research question to findings

*(blue area shows issues discussed in this chapter)*
3.2. Background to the sponsoring company

I have begun this chapter with a description of the sponsoring company, Construction Co., and its projects for two reasons. Firstly, an appreciation for the actors, where they usually work, and their place in the company structure provides important context to later analysis of how these actors might communicate or collaborate “inside the gap”. Secondly, it is also useful for the reader to have an understanding of the way in which Construction Co. works, in order to appreciate why I selected the research approach that is described later.

Construction Co. is one of the larger construction companies in the UK, and in common with its peers, provides both construction and related services to its clients (Figure 3.2). These client services are grouped into different profit centres under the main corporate entity. In addition, there are a large number of supporting specialisms, which assist the company to operate on a day-to-day basis, and to develop strategically over the longer-term. These include teams engaged in: engineering; digital development; finance; environmental issues; strategy; innovation; administration; legal; and others. The individuals in these teams move between the company’s offices and specific projects to a varying extent, depending on their remit. So for example, an employee in strategy might spend a comparatively limited amount of time on construction sites, whereas an environmental advisor might spend a high proportion of time on site. These corporate-based activities are focussed in Construction Co.’s head office and a number of regional office locations around the UK.
In delivering client services, one of the key features of the industry that affects construction actors’ interactions is its project-based nature. Projects are staffed by groups of professionals from Construction Co., selected for the skills required in each project, whether this be construction or additional services. Project staff work on site, and move locations as the work takes them. Each project has its own management structure, headed up by a small group of directors, presiding over teams of staff focussed around particular areas of expertise. This is a common structure in construction, and brings with it particular challenges of balancing projects’ autonomy with the transfer of knowledge and ways of working between the devolved site teams and the main business (Dubois and Gadde, 2002).
Construction Co.’s subcontractors together form another facet of what constitutes ‘construction team actors’. These, rather than Construction Co.’s employees, are responsible for actually designing and building projects. Construction Co.’s staff therefore function in a managerial role, overseeing the design, construction, commissioning, and other work done by the subcontractors. The latter may work either on site or off site, depending on their remit. Additionally, staff from Construction Co. and the subcontractors will revolve as the project progresses. So for instance, there will be a heavier emphasis on design management staff at the early stages of construction, whereas at the later stages, there will be more commissioning staff. What constitutes ‘the construction team’ at any one point in time is thus somewhat of a moveable feast, composed as it is of a revolving cast of actors on site or off site, employed or sub-contracted.
In addition to the structure of the company, the lifecycle of a building project also impacts on actors’ roles and responsibilities. Projects progress through certain common milestones (Figure 3.4 below). The construction period is book-ended by the signing of contracts at Financial Close at its outset, and the reaching of Practical Completion at its end, when all of the tasks for the construction of the building have been completed, subject to defects. Where Financial Close sits within the design process may vary, meaning that some detailed or technical elements of design, including those impacting on energy performance, may still be in progress during construction. This process is the foundation on which construction responsibilities, liabilities, and objectives rest. For energy targets, the transition between the agreement of contracts at Financial Close and the end of construction at Practical Completion is a critical juncture for the emergence of the “gap” between design and operation.

*Figure 3.4 Standard plan of work*

*Adapted from RIBA Plan of Work (Royal Institute of British Architects, 2017)*
3.3. Early research

The early stages of my research not only helped me to get to know Construction Co. better, but also to determine my research approach. This development of experience and methods therefore ran in parallel to the detailed literature review already described in Chapter 2. My relationship with Construction Co. had begun the year before I started the PhD, when I worked with them on an MRes dissertation. However, I still needed to gain a deeper understanding of the business, its projects, and its staff’s perspectives on energy performance. This understanding was critical, as clearly if my empirical material was to come from Construction Co., I would have to connect my research aspirations to the practical availability of data, and tailor my methods so that they functioned in the context of the particular company.

3.3.1. Understanding the company

My first strategy was to gather new data on a school project that I had studied during the MRes, and that had targets for energy and carbon emissions in-use. The school was already occupied, and indications were that it would not meet its targets. Construction Co.’s investigations of the potential causes behind this continued through the first year of my PhD. I was able to attend stakeholder meetings at the school site, meet the technical, management, and commercial team members investigating it, and access their written reports and analysis. Following the school during this time let me explore who was involved in projects with energy targets, and how they dealt with them. It also helped me make a number of contacts in Construction Co., whom I was later to encounter in my main case study. Finally, presenting insights into the school’s energy performance drawn from the MRes was a way to engage staff at Construction Co., establish my credibility, and offer a “quid pro quo” for my own research needs.
(Buchanan et al., 2013). Some findings from the new data I gathered from the school have been used in the analysis presented in Chapters 4-6.

My access to the school project, and Construction Co. in general, was mediated through a company employee, who has continued to act as a point of contact and consultation throughout the PhD. Initial access to a community through a key participant is a point of passage for much qualitative, ethnographic, or organisational research (O'Reilly, 2012; Buchanan et al., 2013). This relationship can be critical to gaining the trust of the community you wish to study, as Whyte’s classic ethnography describes:

"I found that my acceptance...depended on the personal relationships I developed far more than any explanations I might give." (1955:300).

In construction, like others before me, I found that a great deal of emphasis is placed on personal relationships and networks (Thiel, 2013), and so the ability to align myself with an insider was important. For me personally, it was even more valuable as I had no previous experience of the industry, and so little preconceived idea of how to approach it when I started my research. Of course, working with a gatekeeper inevitably brings some risks as well, which I shall discuss later (section 3.9.3).

In addition to the school, I was keen to get to know more about Construction Co. and its other projects. An initial strategy for me was to join the regular environment team meetings at Construction Co.’s offices, as I already knew one person from this department from my work on the school project. The environment team was also an area of the company more inclined to be sympathetic to my concern with climate change and energy, and hence easier for me to access. Listening to the different environment groups discuss their work gave me an insight into some of the ways in
which sustainability was managed in the organisation, and, as each construction project has to have an environment advisor, an overview of all of Construction Co.’s projects. As well as attending the meetings, I was able to chat informally with team members, and shadow environment staff on site.

Besides making links with the environment team, I also participated in other events. I completed the corporate induction process with a group of new employees at the company’s head office. Here, I learned again about how energy fitted into the rest of Construction Co.’s corporate interests, and made a number of new contacts. On another occasion, I attended the presentation of the company’s business plan, including its environmental and energy policy. I also spent some time on Construction Co.’s intranet, as several people had referred me to it as one of the means by which Construction Co. shared its energy knowledge. Finally, I went along to see Construction Co. present at industry events. These activities all helped me frame how Construction Co. discussed the energy and environmental performance of its buildings.

As my interest in building energy performance became known, I made contact with individuals in other departments. In particular, I had several meetings with Construction Co.’s specialist engineers, as energy efficiency is an explicit part of their departmental remit. This included directors, managers, and junior staff. During the first year of my PhD, I was invited to join what I have dubbed the company’s “energy experts” group, which met periodically to discuss energy-related issues arising across Construction Co.. This was an invaluable opportunity for me to see the sort of questions that were raised by the organisation and by projects about energy and carbon, and to see in turn how Construction Co.’s energy specialists discussed and dealt with them. Because of my involvement with the “experts” group, I was invited by Construction Co.’s head
office to participate in the scoping, preparation and presentation of an internal webinar on the topic of working with energy targets. Here I worked alongside three engineers from different parts of Construction Co. and a senior member of staff responsible for knowledge management.

All of these activities helped develop contacts and my understanding of the context of energy performance in Construction Co. However, what I needed for the PhD were building projects with operational energy targets to examine in detail. Ideally, these would also be projects that, unlike the school, were not complete, and through which I would therefore be able to examine how the construction team dealt with energy targets during design development and construction. This period was the one that my literature review had identified as key to the “gap”, and one in which Construction Co. could be a key influence on the eventual energy outcome.

3.3.2. Accessing projects

I had originally hoped to study a few projects with energy targets during the PhD. However, it was here that the practicalities of working with a “real life” business came into play most markedly. Whilst my initial discussions with the gatekeeper at Construction Co. had identified several projects with operational energy targets, these were still at too early a stage of bidding for me to get involved in. In the absence of an active project with operational energy targets, and through a contact in the environment team, I began to explore an office project. This provided several useful contrasts to the school I had looked at before, as it was a project for a private sector developer, under a standard construction-only contract, and at an earlier stage, being still in pre-construction. The office also had an ambition to achieve a very high BREEAM rating over and above that required by local planning, a very high EPC rating, and was considering green leases to maintain these design ambitions during operation. During
my work with this project, I obtained design documentation, visited site offices to meet Construction Co.’s staff, and interviewed five members of the team involved in the design, including two engineering subcontractors, at three different locations. A small amount of the data gathered from the office project also appears in Chapters 4-6.

From the office project I began to learn more about how sustainability was incorporated into a building’s design, as well as how Construction Co. and its subcontractors worked together, and talked about each other. Unfortunately, the project was then terminated before construction began, and the site team disbanded. I was therefore not able to pursue the project any further. At this juncture, it also became apparent the other projects with energy targets I had been waiting to engage with were also not going to go ahead. As a result, I began to discuss with Construction Co. the possibility of getting involved with a hospital project, which did have operational energy targets, and which was already in construction. As it was still in the process of being built, it seemed like a valuable opportunity to explore how energy targets might play out in the construction and commissioning phases. This would give me the insight into "life in the gap" that I was looking for. However, it raised an element of caution around basing the PhD largely on a single project, with only a relatively small amount of comparative data being drawn from the school and the office. It also required me to determine the best approach to obtain data from it.

3.4. Why the research approach was chosen

3.4.1. The value of a qualitative case study

A case study allows the researcher to analyse their subject of study in rich detail. Valuable findings can emerge from the smallest of objects of research in energy and buildings, for example: the discourse around a hospital roof garden (Boudeau, 2013);
the energy performance of a single dwelling (Ridley et al., 2013); or environmental management in one construction company (Gluch, 2005). They may provide situated detail that contributes to the understanding of larger phenomena, such as the performance gap. As Geertz observed, “small facts may speak to large issues” (1993:23). Taking a purely qualitative approach is different in nature to studies using mixed methods to generate a socio-technical perspective (e.g. Wingfield et al., 2008; Chiu et al., 2014; Drosou et al., 2016; Morgenstern, 2016), as it does not rely on quantitative tests or measurements of particular technologies and building elements to underpin the qualitative insights. By contrast, a qualitative case study foregrounds actors’ own perspectives as to what makes up energy efficiency, energy targets, or the performance gap for them in a particular project. This sensitivity to actors’ experiences offers insights that help fill the deficit of research around the specific ways in which construction teams respond to new energy incentives, highlighted in Chapter 2.

However, choosing cases, and in particular single cases as in this instance, does mean that the findings will be specific to the project, or projects, examined. Hence a certain amount of caution must be addressed to external validity, and to what extent the findings can, or should, be generalised (Yin, 2009). The researcher must walk a tightrope between a case study’s simultaneous, and at face value, contradictory, attributes of “uniqueness” and “commonality” (Stake, 1995:1), and I have attempted to observe this balance in the analysis of findings and conclusions. Nevertheless, Flyvbjerg (2006) has defended the method from what he regards as “misunderstandings” of its usefulness, by pointing out that expertise is accumulated from just such context-dependent and practical knowledge as case studies provide. For operational energy targets, which are still a rarity in the construction industry, data can
only come from a handful of projects, and is therefore one of the best available ways in which our knowledge of these incentives can accumulate.

Although my selection of the hospital case arose to a certain extent out of circumstance, before pursuing it, I still needed to step back and consider what “sort” of case it might represent (Ragin, 1992; Yin, 2009). Using Flyvbjerg’s classification, I believe it combines characteristics of a “paradigmatic” and “extreme” case. On one hand, it represents an example of the unusual mechanism of operational energy targets, but on the other it also allows me to reflect on wider issues around how Construction Co. approaches expectations of energy use in the buildings that it builds. However, even determining what a case is can be a slippery business. They may turn out to be about something different to what you expected at the outset of your research, or have negotiable boundaries (Ragin, 1992). Indeed, energy targets do not have clear boundaries of technologies, roles and responsibilities, and this forms part of the challenge in tackling them for construction and policy stakeholders, as well as for the researcher. Delineating the boundaries of the targets was also a consideration of sampling, and will be discussed in section 3.6. As concerns the case though, using this method to approach a topic where the boundaries between phenomenon and context are not yet fully understood can be part of its value (Yin, 2009).

The contribution of qualitative case study work also derives from its theoretical basis. Qualitative work, Schweber (2015) argues, is much more than a rich description or subjective account of what happened. It is systematic, epistemically-controlled, and reflects on the theory employed, and this is what distinguishes its academic contribution to knowledge from narrative storytelling. In this PhD, I hope to fulfil:
“the function of theory…to link rich empirical description to more general processes and concepts which can be mobilized in future studies on similar and very different empirical cases.” (2015:845).

This mirrors Vaughan’s conception of theorising in case studies (2004), in which the researcher may unearth insightful findings from the application of theories across different social settings and contexts. This iterative movement between deduction and induction, pulling and fitting the material of the theory to the case in hand, allows us to see where they meet and where they do not (Vaughan, 1992). It is precisely in making the connection between these micro and macro levels that new insights may be generated.

3.4.2. Finding a practical approach to construction

Researching construction presented me with several practical difficulties. In looking for detailed insights into the experience of construction professionals, one option would have been an immersive ethnographic study. However, a traditional ethnographic model can be problematic when participants are distributed temporally and geographically (Star, 1999), as they are in construction. Organisational studies in multi-sited or multi-disciplinary companies have dealt with this difficulty by combining different data sources in their ethnographic work, such as Orlikowski (2002) and Bechky (2003). Additionally, I felt that my approach needed to be flexible enough to cope with the fluctuating nature of construction projects, with their changing actors and overlapping events (Bresnen 2013). Finally, for an individual researcher, unable to be in several places at once, ethnography can lead to becoming tied to the experience of a particular profession (Thiel, 2013; Forman and Tweed, 2016), and so would not allow me to explore the aspects of collaboration between groups that I wished to investigate. I therefore needed a model that was more flexible.
Ultimately, I followed similar methods to others navigating case studies in construction, such as Gluch et al. (2005), Leiringer and Schweber (2010), Styhre and Gluch (2010), and Bresnen (2010). All of these have successfully combined focussed observation with interview and documentary data, enabling them to get to grips with communications and day-to-day working practices in the large, geographically-dispersed organisations that they studied. Pink et al. (2010) have supported this type of approach, arguing that the particular characteristics of construction make it fundamentally unsuited to traditional ethnography. Instead, Pink and Morgan (2013) have advocated more use of targeted periods of observation, guided by theoretical development before fieldwork, which they refer to as “short-term ethnography”, and which has much in common with the procedure that I followed.

This approach also works well with the demands of research in a commercial environment. If ethnography is to work in organisational contexts, then it must flex (Jordan and Caulkins, 2012). To quote Pink once more, ethnography in professional settings must adapt to commercial circumstances (2006). Easterby-Smith et al. have characterised a similar approach to organisational research as “interrupted involvement”, where the researcher is sporadically present, and combines observation with other qualitative data (2002:100). This, they argue, is a sensible approach when dealing with business personnel who have little time to spare, and are likely to offer the researcher slices of structured time, rather than the extended access needed for long-term observation. My choice of a “short-term” ethnographic method, using a combination of observation, interviews, and documents, therefore aims to gather the widest range of data within the practical constraints of the company environment.
3.4.3. Choosing the theoretical framework

In Chapter 2 I introduced the three theoretical and analytical concepts that I chose to analyse my findings. The selection of these also emerged from my work during the first year of my research. During this year I was reading more about construction and the performance gap in non-domestic buildings, and gathering data from field notes, documents, and a limited number of interviews, through the encounters already described. It seemed to me that both the literature and my own experiences pointed to possible problems of communications and collaborations around energy performance in Construction Co.. Therefore I needed a theory, or theories, which were sensitive to variability in how individuals, or groups of individuals, responded to energy targets, which would provide a framework to help me examine this variability, and also help me explore how they worked and talked together “inside the gap”.

It also seemed to me that data in different forms of interviews, observation, and documents, were highlighting some interesting differences in actors’ responses to energy performance and energy targets. So for example, when I sat down to talk about energy performance with actors one-to-one it differed to the way I saw the issue discussed in meetings, or the way they wrote in documents. Moving from construction sites to Construction Co.’s offices, and meeting staff from different teams, also suggested to me that actors were doing and saying different things about energy, depending on their physical, and virtual, location in the company. It was this ability to help me unpack multiplicity in talk and action around energy targets that fundamentally drove my selection of the three works that underpin this PhD. It seemed that asking what actors do, say, and share in response to the introduction of energy targets would help me uncover contrasting but interlocking answers to the question of what happens inside the performance gap that might affect the building’s outcome. Drawing on the
discussion of theorising through cases above, I was also keen to take the opportunity to apply these STS concepts, that had been formed in the context of traditional scientific domains, like medicine, biochemistry, and zoology, to the very commercial environment of energy use in buildings. In the latter, I hoped that the theoretical concepts could be used to organise the data, with the ultimate aim of drawing out the practical insights that the research aspired to. Therefore, once selected, the three works also influenced the data collection, as will be explained in section 3.6.3.

3.5. Introduction to the case study

As already discussed (section 3.3.2), what drew me to the hospital case study were its contractual targets for energy use. However, it cannot be understood without some background to the idiosyncrasies of its particular sector and procurement route, as these both impact on the decisions taken by the construction team and the challenges for them in meeting its energy and carbon targets. Moreover, as the value of this PhD is in providing a situated account of energy targets in a construction team, understanding the particular context of this project is important.

3.5.1. Energy and carbon in the NHS

The National Health Service (NHS) estate accounts for a hefty slice of carbon emissions, representing nearly 3% of all UK emissions and 30% of public sector emissions (Lomas and Giridharan, 2012:58). The government first set targets for the NHS to reduce carbon emissions from their built estate in 2001. Following the Climate Change Act, the NHS committed to further, and more ambitious, sectoral targets (NHS Sustainable Development Unit, 2009) to reduce carbon emissions over the short, medium, and longer term. At the time, it was also intended to complement a drive towards zero carbon buildings. Whilst progress has been made in improving energy efficiency in NHS buildings (Short et al., 2012) and in reducing total sectoral carbon
emissions, the trajectory towards further reductions remains more challenging (NHS Sustainable Development Unit, 2014).

Reducing carbon emissions is only one of many requirements for NHS buildings. A series of Health Technical Memoranda (HTMs) and Health Building Notes (HBNs), issued by Government, provide guidance on the design and construction of health facilities. Of these, HTM 07-02, or “EnCO2de”, (Department of Health, 2015) deals specifically with energy and carbon management for the NHS and its buildings. Beyond government, a BREEAM for Healthcare standard existed until it was subsumed into BREEAM New Construction (BRE, 2013), but was still extant at the time this hospital was procured. Finally, Government collects energy data from NHS Trusts and sites in England as part of the Estates Returns Information Collection (ERIC) system. Hence the sector specific requirements for construction companies working with the NHS, on energy and other issues, are wide-ranging and complex.

Hospitals tend to be energy-intensive buildings, as they operate 24 hours a day, seven days a week, and contain a great deal of energy-consuming medical equipment. They also require special conditions for operation, such as high air change rates for infection control, which tend to further increase energy use (Kolokotsa et al., 2012). Another challenge in reducing the energy use of hospitals lies in the diversity of activities that these buildings encompass. For instance, the energy use of waiting rooms, operating theatres, laboratories, outpatient departments, and intensive care wards are likely to be radically different. This poses difficulties in anticipating how occupiers will use the building (Bacon, 2014), and for energy modelling in general (Giridharan et al., 2013). However, hospital energy use is shaped by more than clinical work, as indicated by Walker et al.’s (2014) work, quoted earlier in section 2.3.4. Incentive structures, such
as budgetary allocations, may also discourage investment in energy efficiency (Sustainable Engineering Collective, 2014). This combination of factors serves to make energy use in hospitals hard to control.

Given these difficulties in predicting and controlling energy use, it is perhaps not surprising that hospitals also show evidence of an “energy performance gap”, with actual energy as recorded by DECs being several levels worse than EPC ratings (Bacon, 2014; Sustainable Engineering Collective, 2014). Fifield’s (2017) monitoring of three case study hospital buildings of different ages and designs highlighted the difficulties of balancing energy use and internal conditions in hospital buildings, and noted that as a result newer buildings did not necessarily use less energy (in kWh/m$^2$) than older buildings. Morgenstern et al. (2016) have argued that a more tailored approach to understanding energy use through composite benchmarks, rather than a single energy target encompassing all activities, would benefit the control of energy in this sector. However, this approach has not been taken by the NHS in this case study, which relies on single energy targets for the whole hospital, representing a challenging hurdle for the construction team to clear.

### 3.5.2. Procurement under PFI

The responsibilities and incentives of a non-domestic building project are fundamentally shaped by its procurement route, which determines the accountability, tasks and roles of the team (Ashworth, 2005). Procurement via the Private Finance Initiative (PFI) originated under the Conservative government in the 1990s, and continued to expand under the Labour administration, but has now fallen from popularity. However, as the original procurement of the hospital took place over a decade ago (Figure 3.5 in section 3.5.3), PFI was the form selected at the time, and is therefore relevant to the case study. The principle of PFI is to finance major capital
projects with private, rather than public, debt. The private sector then recoups revenues through the long-term management of the facility in question. It is assumed that the private sector is more experienced than the public at managing the risks, costs, and organisation of such complex projects (Mumford, 1998). The long-term service payments under PFI are subject to deductions for poor service or performance of the asset, thus completing another shift in public procurement philosophy, that of emphasis on accountability for outputs rather than assessment of inputs (Smyth and Edkins, 2007). This is the political framework within which this hospital, and its energy targets, were conceived and procured.

That nature of procurement is also likely to affect construction actors’ motivations. The investment of time and money for the private sector PFI partners is significant. Bid costs are higher than in non-PFI projects, due to the level of input into design and consultation required from the competing private consortia, and will only be recoverable by the winner (Construction Industry Council, 1998; Mumford, 1998). As can be seen from Figure 3.5 overleaf, one of the most striking things for an outsider is how long a public sector development can take before a contract is actually signed at Financial Close. The considerable capital finance required is also tied up until the public sector client starts to make regular service payments (Hickman, 2000). It is therefore possible that the construction contractor will feel pressure not only to win the bid, but also to get the building completed as soon as possible (Construction Industry Council, 1998).

Once the bid is won, the successful consortium forms a Special Purpose Vehicle (SPV) in the form of a limited company, often referred to as ‘Project Co’. The legal responsibility for the delivery of the project rests with Project Co. and is governed by a contract (a Project Agreement) between the SPV and the procuring public sector
organisation. Project Co. then contracts, separately, the design and build, facilities management, and other services. Facilities management is further sub-divided into ‘Hard FM’, which includes building maintenance and energy management, and ‘Soft FM’ services, such as catering and cleaning (Construction Industry Council, 1998; Fox, 1999). Contract requirements will also flow down the procurement structure to subcontractors (Hickman, 2000). In the case of the hospital that I studied, two different profit centres of Construction Co. provide the design and build and Hard FM services, while a third party organisation delivers Soft FM. In addition, there are also contracts between Construction Co., in its capacity as the main contractor, and the many subcontractors that will undertake the design and build work. Overall, the PFI process is challenging for construction companies to administer and manage, especially when it requires employees to move between these ways of working and the more familiar practices of other projects (Leiringer and Schweber, 2010).

In addition to defining the legal governance of the project, the contracts also set out what the client (the NHS Trust in this instance) wants from the build. This includes design and construction standards such as energy performance, but also requirements from HTMs and HBNs. The suite of contracts will cover timescales, the process for assessment of operational performance against the requirements, and a procedure for variations (Hickman 2000). Performance criteria, of which the energy targets are one, can be one of the “central battlegrounds” of negotiation between the parties, as well as presenting the client with a dilemma as to the level of performance they should specify (Fox, 1999). For sustainability issues in particular, the allocation of risk, reward, and incentive through the performance specification in the contract can be a key driver of behaviour in the construction team (Hill, 2004; Badi and Pryke, 2014).
3.5.3. The hospital project

The hospital project draws on Construction Co.’s considerable experience in the healthcare sector. The hospital is not an acute general hospital, but a specialist one, and for this reason an important part of the Trust’s design conception of the hospital is achieving clinical excellence in this specialism (Doc - Information for Bidders). Its standing is also of importance in the local community, with much interest in its development being taken by local stakeholders and media (Doc - News 3, Int - Contractor 1). Further details of the hospital have not been provided in order to protect its anonymity. As can be seen from the timeline in Figure 3.5, the fieldwork for this PhD has engaged with the hospital during its construction and commissioning phase. To be clear, the researcher was therefore not present for the design process, and will not be present for the operational phase.

<table>
<thead>
<tr>
<th>Year</th>
<th>Business case, consultation &amp; planning</th>
<th>Bidding, design</th>
<th>Detailed design</th>
<th>Construction &amp; commissioning</th>
<th>Occupation &amp; operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Department of Health approves project</td>
<td>Construction Co. selected as preferred bidder</td>
<td>Financial Close</td>
<td></td>
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<td>1</td>
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<td>PhD fieldwork</td>
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<td>2</td>
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<td>Performance against energy targets assessed (anticipated)</td>
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<td>Practical completion (anticipated)</td>
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*Figure 3.5 Timeline of hospital's development*

3.5.4. The energy targets

The reason for choosing the hospital for research was, of course, its targets for energy and carbon emissions in-use. However, the contracts for the hospital actually contain
several energy- and carbon-related targets, as shown in Figure 3.6 at the end of this section. The ones that principally concern this research are the two that compare energy use and carbon emissions in design with actual performance in operation, as it is this comparison that distinguishes the targets from the usual requirements of Part L or BREEAM. For the sake of simplicity, these two targets will be referred to throughout the thesis as “the energy targets”. The energy targets have the following distinguishing features:

1. They have specified values, in GJ/100m$^3$ for energy use, and tCO$_2$/100m$^3$ for carbon emissions. These must not be exceeded when the building is operational;
2. These values are specified in the project’s contracts, and signed off at Financial Close;
3. If the target values are exceeded once the building is operational, a substantial financial penalty is incurred by Construction Co.;
4. The targets cover all energy use within the hospital, during all operational hours, and include energy both regulated and unregulated by Part L; and
5. Compliance with the targets is assessed by comparing contractual to measured values, during the first two years of the building’s operation.

Not only is it unusual for a construction contract to specify values for energy and carbon in-use, the levels specified are also fairly challenging. The exact value of the energy targets is not given for reasons of anonymity, and because it does not affect the qualitative findings. However, the energy use target falls within the range required at the time of the project’s procurement of 35–55 GJ/100m$^3$ for all new NHS capital developments (Department of Health, 2013). Achieving this level would make the completed hospital far more efficient than many existing hospital buildings in the UK.
Compliance with the carbon emissions target would also put the Building Emissions Rate more than 30% below that required by Part L 2010 (Doc - Sustainability Statement).

As energy and carbon are specified separately, both have to be balanced. So, for instance, complying with the energy target requires the minimisation of the total energy input relative to the building’s volume, whilst the carbon target can be achieved by the use of low carbon energy sources, as well as by energy efficiency. This presents an additional, and unfamiliar, difficulty for the design team, as trade-offs between energy efficiency and carbon reduction may have to be made. Thus overall, the energy targets may be considered to represent a significant and unusual challenge for Construction Co. and its contractors over and above that of standard construction projects without these sorts of target.

In addition, and as also shown in Figure 3.6, there are also a number of other contractual targets related to energy and carbon. Unlike the energy targets just discussed, these do not require a comparison between design and operation. They include:

- The design and planning conditions, including the carbon or renewable content of energy, and BREEAM; and

- Targets for long-term energy use and carbon emissions, to be set once the building is completed, and following the initial two years of operation.

These other targets are worth mentioning for two reasons. Firstly, they interlink with the energy targets. So, for instance, an energy efficient design would help meet both the energy targets and the BREEAM requirement, and pave the way for long-term energy efficient operation. Secondly, when asked about “energy targets”, participants in my
research sometimes became confused between the different types of targets, or talked about other targets instead of the energy targets. I therefore felt that they formed part of the picture of differing interpretations and responsibilities around energy performance that I wished to explore. The precise contractual conditions surrounding the various targets are complex, and split across nine different documents as part of the huge suite of PFI contractual information. They are set out in detail in Appendix B.

Figure 3.6 The hospital's energy and carbon targets
3.6. Researching energy targets

3.6.1. Energy targets as a topic

Exploring the energy targets involved getting to grips with an inherently intangible research subject, reflecting the discussion in section 2.2.4. An expectation of energy use, unlike a finished building, is not a present, physical object (de Wilde 2014). It is defined in opposition to something else, such as a baseline, or a benchmark, and furthermore there is no physical process available to measure it until a future point in time when the building becomes operational. Thus exploring it poses practical as much as metaphysical difficulties. However, the three concepts chosen were selected partly on their ability to deal with this difficulty, as they help explore how the energy targets are brought into being in a multiplicity of ways, through practices, discourse, and collaborative means. The process followed by Mol (2002) was to explore the enactments of a disease, rather than to write an ethnography of the hospital or its community of clinical staff. In this research, I have similarly attempted to focus on the energy targets themselves. The subject of the research is therefore the targets, and the responses that they provoke amongst the construction team.

I used this principle of focusing on the targets to drive my sampling. As already explained, I intended to gather data from interviews, observation, and documents. I aimed to trace the energy targets through various dimensions:

- Time: how did the energy targets emerge in the early stages of the bid, evolve through the design and construction, and how might they evolve further in operation?
- Actors: whose activities and responsibilities were involved with the energy targets, either directly or indirectly?
Form: how and where did the energy targets appear in different documented and undocumented forms?

I employed a snowball approach to my sampling. Snowball sampling is often appropriate when the population of interest is unknown at the beginning of the study, as it makes use of participants’ own social networks. It is hence a useful method in gaining access to a community, and valuable in generating information about how its internal relationships are structured (Noy, 2008). The risk is that it can also confine the researcher to participants’ existing networks. To temper this, I tried to use the snowball process reflexively. Defining the community of study can be determined either by how its own members see it, or how the observer identifies it (Hammersley and Atkinson, 2007). At the outset of my research, I leaned more towards the first, in working through organisational charts and taking advice from my participants. I then tried to challenge these insider views, by tracing the targets in directions that my participants might not consider relevant, but which I thought spoke to a wider understanding of how Construction Co. responded to them and to issues of energy performance. This is perhaps best illustrated by some examples, which I have set out in Table 3.1 overleaf.
My actions | Data generated
---|---
**Snowballing:**
Meet senior member of M&E team as key point of access to site team | • Field notes of meetings with senior team member
Points me to construction contract clauses that contain targets, and introduces me to a construction manager who deals with energy systems | • Contractual documents
• Field notes and interview with construction manager
Construction manager talks me through technology specification and procurement process, and refers me to subcontractor | • Design and procurement documentation
Approval of senior member of engineering team is required to contact subcontractor | • Field notes of telephone conversations
• Interview with senior engineering team member
Meet with subcontractors | • Interviews with subcontractors
• Design documents
**Reflexive consideration of missing leads:**
Contact legal team to understand how energy targets fit within overall project contract structure and negotiations at bid stage | • Contract and commercial documents
• Interview with member of legal team

*Table 3.1 Example of reflexive application of snowball sampling*

In using the energy targets to drive my sampling, I was keen to challenge Construction Co.’s predominant conception of them as an engineering or environmental issue. I therefore tried, as can be seen in Table 3.1, to trace their manifestations beyond these spheres. I felt that this would fit with my interest in exploring the multiplicity of energy targets and energy performance in Construction Co., and add value as an external perspective for them. The diagram in Figure 3.7 overleaf shows the areas I covered with my data collection, and any areas I could not reach. As can be seen from a
comparison of Figure 3.7 to the more sequential RIBA Plan of Work shown earlier in Figure 3.4, my mapping of the hospital’s development presents a more ecological and messy process. Indeed, had I had access to other stakeholders outside Construction Co.’s team, it could have grown much further.

3.6.2. Data limitations

There are a number of limitations of the data collection to consider. As just noted, setting the boundaries of where the targets might start and end is judgemental, and also practical, given the impossibility in construction of “being able to be everywhere at once” (Marshall and Bresnen, 2013:109). Additionally, as can be seen from Figure 3.7, where the areas covered by my research are in bold type, I did not cover all possible variants of the energy target. My research omits a number of stakeholder groups, including: the client (the NHS Trust); occupiers (clinical staff, patients and others); planners; regulators; industry bodies; local communities; Construction Co.’s competitors; and others. I did not engage with organisations that were not directly contracted to Construction Co., such as the Soft FM provider. Nor did I focus on members of the large community of site workers, who are responsible for the physical work of constructing a building. The influence of these other, absent, stakeholders is clearly felt in some of the findings, if not explored directly, and would be an interesting topic for further research on responses to operational energy targets.
Figure 3.7 Data collection focussing on the energy targets

(text in **bold** shows where data have been gathered)
Another important dimension of large construction projects, such as the one I was looking at, is time. The hospital project, and hence the genesis of the energy targets, began long before I started my PhD. The eventual assessment of the energy targets’ success or failure will not happen until after I have completed my PhD. Hence my interaction with the energy targets was only ever going to be during a particular slice of time. Whilst I was expressly interested in the construction phase, nevertheless it is affected by what happens before and after it. For this reason, I have tried to make use of different forms of data to reach things that have happened already or have not happened yet, a technique also used in construction by Thiel (2013). In doing so, I had to accept that the result would be partial to some extent, and view events past and future through the lens of the participants, or the data type, describing it.

In gathering data, I have done my best to touch on as wide a variety of professions and seniority in project, company and subcontractors, but this is clearly cannot be comprehensive. If a focus on the targets was the principle to start sampling, deciding when to stop was an equally important consideration for me. The question of what constitutes “enough” qualitative data can be controversial (Baker and Edwards, 2012; Galvin, 2015). In my case, I found that energy targets, rightly or wrongly, still have a fairly limited and specialised reach within construction. Therefore in the spirit of following them as far as I could, I nevertheless found that after a while I had pushed their boundaries as far as I could.

Despite my best efforts, it was not possible to gather all of the data that I would have liked. For practical reasons, I found it difficult to obtain many examples of informal, personal communications, such as telephone calls and emails, despite the fact that these are a major component of daily life in Construction Co.. There were also
participants I could not reach. In the case of staff involved in the original bid, some of these had left the organisation, given the length of time involved. Some participants refused to take part either because they were too busy, or because they were anxious about being involved in research. The effect of these omissions on the findings is unknown. They also, I think, say something about the nature of working in construction. In a highly time-pressured environment, finding the time to sit and reflect on energy performance might not be a priority, particularly for subcontractors once their involvement in the project has ceased. Additionally, in construction one party is reporting into another, with performance failure potentially being met by blame or financial penalties (Bresnen, 2013), both of which are likely to inhibit honest discussions about the difficulties of guaranteeing energy performance. Finally, the regularity of staff turnover is a problem that some of my participants wrestled with as much as I did.

Documentary data can also be especially vulnerable to omission. As Scott (1990) observes, documents are inevitably a pre-selection of what has been kept available for access. As I had to request all the documents I used, it is entirely possible that participants gave me what they considered the most favourable, or perhaps the easiest to find, rather than the most informative material. I also encountered several instances where I was not permitted access to documents that were considered commercially sensitive. I also had some instances of documents that I never received despite repeated requests. As Phillips and Brown (1993) observe, documentation is a key way in which company managers use power to control the presentation of the company, and in these two latter instances, I felt that being a student reduced my commercial leverage to get things done.
3.6.3. Data sampling and the three STS works selected

A further consideration for data collection was that to address the three framing concepts of this PhD, the data gathered needed to suit each. Staring with Mol, her work relies on what she terms a “praxiography” (Mol, 2002:31), or an ethnographic study of practices, because her work investigates the practical means by which reality is brought (or “enacted”) into being. Although Mol herself complemented her field notes with interviews and written sources, my fieldwork placed less emphasis on observation, and so I relied to a greater extent on my participants’ ability to express their everyday practices in interviews. Given the amount of ground I needed to cover, I felt interviews were the most practical solution, being a “flexible and adaptable way of finding things out” (Robson 2011:272). During my interviews, I tried to encourage my participants to tell me about their everyday actions using practical examples, aiming for an “efficient means of understanding how it is to embody certain practices” (Hitchings, 2012:66). Prior (2003) has emphasised that a situated understanding of how documents are consumed and used is also a critical part of research in organisations. I found myself that documents did form an important part of construction practices, for there are documents of many sorts everywhere on a construction site (Figure 3.8 below).
For Gilbert and Mulkay, the aim is to explore discourse not as a “resource” to inform you about what happened, but rather as a “topic” whose interest lies in how it is socially generated (Mulkay et al., 1983:196). Gilbert and Mulkay (1984) used data from interviews and written sources produced by a community of biochemists. From this data, they drew out recurrent patterns in which scientists expressed their work that they termed “interpretative repertoires”. Although discourse analysis can be carried out on very small samples of data, perhaps even a single document, if looking for recurrent patterns, such as Gilbert and Mulkay’s repertoires, then a larger data set is needed (Potter and Wetherell, 1987). In order to compare the effects of “social context” on actors’ discourse, I also needed a variety of sources, verbal and written, composed for different reasons, and in different formats (Gilbert and Mulkay, 1984:7). Practically, this mostly meant interviews and documents. In comparison to a research stance that uses interviews as “mining” for information or “travelling” for tales (Kvale, 1996), or that assesses documents for credibility (Scott, 1990), I was actively looking for inconsistencies and variations in discursive accounts in order to unearth the “interpretative work carried out by participants” (Mulkay et al., 1983:188).
Star and Griesemer (1989) used archival records for the historic case study of the zoology museum from which they drew the concept of the boundary object. However, in her later reflections on the boundary object, Star explains how ethnography may explore what she calls "the ecology of the workplace - all of the things that are involved in the mediation of knowledge" (Star, 2010:605). The concept of the boundary object is an analytical one, and hence it did not require me to collect particular sorts of data. Rather it required a shift in perspective, so that I incorporated specific interview questions and document requests around systems and sharing. For this reason the variety of data was useful, and indeed Star suggests a combination of data is beneficial when looking relationally at how people shape something, in different ways, in different places (Star, 1999). In addition, analysing where energy was not present in information-sharing systems, and where documented official processes differed to participants’ informal accounts, also helped reveal interesting inconsistencies between formal and informal channels of information sharing (Brown and Duguid, 1991; Yaneva, 2009).
3.7. Data collection and analysis

3.7.1. Data gathered

In total the volume of data gathered was:

<table>
<thead>
<tr>
<th>Type</th>
<th>Main case study</th>
<th>School, office, early work</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interviews</td>
<td>31</td>
<td>7</td>
</tr>
<tr>
<td>Documents</td>
<td>177</td>
<td>8</td>
</tr>
<tr>
<td>Observation</td>
<td>73 hours</td>
<td>51 hours</td>
</tr>
</tbody>
</table>

*Table 3.2 Data volumes gathered*

In the findings, where I refer to data sources, I will do so by data type and source name. So, for example:

- “Int - Environment 1” would represent an interview transcript with team member 1 from the environment team;
- “FN - Induction” would represent an extract from my field notes of the induction event;
- “Doc - Sustainability Statement” would represent an extract from a written copy of the Sustainability Statement.

Where the participant has been fully anonymised they simply appear as “anon”. Where I have spoken to participants on several occasions I have also appended a letter (e.g. Int – Engineer 2b). A more detailed schedule of the data gathered can be found at Appendix C.

3.7.2. Interviews

Interviews lasted from 22 minutes to over 2 hours, but the majority were between an hour and an hour and a half. They almost always took place at the participants’ place of
work. I met directors, managers, and staff, but overall, I met more managers than I did others, simply because they were more likely to be directly involved with energy targets. Had I considered strategic visions of energy targets, or the installation of energy-saving technologies on site, I would most likely have had a very different demographic. Those I met encompassed participants from:

- Design;
- Construction;
- Environment;
- Legal;
- Strategy and Innovation;
- Engineering;
- Facilities Management;
- Support;
- Commercial; and
- Subcontractors (architects, consultants, M&E designers and modellers, technology designers and suppliers).

The interviews that I had carried out in my early work on the school and office projects were more exploratory in nature, helping me to explore potential themes for the PhD (Fielding and Thomas, 2008). By contrast, the interviews for the main hospital case study all had a common structure, which reflected the three theories I had by then chosen (see Appendix D). I produced an interview template that was then tailored slightly to fit each participant (Appendix E contains some examples). The idea was to make sure that the areas covered were always similar, as otherwise it would not have been possible to compare across data. However, I avoided reading out the same questions in the same wording, as the appropriate phrasing would vary, for example,
between a director in Construction Co’s head office and a member of the on site support staff. I might also find that the order of the questions varied with the conversation, and that sometimes unexpected issues came up that were relevant and worth discussing. I was therefore aiming for a sensible balance between consistency and tailoring (Mason, 2002). Interviews were recorded with the participants’ consent. Two participants preferred not be recorded, but were happy for me to take notes to include in my research.

3.7.3. Field notes and diary

I used my field notes to record my observations and impressions, including descriptions of places I visited and events I attended. I tried to describe what I saw and heard, and also my responses to them. I used a notebook to record as much as I could for writing up later. My presence was never covert, and I was quite clear in all formal and informal meetings that I was a student doing research for a PhD. Writing up I did as soon as possible, often on the train, or at home in the evening. I also kept a reflective diary throughout the planning, pilot, and fieldwork stages. In this I included ideas, possible directions, thoughts on analysis, and on my own practice, and reminders of things to follow up.

I observed a wide variety of activities, including:

• On site activities: attending air tightness testing; shadowing commissioning engineers; walk-around with site managers; shadowing independent tester and compliance walk-around;

• Meetings: either participating (for example update meeting on target progress with site director and facilities); or observing (group meeting on energy monitoring strategy);
• Meetings that cannot be classified as interviews, because unexpected, or with exploratory questions, or longer phone calls, which provided information but could not be classed as interviewees, or when introduced to someone spontaneously;
• Various Skype and conference calls;
• Observation activities of being on site, travelling with staff, or being in offices, chatting, having lunch, etc..

3.7.4. Documents

I collected 450 documents in the course of my fieldwork. For the practical purposes of analysis, it was necessary to whittle these down. Following Prior (2003), the criteria I used for selection were based on my research aims: the document’s relevance to the principle of tracing the target; and its usefulness in providing data for the three STS works. In addition, I also considered documents’ representativeness (Scott, 1990) and relationship to the community under study (Hammersley and Atkinson, 2007), so that I did not unduly bias my selection to a particular type of document or group of people.

Please see Appendix F for a fuller description. This reduced the document sample to a total of around 175, as shown in Table 3.2. The type of documents gathered encompassed:

• Contracts;
• Specifications and technical documents;
• Intranet files;
• Drawings and plans;
• Working papers, calculations, and spreadsheets;
• News items;
• Reports;
• Protocols, policies, and standards;
• Powerpoint presentations;
• Website pages;
• Forms and certificates;
• Organisation and flow charts;
• Proposals and marketing materials;
• Emails;
• Board papers; and
• Meeting notes.

3.7.5. Coding and analysis

I uploaded data from the documents, interviews, and field notes into NVivo. Using the three theoretical and analytical concepts provided me with an external framework (etic) basis to develop the majority of the codes for analysis. Each single code might relate to one, two, or all three. In my analysis, I then separated the findings from each code along the lines of the three STS concepts. However, in my initial reading through of the data, a few unexpected themes emerged, which I felt were relevant, and which I then included as additional emic codes generated from the data itself. Overall, I developed a set of 49 codes. The process of analysis that I followed was based on the thematic approach defined by Braun and Clarke (2006), which lays out the six steps of familiarisation, coding, searching, reviewing and defining themes, and reporting. I felt that the thematic process was rigorous but also flexible enough to take account of the need to analyse the data into three different theoretical and analytical sets of findings. This meant that I read through the coded data several times, and sometimes re-coded as I reviewed it. I then wrote a long initial summary for each code that described what I felt the themes arising were, and then revisited this to produce a shorter summary based on further reflection. This process allowed for a useful “clustering” of themes (Saldaña, 2014), which allowed me to see how they might be grouped together to
produce findings. These summaries, and the underlying data on which they draw, provided the backbone to the empirical chapters.

3.8. Research practice

3.8.1. Confidentiality

The partnership with Construction Co. is governed by legal agreements that set out the aims and undertakings of the university, the student and the company. All information gained from the company is treated as confidential unless it is already publicly available, or approved for release by the company. Although this does not explicitly require anonymisation of the names and characteristics of Construction Co. and its staff, I have chosen to do so. Firstly, I believe that this protects the research participants who work within the company from potential blame or harm arising from the views they gave. Secondly, corporate discussions of sustainability can be subject to “greenwash” in public (Lyon and Montgomery, 2015), so I also hoped that an anonymous discussion might encourage participants to speak a little more honestly about their experiences.

To protect participants’ identity, they will be referred to by their professional team or function, rather than their precise title. So, for example an Environment Advisor might become “Environment 1”. Additionally, given that sometimes there are only a few women in particular teams it could make participants very easy to identify if given their correct pronoun. For this reason, I have referred to all participants as “he”. In addition, where I felt that a participant had said something in particular that might expose them to blame I have fully anonymised their contribution, referring to them as either “a participant” or “anon”.

3.8.2. Data protection

During the PhD I collected personal data, but no sensitive personal data. The PhD has been registered with the UCL Data Protection Registration Service, and have tried to store the personal data that I collected securely, in order to protect it from unauthorised access, disclosure or loss, as required by the Data Protection Act. This included secure storage of paper documents, removing files (in particular interview recordings) from portable storage as soon as possible, and password protection for external electronic devices and applications (such as NVivo). Additionally, I also held commercially-sensitive information that was not in the public domain. Whilst it is relatively easy to anonymise an interview transcript or field notes, this is not the case with the large number of documents that I collected. It is not possible, for instance, to edit pdf copies of board papers, planning submissions, organisation charts and so on. For this reason, I have encrypted the hard drive of my laptop, so that in the event of its loss, the data would not be easily accessed by a third party. The research data for this project have been backed up only to UCL servers, not to any cloud-based storage. New data protection legislation came into force during May 2018, but all research data for this thesis had been gathered prior to that point.

3.8.3. Ethics

Guidance on research ethics often focuses on vulnerable participants (Byrne, 2016). However, in a paper on ethics, Bell and Bryman (2007) argue that management research is significantly different to other types of social research. The researcher often has, as I do, an affiliation to or funding from the organisation they are studying, and the balance of power and knowledge does not always rest with the researcher. Many of the individuals I met were very well informed about the performance gap and energy efficiency, or were more senior to me. Sometimes they opened with a mini interview
about my qualifications, before I could begin to interview them. This has relevance for the treatment of informed consent as a process-driven exercise, embodied by the signing of a form (Sin, 2005). Bell and Bryman recommend basing a relationship with organisational participants on a more reciprocal footing, with consent being more of continuous negotiation, something that is also recognised by Wiles (2013). In this case, I have tried to fit my research process to the business-orientated norms of review with which my participants are more likely to be familiar, an approach also used by Mäki and Kerosuo (2015) in their work with a construction company. Please see Appendix G for a full discussion of the ethical approach.

### 3.9. Reflections on the research process

Before presenting the findings, it is important to pause and reflect on my own potential influence on them. As Whyte observes, "the researcher, like his informants, is a social animal" (1955:279), and I will outline three aspects in which my subjectivity is a possible influence: the impact of my own identity during the fieldwork; my own shaping of the findings, methods and data, and how I sought to mitigate these; and additional considerations arising from working on a collaboration between academia and industry.

#### 3.9.1. My identity during fieldwork

In conducting qualitative fieldwork, the manner of "identity work" through which you present yourself is key to your engagement with participants (Mason, 2002:93). The research was challenging for me personally, as, although I had worked for many years in energy and climate policy, I had no prior experience of working with the construction industry. This inexperience I felt presented two dangers: one that I would lose credibility with my participants; and two that I would misunderstand information, or miss potential lines of enquiry.
In terms of the first, I did not present myself to my participants as an expert in construction, instead emphasising the research as an opportunity to share the academic knowledge of UCL with the industry knowledge of Construction Co.. The Information Sheet (appended at Appendix H) for example uses this as the justification for the project. In meeting junior staff and middle management, I found that simply being interested in finding out what they did in their day-to-day work was positively received. Establishing credibility was more of an issue with senior staff in Construction Co. and its subcontractors, and I found that I had to actively sell my own qualifications, and the value of the research to the business, before they were willing to talk to me. One senior manager, for example, would not talk to me until he was assured that Construction Co. was funding the research. In other instances, I found that the strategic deployment of technical facts about building performance that I had gained from my Masters programme, and from reading technical, as well as sociological papers, helped in establishing credibility.

The second danger was one of misunderstanding what might be “common frames of reference” specific to a community (Macdonald, 2008:199). This, I attempted to mitigate by simply asking participants to explain if they mentioned something that was unfamiliar to me. In doing so, presenting myself as a student, rather than, say, a quasi-consultant to Construction Co., allowed me to admit to a lack of knowledge. I made great use of construction textbooks, which set out common team roles and contract structures, for example. In doing so, I followed Vaughan’s approach “to sufficiently master the technical details necessary to get at the sociological questions” (1996:40). So I attempted to gain a sufficient understanding of construction in order to ask and understand sensible questions of technical people about why and how they chose to do things, in order to help assemble a socio-technical analysis of their work.
Gaining familiarity with a community thus involves a delicate balance between being a “total newcomer” and going native (Latour and Woolgar, 1986:44). One of the most interesting parts of the research was getting to know the world of construction and its idiosyncrasies. For example, I learnt the importance of acronyms and nicknames for processes and people, of learning the rules (for example the overriding importance of health and safety), of the best means of getting hold of someone, and finding out who was mostly likely to know what. I found that little things, like knowing that when people talked about “the trades” they meant the subcontractors, or how I needed to customise my safety gloves to use a touch-screen on site, all added up to a sense of what it might mean to belong to a community. At the same time, I was still a student, and so some of the taken-for-granted ways of daily life in construction still appeared strange to me. For example, it interested me that I saw staff on the project switching between marker pens on paper and the virtual environment of BIM, or the way in which I observed that company and subcontractors had been physically separated by locked doors on site, which staff accepted as being the way things always were. I have tried to maintain this ability to see the “strangeness” from which the insights of fieldwork may arise (Star, 2010:605).

“Going native” was not such a danger on the construction site, as being one of six women on a site of around five hundred men there was little chance of blending in. Sometimes those on site found being researched an interesting novelty. They wanted to know what a PhD involved, and why I was doing it. At other times my identity as an outsider was a problem, as taking time out from working full tilt on a project with tight deadlines to sit and chat with a student was the last thing they wanted. I found that a little sympathy about the pressures of work, and balancing it with home life, went a long
way to smoothing the way. In Construction Co.’s head office, I found that I fitted in more
easily, finding the language, dress code and background more familiar to my own. I
consciously behaved in a more “professional” way in the way I spoke and dressed in
the offices compared to my more informal demeanour on site, so as to mirror the staff I
was meeting. However, wherever I was, I was always careful not to express things in
academic jargon (Robson 2011; Buchanan et al., 2013).

3.9.2. Taking a reflexive perspective

I also needed to consider how my own framing of the research might affect the validity
of the findings (Creswell and Miller, 2000), and to pay heed to my own positionality
(Ybema et al., 2009) in generating my lines of enquiry, my interactions with my
participants, and the conclusions that I drew from them. So, for example, in my data
collection choices, because I gathered a large number of legal documents, and
interviewed lawyers, to find out more about the contractual energy targets, it might
become more tempting for me to emphasise legal issues for the construction team.
However, as Robson (2011) notes, what you avoid as much as what you choose to
look at can also be a source of bias, as has been considered in the data limitations set
out earlier. Law and Ruppert, quoted earlier, have argued that where we set the
boundaries of our methodological “devices” is inherently subjective and that therefore
one “looks, and in some measure one discovers, the patterns that one is searching for”
(2013:233). I have found this a valuable consideration to keep in mind when taking
decisions on how to collect and analyse my data.

In my case, I felt that the risk was that my attempts to define the boundaries of my
research topic might also restrict it. This could effectively iron out its inherent
messiness in an attempt to make an ordered account for the reader (Law, 2004), or
selectively identify data to create a clear storyline (Silverman, 2014). Indeed, Geertz
(1993) suggested that a coherent account does not necessarily make a good account, because cultural systems are often incoherent. However, the difficulty is to be reflexive without tying yourself in an intellectual knot, where everything becomes deconstructed and unknowable. After all, the researcher does have a responsibility to produce useful findings (Collins and Yearley, 1992). This, I believe, is especially true in the case of applied research such as this, hence I have tried to mitigate against subjectivity in a number of practical ways.

Specific guidance for research students on how, practically, to become more reflexive may be scarce (Mauthner and Doucet, 2003). The latter suggest that the student considers the possible influence of their background on their interpretations, and stress clarity about the epistemological and ontological position in reaching conclusions. Regarding the second of these, I believe that having employed three different approaches to epistemology and ontology has required me to think more explicitly about these than I might otherwise have done. The first of these suggestions has required me to think more about my motivations. I had to acknowledge that working with a research question based on the “performance gap” might pre-dispose me to emphasise problems in how Construction Co. dealt with the energy targets. I have made a conscious effort to also note positive aspects of the ways in which the construction team deal with energy targets. I have also tried to avoid judging participants if they do not attach the same importance to energy use and climate change that I do.

There are also other risks in how I analyse my data. Using pre-selected theories might encourage me to force fit data to these (Sandelowski and Barroso, 2002). I have tried to employ several means of mitigating these risks of partiality. Firstly, I have made use
of the three different data types, as recommended by Silverman (2014) and Berner and Björkman (2017), to compare interpretations. Using other case studies to compare to can be a good solution (Stake 1995). As I have also worked on another research project around non-domestic energy targets at UCL this has given me some comfort that my findings are not completely anomalous, although this sort of comparison cannot of course control for the complexities of individual projects. I have also tried to implement Vaughan’s view that the most interesting insights are those where the theory you apply fails to fit (2014). Hammersley and Atkinson note that:

“in moving between data and concepts we must take great care to note plausible alternative links to those made in the emerging analysis.” (2007:218).

A practical way for me to do this has been to present ideas for emerging findings, such as at academic conferences, to Construction Co. staff formally and informally, to other research groups at UCL, and to my supervisors, which gives these very different audiences a chance to challenge my interpretations.

3.9.3. Additional considerations arising from an academic-industry collaboration

Academics might view collaboration with industrial partners with trepidation, often encountering problems with conflicting values and expectations (Harty and Leiringer, 2007; Sintov and Schuitema, 2018). I personally have found that working with an industrial partner involves an ability to juggle the priorities of two very different stakeholders. It can sometimes require explaining to each party how the other institution functions. So for example, the concept of spending an extensive amount of time on a literature review needed to be explained to the sponsor, as it this is not necessarily either familiar or visible to them. From the academic side, it requires realism about the data available for study. As Buchanan et al. note, fieldwork in
organisations “is permeated with the conflict between what is theoretically desirable on the one hand and what is practically possible on the other” as in businesses, “the members of the organizations block access to information, constrain the time allowed for interviews, lose your questionnaires, go on holiday, and join other organisations in the middle of your unfinished study” (2013:53-54). My work with Construction Co. offered an opportunity to access staff and data that would not be available to a researcher without such an agreement. However, it also had a noticeable downside in restricting the availability of case studies available to me, which would not have been the case had I worked with publicly available dataset, for instance. In common with Bordass et al. (2001), who have championed a pragmatic, “real world” approach to buildings research, I believe that these difficulties are worth overcoming.

Access to Construction Co., as I have already noted, was dependent on my initial gatekeeper, which brings with it a danger that they might exert undue influence on my research direction (Easterby-Smith, 2002). I tried in my sampling approach to think beyond the boundaries that my participants suggested, and to offer this alternative perspective back to Construction Co. as a benefit of the research. It is possible that my feedback to Construction Co. could have influenced them to change their choices and hence the research setting, but the alternative of unresponsiveness would be very impractical. I also think that for my gatekeeper, the partnership with UCL was an opportunity to ask questions about how Construction Co. dealt with energy that he might not otherwise be able to for reasons of time and access. Sometimes we discussed issues of energy or sustainability that would not necessarily move the PhD research further, but did move the relationship forward and help create mutual trust.
Research in collaboration with industry is a paradigm that funding models may increasingly encourage universities to adopt (Biggart, 2016; Engineering and Physical Sciences Research Council, 2018). This is especially important given that one of the stated aims of this PhD has been to help bridge the knowledge divide between academia and industry. As a result, I have tried to convey findings in both academic format, and in a form that speaks more directly to the practical and commercial needs of Construction Co.. Some of the latter outputs have been included at Appendix I as an illustration of this approach. Cooperation does not necessarily have to mean compromise. Vedel and Irwin (2017) have put forward an interesting concept of "unalignment" when thinking about academia and industry. They suggest that they should not seek complete alignment, but that both should be able to learn something from their differences, which provide a spur to further learning. This is the spirit in which I tried to pursue this PhD. With these considerations in mind, it is now time to turn to the empirical findings. These will be formed of three chapters relating to the three theoretical and analytical concepts employed, and, as initially promised, will start by outlining more about the concepts themselves.
4. What do actors in the construction team do in response to the energy targets?

This chapter is concerned with what actors do in response to the hospital project’s energy targets. Bearing in mind that these sorts of targets are still outside the normal field of experience in the industry, an understanding of actors’ practical responses “inside the gap” is therefore very valuable. The theoretical basis for the analysis draws on the work of Mol, in which she introduces us to the idea that reality is brought into being through practices (2002). Mol is an interesting place to start for the empirical chapters, as her work requires an engagement with the fundamentals of what energy targets are, how they might in fact be many things, and hence what implications arise for how we judge a building to be energy efficient or low carbon. Her ontological concept is philosophically stretching: but it also practical, as it considers the implications of day-to-day actions in the workplace. Thus Mol engages directly with the question of what happens “inside the gap”.

In the opening section (4.1), I will set out the concepts that will be used to guide my initial analysis, including Mol’s assertion that differing “enactments” of an object lead to multiple realities, which nevertheless “hang together”. I will also highlight the importance of whether these realities are aligned (“coordinated” in Mol’s terms), and the opposing possibility that they remain “distributed” (uncoordinated). These key
concepts will be applied to the empirical material that I have gathered, in sections examining how the energy targets are enacted (4.2), how they are coordinated (4.3), or how they remain distributed (4.4). The insights from these findings are then used to step back and consider the potential reasons behind them in section (4.5), which are specific to the empirical circumstances of this case and therefore go beyond the boundaries of Mol’s work. Together, Mol’s concepts of enactment, coordination, and distribution allow the work in this chapter to conclude on the normative implications for building performance of who makes energy targets real, and how (4.6). A final section (4.7) will consider what the choice of this Mol’s work has offered to the thesis.

In approaching this chapter, the reader is reminded that the intention of the thesis, as set out in Chapter 1, is to mobilise the chosen concepts from STS to draw out practical insights from the empirical data. This is consistent with its aim to provide practical advice to industry and policy. It will not, therefore, provide a theoretically pure analysis that stays within the ontological lens of Mol throughout. The structure of the chapter is instead designed to move from an initial focus on Mol’s concepts as applied to the data, followed by a deliberate step back to consider the implications for energy and building performance from the case at hand. This pattern will also apply to the other two empirical chapters that follow this.
4.1. An introduction to “The Body Multiple”

4.1.1. Key concepts

Mol’s “The Body Multiple” (2002) formed a central part of a wider ‘turn to ontology’ in STS (Woolgar and Lezaun, 2013). It has been a highly influential work within the discipline, and has already inspired some work in energy and carbon (section 4.1.3.). Woolgar and Lezaun explain how the turn to ontology “addresses itself directly to the composition of the world” as it is constituted through everyday practices (ibid:322). This encourages a “renewed critical attention to objects that might otherwise appear ‘finished’ or ‘ready-made’” in other branches of STS (ibid:323). Mol’s work in “The Body Multiple” exemplifies this ontological approach. Unboxing everyday objects allows Mol to reveal their underlying multiplicity, and their corresponding potential to be configured in alternative ways.

The genesis of these ideas lies in several strands of STS thinking. From Latour (1993), Mol takes the distinction between knowledge articulated and knowledge embedded in practices (2002:30-1). This she weaves together with a concept of multiplicity that comes originally from Haraway’s cyborg, an entity that is neither completely one thing nor the other: “one is too few, but two are too many” (1991:177). Haraway in turn inspired Strathern to develop the idea of “partial connections”, in which something may be “neither singular nor plural, neither one nor many” (2005:54), so that an object is not one thing with a generic meaning, but simultaneously several specific things to different people.

Prior to “The Body Multiple” Mol was already drawing on these ideas in her highly influential paper on the Zimbabwe Bush Pump (de Laet and Mol, 2000). This work
showed how a pump intended to deliver fresh water to a rural population was “fluid” in many senses, being created not by one person, but by many. In this way, it could be simultaneously: a mechanical device; a community project; and an advance in public health. Because it can be all these things and more, it is hard to judge the pump’s success, as for each of its identities success will be different. As a result, you cannot simply ask a “binary” question as to whether the pump is “working” or not (2000: 252). It is this fluidity in the nature of objects, and the consequences of it, that Mol develops further.

In “The Body Multiple”, Mol observes the practices relating to a particular disease, atherosclerosis, in the setting of a hospital. Her emphasis is not how medical professionals come to know the disease, but what they actually do in their daily work. She finds that there are different atheroscleroses, each brought into being (“enacted”) by different actors. So, for instance, a doctor enacts atherosclerosis by meeting and talking with outpatients about their leg pain, whereas a pathologist enacts atherosclerosis by viewing arteries from post-mortem samples under a microscope. These are both versions of atherosclerosis, but “they cannot be realised simultaneously” (2002:35). The more practices Mol observes, the more the versions multiply. However, “the body multiple is not fragmented”: it also “hangs together” (ibid:55), as the different sets of practices are still entangled, and often defined in relation to each other.

In addition to these “partial connections”, differing realities may be explicitly “coordinated” (aligned). This is achieved by various means, such as: establishing a hierarchy of data; calibration between differing measurements; or relying on prior experience. Coordination of professional practices in Mol’s hospital was often driven by
immediate practicalities, such as the need to deliver a diagnosis, or to determine the appropriate treatment. Yet if there is not a pressing need to find a consensus, if actors wish to avoid conflict, or if they do not meet or communicate effectively with each other, then the versions will remain “distributed” (unaligned). Thus “overt, ongoing incompatibilities” between versions of the disease may persist (ibid:88). Hence Mol suggests that coordination will only take place if the different versions encounter each other, without which any “frictions” (ibid:119) between them will neither be identified nor resolved.

Mol’s view of reality as enacted has many implications for her subject area of health, the body, and its treatment. For example, whether a patient’s atherosclerosis is enacted as operable or inoperable by medical staff changes the reality of the disease, and hence the patient’s life. However “reality moves” (ibid:165): if it is formed by practices, then it can be unformed. This means not only that there is “a permanent possibility of alternative configurations” (ibid:164), but also that there is a politically-charged question as to which reality is more desirable or ‘better’. Finally, enactments can be normative. Cholesterol levels affect atherosclerosis, and ‘acceptable levels’ are often taken from national averages. The determination of whether a patient is well or sick is therefore determined by the size of the general population being considered, and their relative levels of blood cholesterol. Figure 4.1 summarises the concepts from Mol that this chapter will use.
How reality is enacted (Mol, 2002).

**Enaction**
Objects are brought into being by everyday practices (they are “enacted”). However, partial connections allow the multiple versions that are enacted to “hang together”.

**Coordination**
Different enactions may be brought together and *coordinated* (e.g. by hierarchies, or calibrating measurements).

**Distribution**
Uncoordinated practices mean that different realities remain distributed. Various professional reasons may lie behind this.

**Implications of reality as enacted:**
- Enactions create normative expectations;
- Alternative versions may not be enacted;
- Policy may determine which enactions are desirable.

*Figure 4.1 Key points of Mol's work used in this chapter*

### 4.1.2. Why apply this work to researching energy targets?

I felt that Mol offered a good match to my research aims for several reasons. Firstly, “The Body Multiple” deals with separations of practices in a multi-professional
environment, enacting what is presumed to be a singular disease. This suggested a fruitful analogy to a multi-professional construction team working on energy targets. I also found her approach particularly interesting, as what Mol writes is not an ethnography of the actors, but of the disease. This, she argues, enables her to explore the co-constitutive practices by which it comes into being, whereas, if she were to focus on the human actors, she would identify a series of separate perspectives. As one of my main methodological challenges was to engage with the abstract object of an energy target, this seemed a very promising way to formulate my research. I was interested in tracing how actors brought different aspects of the building’s design and construction to the fore, as each addressed themselves to energy efficiency or carbon reduction, analogous to the way in which medical specialists each address their patient differently, and hence uncover their own versions of disease.

In addition, my early fieldwork was providing me with different accounts from different actors of what energy targets were for them (section 3.4.3). This echoed the concerns around collaboration in construction being raised in my literature review. The adverse impacts on collaboration of professional divisions are well recognised by both academic and industry literature (for example: Janda, 1999; Bresnen et al., 2003; Carrillo et al., 2013; Fedoruk et al., 2015; Hietajärvi and Aaltonen, 2018). These professional divisions can also be enhanced by a long-standing tendency in construction to neglect “the integrity of the built product as a whole” in favour of “a set of sub-systems” (Winch, 2000:153). Using Mol, however, offered the potential to unpick in detail the ontological nature of such divisions, by exploring how energy targets are enacted in construction.
I was therefore intrigued by the possibility that failures in professional collaboration might be due to something more fundamental than differences in perspective. If actors were either failing to coordinate different versions of energy targets, or attempting to coordinate versions that were ontologically distinct, this could shed light on why collaboration and communications around energy might encounter difficulties in construction teams. Mol could help me ask what an energy target might become in the hands of different actors, and how the actors might go about coordinating any differences. Moreover, if the energy targets were not just two numbers in a contract, but many things to many people, this could also have consequences for how the building’s eventual energy performance would be measured and disclosed. Mol’s proposition that reality can be made and unmade also raised questions for me about how a building might be diagnosed as energy efficient, and who might make this decision. This is especially relevant to this case, as the energy targets are an unusual requirement for Construction Co., and hence actors may lack established practices to deal with them.

4.1.3. This work in context

Other research has already appreciated the relevance of Mol to environmental themes, using her ontological lens to explore how intangible concepts, such as energy or carbon, may be given form and salience. Eidenskog (2015) investigated “how sustainability is done, through actions, and in talk and texts” in a business (2015:8), and is the work most closely similar to mine in its methods and application of Mol to a commercial case study. However, her emphasis is different, in focussing on how employees of the case study company “care” for sustainability, and how this fits or clashes with other business priorities. Asdal has employed Mol to assess how accounting practices create “nature” as an object that is measurable and valued. She observes that only once measured could emissions of a pollutant be found to be “too big”, and a concurrent requirement to reduce them be given (2008:125). Lippert (2015)
has also considered carbon accounting, and similarly to Asdal, shows how a company’s carbon footprint becomes multiple as it travels within and without the organisation. Elsewhere, Lippert looks at the “messiness” of carbon footprinting, and in particular how, as it is calculated, uncertainties, localised interpretations and inconsistencies gradually accumulate. This messiness is not recognised in the official results, which prevents a “consensual understanding of the environmental impacts” (2016:4). Zegwaard et al.’s (2014) case study of climate change experts used Mol not only to identify ontological differences arising between different professional teams, but also to show how practices of environmental management also shaped the problems they apparently addressed. Thus Mol seems to engage well with the sometimes-nebulous character of environmental issues, and actors’ attempts to materialise them.

These works have close analogies to energy efficiency in buildings, but none have dealt directly with it. The question of what is being constructed (physically and metaphorically) when we build a building is clearly fertile ground STS (section 2.3), so it is no surprise that research has already considered ontological framings of construction (Rooke et al., 2007; Sage et al., 2013; Sage et al., 2014; Harty and Tryggestad, 2015; Sandberg et al., 2018). In terms of energy, the ontological turn has much potential to reveal the political and normative import of “eco” buildings (Marres, 2013). However, a “performative” emphasis on the interplay of enactments amongst the varied professions in construction management has not been fully explored (Mogendorff, 2016), nor has Mol’s specific work yet been applied to energy in construction. This chapter will show how her work can provide a valuable perspective on this sector. It will start with an open mind, by examining how the stakeholders in the hospital project enact their own versions of the targets, which is the subject of the following section.
4.2. How are energy targets enacted?

4.2.1. Enactments in bid and design

The first enactment of the hospital’s energy targets is by government, deriving from the national NHS carbon policy aspirations described in section 3.5.1. The targets were thus not bespoke to the project, but part of the standard form contracts for the sector. If Construction Co. wanted the hospital contract, it had little choice but to accept the targets. As Legal 1 explains, “we have to look at it [the contract] and work out how to make it work” (Int - Legal 1). The carbon element of the targets provoked the most anxiety, as expressed by Facilities 1 and Environment 6 who believe that “our feet are nailed to the floor” around the design conditions needed to comply with it (FN energy experts meeting 2). This means the initial enactment of the energy targets is as an apparently inflexible requirement imposed onto Construction Co., whose first engagement with the targets is therefore reactive.

Construction Co.’s first steps in response are to recast the targets as a risk relative to the opportunity of winning business in the healthcare sector. The risk assessment of the contracts is important to Construction Co., because once the contracts are signed it becomes legally committed to the delivery of the energy targets. As with all large projects in Construction Co., the potential risks and rewards of a bid must be assessed by senior management, and other internal experts. Papers are provided to the Board by the bid team, which note the energy targets as a risk, but a manageable one. During these initial project phases, the legal team are also heavily involved in the review of the contracts, “camped out at Project Co.’s lawyer’s office” with “the whole project team” (Int - Legal 1). In addition to the legal team, a Construction Co. engineer also acted as a technical advisor on the energy targets specifically. In my discussions with this
engineer he is able to quote schedules and clauses off the top of his head quite as well as the legal team Int – Engineer 2b). His remit is to advise on technical feasibility, but this is also enacted as risk:

“as much as...we want to be seen as the most energy efficient, green contractor, I’m really looking at risk.”

(Int - Engineer 2b)

Thus the energy targets in their first guise are risks for Construction Co., formed in contractual terms by in-house lawyers, and in technical terms by engineering, and hence giving rise to practices intended to manage them as such.

Having decided to bid for the contract, the energy targets then become a technical challenge for the wider design team, and the mechanical and electrical (M&E) contractors in particular. For the M&E team, one of the key means of enacting the energy targets is through a dynamic simulation model (DSM). Clearly, neither the hospital nor its energy systems yet exist, so the model enables them to be brought into being through virtual means. The modelling was more “detailed” than usual, and allowed the modeller to provide “background design calculations” that helped the design team evaluate options. He describes how he would “go back and try different things which works and you know they [the design team] probably decide which is the most cost-effective or ...achievable” (Int - Contractor 8). The aim of energy modelling at this stage is intended to be “strategic” and focussed on demonstrating that the client’s expectations can be met. It is only later that specialist designers will be employed to consider “how everything will be delivered” (FN - talking with Engineer 3). The model therefore appears as a facilitator of the bidding process, and the modeller describes himself as an “advisor”: 
“it’s this kind of almost support of the design team …I give them information so they can get on with the design”

(Int - Contractor 8)

Nevertheless, there is a considerable investment of time in the construction of the energy model. The modeller describes the process of how he “builds” with the software: “This is how it looks…So you physically, actually build each room…room by room, using the plan drawings” (Int - Contractor 8). The model building is its own world, with time represented in seasonal and daily profiles, and its population by generic occupant “types”. The latter are constituted in units of energy, so, for instance, a patient is a “stationary” occupant with a contribution to internal heat gains in Watts. Alongside the detailed DSM exercise, the modeller must also create a separate model building that demonstrates compliance with the subset of energy regulated by Part L (Doc - bid team answer plan). This model is in turn adapted to the requirements of BREEAM certification. Thus, modelled enactments of the energy targets start to overlap with other modelled versions of the building’s energy use.

Despite its centrality to the assessment of whether the energy targets can be achieved, the modelling is created and controlled only by the modeller. The compliance modelling exercises are more familiar to the rest of the team, and governed by rules or processes. Whilst the calculations for Part L “have to be done a certain way”, “there is no specific way” to create the detailed DSM model, and as a result, the energy modeller has created a personal process of spreadsheets, data, and reference points from which he assembles the building energy use (Int- Contractor 8). His M&E colleagues are aware of the ingredients that go into this, but “do not necessarily know how to use” the software (Int - Contractor 8). Beyond the M&E team, Construction Co.
has access only to the models’ headline results, and cannot run the software themselves (FN - meeting with engineering team). As one member of the construction team admits: “I wouldn’t know if the model is right, wrong or indifferent” (FN - meeting with construction). So whilst the energy modelling is critical in envisaging the hospital’s future energy use, the work done may be impenetrable to non-experts, in the same way that specialists in Mol’s hospital do not necessarily encounter each other’s work (2002:112).

For others in the M&E team, the energy targets are a puzzle to be solved. Contractor 6, one of the engineers, tells me the design for the hospital was “really pushing it”, due to the particular combination of the energy targets with Part L, BREEAM, local planning, and architectural issues such as building orientation and internal conditions. His approach was to start with what the energy targets were not: “what we always do, what we always work away from is a conventional system”. Onto this he introduces low carbon technologies to establish “what would happen” and to “look at loads of different scenarios” (Int - Contractor 6). The scenarios are taken to design team meetings with Construction Co. and the architects for decision-making on the best energy solution. Once the solution is agreed, Contractor 6 is able to complete his main task, which he describes as “writing the engineering aspects” of the design proposals. Once all the proposals and specifications are written, the design energy model completed, and suppliers selected, “that’s us done” (Int - Contractor 6). So whilst the energy model will be updated eventually at the end of construction, the M&E consultants cease to be a significant presence during construction. Their legacy of the targets is therefore an overview of expected energy use, and a series of technical specifications that together should deliver it. Their work on the energy targets as a puzzle is therefore complete after detailed design, and is passed on to technology suppliers and installers.
The design team is of course made up of other specialists besides M&E. However, for these, the energy targets are often enacted as peripheral concerns. The architects’ emphasis, for instance, is on the physical form of the building, for which energy can be a constraint, rather than a central consideration. Their design practices around energy encompass BREEAM. They describe the importance of “knowledge management” around BREEAM, particularly in the earlier design phases, and monitoring design changes that could affect the score. However, the energy targets are not something they mention spontaneously, and indeed they are clear that the details of energy demand are part of the M&E contractors’ duties (Int - Contractors 2 and 4). For the architects therefore, energy targets are a marginal concern.

The Building Information Modelling (BIM) team are working on “a digital asset” to hand over to the client (Int - BIM 2). Using a Construction Operations Building Information Exchange (COBie), future users will be able to see the energy systems in a room, and move through to the corresponding design, maintenance, and performance data behind it. However, no software link exists between the two virtual worlds of BIM/COBie and the energy model, to the “great frustration” of BIM 2 (Int - BIM 2). In design, the BIM team also built a 3D model to help the client review the proposals (Int - Design 3). However, as one of the construction team managers observes, this virtual object is not the same as the “touch and feel” of a building (FN - site inspection tour). The 3D design cannot convey sensations such as thermal comfort or glare, and thus these energy-related aspects cannot be reviewed by the future occupiers. BIM therefore currently fails to accommodate energy, and prevents this team contributing their enactment of the targets.
4.2.2. Enactments in construction, commissioning, and operation

Once contracts are signed, detailed design and construction begins: the phase that determines “how everything will be delivered” that Engineer 3 anticipated above. Building a large, complex building like the hospital requires a range of skills, and the detailed work is broken down and contracted out to many different specialist companies (Int - Design 3). The construction work is divided by floor level, by building area (such as ceilings, facade, or fit out), and into work “packages” corresponding to contracts for various building elements (such as lighting, cladding or joinery) (Doc - Package Responsibilities). Consequently, the energy targets cease to be enacted as versions of the whole building, and start to be enacted in smaller pieces, as part of the many different physical elements that will make up the hospital, and influence its energy use. The energy targets, as a result, fragment.

This is best illustrated by an example. Lighting is one important source of energy demand in the hospital, and making it efficient is a part of the strategy to meet the energy targets. It is installed across all the floors of the hospital. However, through a work package, it is designed and supplied by one company, but installed and commissioned by another, and maintained by a third (Int - Contractor 9). The lighting will also be controlled centrally by the Building Management System (BMS), on which another, separate, contractor is working. Around this, the electrical supply and cabling for the lighting is also being worked on by separate teams (FN - commissioning). Moreover, this only takes into account the fixed lighting, regulated under Building Regulations, excluding other, portable lighting sources. Thus not only is it hard to coordinate the singular energy targets with energy in lighting, lighting itself is also multiple. The phenomenon can be perceived more widely in the design drawings for the hospital. As Figure 4.2 and Figure 4.3 show, drawings may show radically different
versions of the hospital’s energy systems, depending on the specialism of the individual producing it. Whilst the division of work is a practical necessity, for the energy targets it precipitates a multiplication of enactments. This stretches the partial connections between the many professions and the different energy-using components for which they are responsible, and hence affects the extent to which the overall building’s energy performance continues to “hang together”.

Figure 4.2 Floor 1 as small power circuits (left), or alternatively, as mechanical ventilation (right)

Figure 4.3 The whole building constructed as electrical low voltage (left), or alternatively, as the elements of a Building Management System (right)
The fragmentation of versions of energy targets is also evident in the individual work specifications. Contractors who were involved in construction were mostly aware that the hospital had overall energy targets, but were not always clear on what the details or values of these might be. Instead for them, the energy targets were part of their concern to produce their specialised part of the system. Returning to the example of lighting, Contractor 9 tells me that “we’ve offered a solution which is in line with the project requirements” and which will “achieve the Watts, and the luminaire lumens per Watt”, and the required percentage of LEDs (Int - Contractor 9). Hence for individual contractors, the energy targets are enacted in the units of their particular technology. The interaction of their part with the rest of the system is something that contractors cannot accept liability for, as they cannot control it:

“Contractor 7: Well we guarantee that the [technologies] have a certain COP. We guarantee that the ratio of input energy to output energy is on a certain level. That’s the overall efficiency...And we guarantee that the temperatures in the building will be as displayed. Ok? But we cannot guarantee for sub-systems ok?

CW: And what counts as a sub-system?

Contractor 7: Anything. Any part you know where other people also work.”

(Int- Contractor 7)

The transitions between actors’ energy responsibilities may be abrupt, occurring even part of the way down a piece of wiring:

“The computer belongs to the NHS, the lead going to it to that point there [points to socket], that belongs to me...So they know how to use the computer; I know how to get power to it.”

(Int - Facilities 2)
“I mean the way it’s designed, it’s pretty simple actually. Everything to this point – to this line actually - is provided by us. Everything here is provided by [the BMS contractor].”

(Int- Contractor 7)

This leaves actors in a paradoxical position of having to provide technologies that work both independently and as part of a system. As Construction 1 puts it succinctly: “So there’s all these other elements that have to join up” (Int - Contractor 1). This paradox is manifested in many mundane places, such as technical specifications:

“The Boiler system shall include all control, monitoring and alarm signals to provide a fully functional system in its own right, but [be] fully integrated into the main building management system and the other heating sources.” [my italics]

(Doc - BMS specification).

Perhaps as a consequence of this, during my interaction with the hospital’s construction phase, I often heard single solutions to the energy targets being proposed. These are claimed to enable the team to “smash the target” through a technological silver bullet or two (FN - talking to Environment 6). So for instance, the renewable energy system, lighting, and fans are expected to be significantly more efficient than the original suppositions made at the time of signing the contractual energy targets, leading the team to be confident that they can undershoot the targets (FN - meeting between construction and facilities management). The hospital in construction does therefore appear to be the sum of many parts, and indeed must necessarily be for the construction work to be completed. However, in terms of energy, the connections between individual energy-using parts and the whole are not always clear.

In being divided into multiple tasks, the enactments of the energy targets reflect the overall construction process. As Construction 3 notes, “we don’t have meetings about
the whole building” (FN - meeting with construction). Commissioning and testing practices are also focused around individual systems or parts, such as the Independent Tester’s “witnessing”, or the pressure tests, which are both done on a sample of building elements (Int - Contractor 3, Doc - pressure testing schedule). Likewise, Facilities 2’s priorities for preparing for handover are focused around the basics of ensuring that equipment individually “works”, and that his team “know what it is and where it is”. Whilst he understands that the energy targets are “very important” and that he will be eventually responsible for reporting on the overall energy use, this is not something that he was actively preparing for during construction, as he believed that plans for the metering systems would be taking care of it (Int - Facilities 2). Hence the energy targets’ multiplicity is entangled in that of the individual tasks of construction.

The plans for metering and monitoring are a final enactment of energy targets during construction. The construction team tells me that they have invested more than usual in measuring and monitoring systems (FN - meeting between construction and facilities management). However, less emphasis appears to be placed on handover processes to the building’s operators and users, whose activities will ultimately affect the numbers visible through meters or software. Contractor 7 suggests that more should be done, as “it’s not a couple of days where you show them the buttons. It’s a lot more” (Int - Contractor 7). Furthermore, although the project is following some of the principles of Soft Landings, none of my participants could mention anything they have actually changed as a result of it. The enactment of energy targets in operation therefore appears to be more focused around practices that plan technology solutions, rather than training or communications, although this could be a factor of the time that I engaged with the hospital.
4.2.3. Reflections on the enactment of energy targets

The findings above indicate that from the project’s inception energy targets are differentially enacted. This is illustrated in Figure 4.4 overleaf, showing how enactments of the energy targets multiply through the hospital’s development. Energy targets may be central or peripheral to professional practices. Sometimes the way targets are enacted may have little to do with energy, such as when enacted as a legal risk. At other times, enactments are apparently fully focussed on energy, such as in plans for the hospital’s metering. In some cases, the targets’ enactments overlap, or become confused with, other related practices, such as those relating to energy performance in BREEAM and Part L. Given this multiplicity, comparing the original contractual targets of predicted energy use to actual figures eventually obtained from the BMS, as the contract requires, is likely to be problematic. Not only are the two not “made” by the same means, they are also the start and end points of a series of many other enactments of energy targets.

Not only are enactments of energy targets different in form, they are also different in scale. As such, energy targets are sometimes enacted in relation to the whole hospital’s energy performance, as in the energy model for instance. At other times they may be enacted in small components of the overall energy use of the hospital, such as in lighting’s contribution to energy efficiency. Their fragmentation into smaller pieces is most marked during the construction phase, with the packaging of works, the focus on particular low carbon technology solutions, and the cessation of energy modelling. Consequently, the partial connections between differing enactments of energy use become more stretched during this phase, and it becomes difficult for Construction Co. to keep track of overall energy performance. It is therefore possible that the different versions of energy targets do not, unlike Mol’s body multiple, ultimately “hang together”,

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and reflect confusion as well as multiplicity. With this in mind, coordination of multiple enactments is clearly important, and I will now turn to consider to what extent it may occur.

![Figure 4.4 Multiple enactments of energy targets](image)

**4.3. Two worlds collide: how are practices coordinated?**

Mol suggests several possible means by which diverging realities may be coordinated, including: establishing a hierarchy; identifying discrepancies; agreed means of calibrating between measurements; and the use of prior experience. These forms of coordination iron out differences, enabling agreement on a single version, either by selecting a winning enactment, or by merging attributes from several. In Mol’s hospital
this might be achieved by the comparison of different test results, or reaching an agreement on a patient’s treatment. This section will explore what means the construction team use to coordinate versions of the energy targets, considering when efforts are made, by which actors, and with what aims.

4.3.1. Coordination during bid and design

There are points during the hospital’s construction process at which coordination of practices appears more pronounced than others. The early design and bid is one of these. Members of the design team recall frequent workshops, meetings, and discussions that included key actors such as architects and engineers, and specialist advisors. Information appears to have passed regularly back and forth between the architects and the engineering designers to enable their energy calculations, and negotiate any differences. For example, architectural plans for glazing ran into energy model predictions of overheating. This conflict was won by the architects, as the software defaults were found to be too “generic” and “conservative” (Ints - Contractors 2, 4 and 6). The specialist engineer on the bid team also aims to provide what he calls a “critique”, and rein in the bid team from offering anything too “bullish” that Construction Co. cannot technically deliver (Int - Engineer 2b, Doc - engineering comments on bid). Bidding for the hospital also required the team to evaluate their own proposals in relation to competitors, and the “tactical” possibility of “offering a lower figure” in order to win (Doc - engineering comments on bid). Therefore it does appear that coordination has been stimulated around the targets’ enactments of eventual energy use and the means to achieve it during bid and design.

However, a driver for coordination of energy matters is sometimes compliance with regulation and standards, rather than the energy targets. Contractor 6 tells me that he went out in person to negotiate with Building Control to “sit down and explain what we’d
done” which resolved a difference in the Part L calculations (Int- Contractor 6). Engineer 3 also tells a story about how they resolved another Part L issue by working with suppliers:

“[The construction team] came to us and said we’ve got a problem with Part L, and one of the manufacturers is suggesting this, what do you think? So we had a look at it, we went and talked to the fan and motor manufacturer, looked at the numbers and went, yeah all right. And they've tested a couple at the factory, and really it is delivering what it says.”

(Int - Engineer 3)

Hence practices exist for coordinating energy in the context of regulatory compliance. BREEAM similarly has defined working processes for identifying, tracking, and demonstrating compliance with its energy credits (Ints - Support 3, Contractor 1). These are able to cope with its “fluidity”:

“BREEAM is kind of a fluid process throughout. So people will say ‘what’s the score?’ But that changes - every month basically.”

(Int - Environment 4)

By contrast, coordination processes are lacking for energy targets. The targets, for example, do not appear in a risk register during the construction period (Int - Environment 1), and are not reported against as KPIs (Doc - environment targets dashboard).

Comparison to benchmarks and standards could is another means to coordinate design energy projections:

“We do a lot of benchmarking. …You know we’ll benchmark our W/m² heating and cooling against known benchmarks, CIBSE and things like that. And we will also benchmark against previous projects…generally benchmarking’s probably the
thing we would to make sure that we’ve got you know figures that…look sensible effectively.”

(Int - Contractor 6)

Contractor 8 says he also uses CIBSE benchmarks and guides as inputs to the energy model. However, benchmarks may be hard to locate. So whilst values for equipment can be quite easily accessed, Contractor 8 finds it much harder to find useful benchmarks for occupiers. Even if benchmarks are available, they are tricky things to use as comparison points. Different groups will, for example, use their own sources. For instance, the architects and M&E contractors, whose influence on design is significant, use two very different processes to enact energy efficiency solutions. One, for instance, uses a decision hierarchy based on Greater London Authority criteria, the other their own green design prioritisation (Int - Contractor 6, Doc - architects’ design criteria). Whilst professional or organisational differences are to be expected, the point is that once again this leads to multiple enactments.

Previous experience from other projects is a frequent source of comparison (Doc - engineering comments on bid, Ints - Contractor 6, Engineer 2b). However, actors can be sceptical about it:

“We do use historic data. But …it only tells you what you know about the past. It never tells you what you could know about the future.”

(Int - Engineer 3)

Additionally, making sure the comparison is a sensible one can be difficult. Engineer 2 tells me how another unit in Construction Co. “said our hospitals are twice as good as yours”. Yet on further examination, difficulties emerged for the two teams in coordination:
“If you knew your energy in terms of volume, you get one answer, if you model it in terms of patient through-put, you get another answer. If you measure it in terms of beds you get another answer.”

(Int - Engineer 2a)

He goes on to point out that there is also a huge variability in energy-using activities in a hospital, which could include “sterilisation, pharmacy, pathology, catering, laundry, absolutely everything”. Overall, the mix of these activities and differing levels to which NHS Trusts outsource them will render a “like-for-like comparison” problematic (Int - Engineer 2a). This makes an effective “calibration” of the numbers difficult for the team.

Coordination can also be shaped by commercial aims. For instance, there could be pressure on the energy modeller to produce a number that aligns with the client’s expectations. This might have caused problems in the school project that I studied early in the PhD (FN - call with Engineer 2), and can occur on other projects (Int - Engineer 1). Construction Co. is also aware that the choice of software brand can affect the results, a phenomenon also observed by Raslan and Davies (2009). Consequently, “if it’s a hard target” they may be more inclined to use a particular brand (FN - energy experts meeting 2), which helps them create an energy performance that meets targets more comfortably at design, and therefore reduces the capital investment required in energy efficiency. Hence coordination efforts can be harnessed to favour commercially desirable enactments.

Another way of aligning the design to the client’s energy target expectations is through controlling the volume of the building, which is critical as the contractual targets are expressed in energy and carbon per 100m³ of building volume (Int - Project Co. 1 and 2). Actors believe that the way they choose to calculate it may have a significant effect on the result:
“So how to measure the volume? ...It's very precise. And also it's mentioned in EnCO2de as well. What you do is you measure the gross internal area, you deduct risers and lift shafts. You then take off 6% for partitioned area. And then you multiply that by the finished floor level to the soffit. Now... strictly speaking there are some that say you measure to the other side of the suspended ceiling, but we interpreted EnCO2de to say the soffit. Because obviously we are looking for a bigger volume. Because obviously it's a ratio you are chasing.”

(Int - Engineer 2b)

In addition to calculation issues, the volume is also affected by design changes, as much as the energy use is. Environment 6, for instance, notes that there seem to be various versions of the floor area circulating, making the targets harder to pin down (FN - talking to Environment 6m). Therefore it does appear that the various professionals involved in design are meeting and talking about energy targets, and coordinating their different enactments. However, the purpose behind the coordination varies, and may not always be aligned to achieving the most energy efficient building in operation.

4.3.2. Coordination after occupation

The other period in which actors “spend a bit of time” on coordination is during the initial stages of operation, “trying to spot where it's different from what they said” (Int - Engineer 3). This coordination is unusual, as on most projects without energy targets, performance against design is not assessed. As the hospital is not yet operational, it is worth briefly considering the completed school project that I studied to shed light on how coordination might take place after occupation. In the school, coordination takes the form of comparing BMS data to the energy model. This seems to be the established process, as it does mirror plans for the hospital, and Construction Co.'s internal energy audit procedure for other projects with targets (Int - Engineer 2a, FN - conference call with Engineer 1).
Coordination of the energy targets in operation was not simple in the school project. For instance, the energy model appeared to omit some late design adjustments, the individual meters did not collectively agree to the BMS figures, and different figures for energy use were provided by different departments of Construction Co. (Doc - School energy consumption interim review, Int - Commercial 1). One challenge was therefore to agree on a definitive set of energy data (Doc - commercial report on school performance). Once the comparison points were established, Construction Co.’s investigating team moved to explain the differences between the model (held to represent what energy the building should use) and the BMS (held to represent what energy the building did use). Coordination took the form of attempting to uncover faults in these comparison points, deriving either from the practices of the occupiers who were in the wrong in their use of energy, or whether it was the work of the original modeller who was at fault. This question had to be asked again and again for each divergence from the model, and a solution found in negotiation between client and Construction Co., as to what the school’s ‘real’ energy use should be.

The school also displays another interesting aspect of the negotiation of reality, as even if actors can obtain metered data, making meaning out of it is tricky. Engineer 3 highlights that it can be “contentious”, describing a previous disagreement with a client “about whether we were meeting the target or not.” Eventually, he tells me, he produced measurements that indicated it had “passed” (Int - Engineer 3). Engineer 2, however, tells the same story, but concludes that the building “failed” its target. The difference in results seems to have arisen over the contested allocation of energy data between retained and new estate, and how the effects of poor energy “housekeeping” by users were calculated. Coordinating a result that determines whether a building is
deemed efficient or not is therefore an active interpretation of the data, based on uncertain realities.

This is likely to cause issues for the hospital as well. As Design 2 admits:

“We do meter every [hospital] department I think. So they can look to see where the energy has been used. And then do some sort of spot analysis….um but that is one of the grey areas, where how do you know what’s the root cause?”

(Int - Design 2).

The hospital’s metering may be extensive, but reporting the data from it involves “translation”:

“So it’s not just a matter of all the sub-meters adding up to the main meter if that makes sense? …Some things have to be… some things are actually a negative usage for er usage. It’s, it’s…when we get, when we get all the meters, then we have to sit down with construction and say what now exactly are we measuring and how that is going to translate itself into the reports that we have to give to the client.”

(Int - Facilities 3).

In the case of the school, performance is resolved through physical changes to the building’s controls, and through adjustments to energy use that Construction Co. is either not contractually responsible for, or can treat as an allowable variation to the original target. The school’s energy use after the adjustments have been made is significantly closer to the original target. Indeed, when compared with other schools in the area, it now appears to be “a really optimised building” which is “performing a lot better than the rest of them” (Int – Commercial 1). Thus the reality of the school’s energy performance moves from aspirational, to problematic, and then to optimal, and
this is achieved partially by physical changes made on site, and partially by accounting changes to the numbers.

This is a principle that may be derived from standard projects without energy targets, as illustrated by a member of the environment team, as he tells me an anecdote about an office building he was involved in:

“We had this issue that the specific fan power wasn’t what it was in design, and therefore it’s a problem. So we had to obviously either physically change something on site or change something within the model to make it spit out the right number.”

(Int - Environment 4)

In the end, he explains that his team incorporated some different assumptions about “real world actual performance” into the model which made the answer align with Building Regulations, but which was not “unrealistic”. With the presence of an operational energy target this process should be different. Yet in the hospital, where operation is still in the future, incentives to flex its reality already exist, and will be discussed in section 4.5.2.

In summary, the findings suggest that coordination of differing enactments of energy targets does indeed occur, but is concentrated on curating data at the two points of design and early operation that the contract requires. This neglects coordination during construction and longer-term operation (see Figure 4.5 overleaf). It also suggests that coordination of energy performance is driven by compliance, represented by the contract for energy targets, but also by the different, but overlapping, requirements of Part L and BREEAM. Delving into how divergences between versions of energy performance are coordinated also reveals ways in which Construction Co. struggles to
interpret data, and how it mitigates these struggles through offsetting commercial practices, including the negotiation of liability for discrepancies between versions of the target energy use.

"Coordination" (reconciliation) of energy targets takes place at two contractual points, rather than consistently across the project lifecycle.

Figure 4.5 Coordination of energy targets is neither consistent nor continuous

4.4. Parallel practices: distributed enactments of energy targets

The previous section has already outlined variable coordination of the enactments of energy targets. However, as in Mol’s hospital, there are areas where professional practices do not meet at all, and continue to run in parallel, meaning that incompatibilities between different enactments are unobserved or unaddressed, and hence remain “distributed” (unaligned). For Mol, this might relate to diverging research practices carried out in different geographical areas, or the differing enactments of daily medical practice and clinical trials. In the hospital’s construction, distribution occurs along two principal fault lines: firstly, profession; and secondly, time:
“And it is a fact that you get a whole team of people that win the job and another team that build it. And it has caused some grief in the past...[and] Facilities run it. There is a disconnect there. I can't gloss over that. It's a fact.”

(Int - Engineer 2b)

This section will explore these two sorts of distribution.

4.4.1. Distributions between professions

Mol describes how “architectural divides” (2002:112) in professional boundaries often correlate with physical separations, preventing different specialists from encountering each other, and hence aligning practices. In the case of the hospital, I notice on site that contractors and Construction Co. are physically separated from each other, one floor above each other, creating parallel on site worlds of work spaces, meeting rooms, and communal areas. One contractor, for instance, tells me that “he has never been upstairs” (FN - commissioning). Off site, the contracted M&E designers and architects are both based in their own offices, and say that they rarely go out to site (Ints - Contractors 2, 4, 6 and 8). Indeed, one of architects mentions as I close the interview that he is excited to go and visit the hospital soon, as he has yet to see the physical building that he designed.

There are also separations between what Mol would describe as the different professional “populations” and their activities (2002:111). For instance, she observes that surgeons do not examine blood, and haematologists do not see patients. In this case study, participants often express a puzzlement as to what it is that other actors do (FN - environment team meeting 3, Ints – Contractors 3 and 8, Design 2), or define themselves as having different “mind-sets” (Int – Contractor 6) or skills (Int – Engineer 2b). Project Co. 1 says that “you will find our views probably slightly different to everyone else you speak to because we don’t work in construction” (Int - Project Co. 1
and 2), whereas Contractor 3, a designer, describes his operational colleagues as “a kind of different breed” and suggests “no one knows what they do” (Int - Contractor 3). Whilst there may be sensible commercial reasons for these separations, they raise the potential for incompatibilities between energy enactments to go unnoticed.

As Mol found in her hospital, distributions can also be manifested in specialised professional jargon. Energy performance appears particularly vulnerable to this. When I meet Engineer 3, he is confident that it is easy to talk to anyone about technical issues, but peppers his conversation with acronyms and technological specifications that really only another engineer would understand (FN - reflections on meeting with Engineer 3). This can cause problems for non-engineers in understanding what is being done to enhance energy performance. For instance, the efficient operation of fans is a key strategy towards meeting the hospital’s energy targets. However, to the non-engineer, the logic is unclear:

He wants to find out how they can capture learnings. However at the moment he is having trouble understanding the emails from the contractor. Someone sent him
an email saying ‘Dear X, it is very simple, it is just about the affinity equation’! He would like them to express it in ‘English’.

(FN - talking to Environment 6)

This means that actors have to place trust in the advice that they are being given:

“I mean I’m not such an expert on the actual technical side of this you know. I very much feed into the contractual provisions. I’m aware of what they say and things, but equally sometimes I have to, you know if someone gives me a number to put into the provision, you know, I would do it, rather than questioning why it’s X, Y, Z.”

(Int - Legal 2)

Mol noted the importance of having agreed forms of “calibration” between different units of measurement. Whilst the targets are expressed in GJ and tCO$_2$ per 100m$^3$ in the contracts, the many design and technology specifications intended to deliver them are expressed in varied units: U-values; coefficients of performance; lumens/Watt; °C; European Standard ratings; average unit costs; turn-down percentages; and many more. This can cause confusion. For example, one senior member of staff spends our entire conversation referring to “gigabytes” rather than “giga joules”. Unless actors are familiar with the units being used, energy performance criteria, such as those in proposal documents, can be hard to assess:

“People go oh it's got a 30,000 hour life! And you think, well go and work it out. If you run it 24 hours a day, it's not very long.”

(Int - Engineer 3)

Moreover, unfamiliar technologies can be intimidating even to the technically-minded. Facilities 1, an engineer himself, is unnerved by the new renewable system, and unsure whether he can trust what he is being told about its performance by the construction team (FN - meeting between construction and facilities management).

One environment manager also admits:
“even being an environmental person, who’s worked on the environment for about eight years, tonnes of carbon doesn’t really mean very much to me.”

(Int - Environment 9)

Given this, specialists may consciously limit the more technical details of energy when communicating with non-specialists. So when I ask Contractor 7 to explain a technological issue to me, he is not sure he can: “that’s a technical detail actually. Hard to explain if you’re not an engineer” (Int - Contractor 7). However, other members of Construction Co. might also be treated in this way. Construction 3 notes that the facilities team might be given the “simple” version of the building operation manual (FN - meeting with construction). Alternatively, discussions may be tailored in the expectation that the non-specialist is uninterested in technical details:

“So you know they [Construction Co.] wouldn’t necessarily have been interested in all the back-house stuff that we do. Because to them I suppose it’s not…erm …what they need to know at the time. But they would certainly want to know what products we’re using…They take a real interest in that because obviously that’s part of the showpiece, what they have to offer back to the client themselves.”

(Int - Contractor 9).

Contractor 8 feels the same way:

“the calculations I do, they’re almost like a background design calculation if you like. … It’s not like a thing architects would need.”

(Int - Contractor 8).

As a result, he explains he has not included any information on the central document management system about the energy modelling. For Construction Co., outsourcing detail is justified by efficiency:

“We try not to go too far into the detail…I mean providing we’re happy with how they’re modelling it, and who’s modelling it, and what the sort of outputs look like,
you have to say, you can't get in there...If we have to check everything they do, we shouldn't be employing them."

(Int - Engineer 3)

Clearly, it would not feasible to coordinate all possible enactments of energy in the hospital project. However, because energy targets are unfamiliar to the team, these professional boundaries raise the risk either that important differences in enactments of the targets remain distributed because they are not noticed, or because the parties do not understand each other clearly. Moreover, even if they are brought together, there are no established practices of alignment for energy, or what Mol would call “modes of establishing coherence” (2002:63). The company has put considerable resource into new systems, like BIM, that can pick up physical and practical incompatibilities, and hence encourage greater coordination of these aspects. However, these systems are, as mentioned earlier, not linked into energy data, such as the energy model. Finally, systems for professional interaction are adequate to get the physical project to Practical Completion, but less well suited to coordinating practices to control energy in operation.

4.4.2. Distributions along temporal boundaries

Distributions of energy target enactments are also caused by time. A building proceeds in stages, and evolves with each one, with implications for the energy targets. Earlier, I described how attempts are made to coordinate energy targets in the design stage, but then subsequently fall away. This reduction in coordination is also manifested in the hospital’s design variations. Whilst the energy impact of changing the function of a hospital department, or the renewable energy supply, might be obvious enough to be noted by actors (Doc - energy flowchart, FN - talking with Engineer 3), there are numerous smaller changes for which the energy impact may go unremarked. A key
problem is that whilst variations have a standard recording process to track their nature and cost, this process does not record energy implications (Doc - Project Co. contract management plan). Engineer 1 suggests that a “continuous updating” of the energy model for design variations can be a key success factor for projects with energy targets (Doc - webinar slides). However, it is not a standard practice to re-run the model during construction:

“Project Co. 1: You can’t re-run a building model every time you do a variation…. It’s expensive. Every time you run the model it takes sort of 3, 4 days for the model to run through and then only just gives you an answer. You do something else, you run it again.”

(Int - Project Co. 1 and 2)

Staff in Construction Co.’s head office are keen for the hospital’s model to be regularly updated (FN - energy experts meeting 3), but express concern that the site team do not see that it merits the cost (FN - talking with Environment 6 and FN - talking with Engineer 3). Therefore, design variations may cause multiple distributions.

However, there may be other reasons besides cost for avoiding coordination. The expectation that variations will occur can mean that Construction Co.’s responsibilities for energy are harder to enforce:

“Project Co. 1: So you got – on these big projects – you got xyz target at the start of the design process, you go through, once you’ve signed all the Financial Close documentation on design, something will change...And therefore all bets are off. Because they will change something that does actually affect the energy target. And therefore the energy target that was agreed is no longer actually the same...It doesn’t mean anything because there’s been design variations throughout the process.”

(Int - Project Co. 1 and 2)
Focussing on getting each design change signed off by the client helps de-risk the process for Construction Co. in the event that variations are found to increase energy use (Doc - Variation Enquiry form, Int - Environment 1). This route is perhaps easier than the alternative of coordination by the revision of contractual terms, which can be a laborious and expensive undertaking (Int - Legal 2).

It is not just design changes that impact on the energy targets, however, but also “value engineering”, in which Construction Co.’s procurement staff may substitute an energy efficient product for a cheaper, but less efficient, alternative. This is very common on standard projects without energy targets (Int - Engineering and Environment Office).

The result, as described by Environment 6, can be “death by a thousand cuts” for energy efficiency (FN - energy experts meeting 2). Metering, many actors agree, is a frequent casualty of “VE”. Project 1, who deals with a number of projects with energy targets, appears sceptical about metering for the hospital:

“Project Co. 1: Probably got VE’d out. As usual...And then we'll go down the road two years, and we'll think 'Oh God we need that information.'”

(Int - Project Co. 1 and 2)

It was hard for me to assess the impact of any “VE” on the hospital given the timing of my research. However, the school's energy performance was undermined by late value engineering adjustments (FNs - meeting with engineering team, call with Engineer 2), the energy impact of which was “missed” (Doc - email update on the school, Int - Commercial 1). Failures in coordination such as this may occur because actors are unaware that something has an energy impact (Int - Environment 4). Therefore coordination is reliant on them being “mindful” (FN - talking with Engineer 3). Whilst design changes are part and parcel of construction, they do pose significant difficulties for coordinating versions of energy use, if there are not the means to account for the
impact of variations and value engineering that has occurred. This compounds the
tendency to distribution arising from the professional divisions that have also been
described.

4.5. Reflections on the case: reasons behind coordination lapses

The previous sections have discussed how Mol’s concepts of enactment, coordination,
and distribution reveal some lapses in the alignment of different versions of the energy
targets. These often arise from established divisions between professions and project
phases in construction work, which do not sit well with the need to coordinate
enactments of the energy performance of the building as a whole. This section will step
back from Mol’s work, to consider why these divisions are not overcome by the new
incentive of the energy targets. It suggests two key reasons why coordination is
incomplete: firstly, who is responsible for energy targets, as this affects the extent to
which versions can be coordinated and ultimately “hang together”; and secondly,
whether contractual terms or departmental separations might actually mean that the
co-existence of multiple and distributed realities of the energy targets is convenient for
some members of the construction team.

4.5.1. Who is responsible for coordinating the energy targets?

I often found that participants were happy to tell me who was responsible for energy,
but less likely to admit that it might be them. Construction Co. staff, for instance,
pointed to the design contractors, and vice versa (Ints - Engineer 3, Design 1,
Contractors 2, 4, 6). Some actors believe that the environment department might be
responsible for energy targets (Int - Facilities 2, Int - Legal 1). Environment, however,
feel responsible only for the construction period, during which their focus is BREEAM,
rather than the energy targets (FN - on site field notes 1, Int - Environment 1). As Environment 4 admits:

“The energy has always been something in my mind that is done by ...someone else! [laughs] I don't know who that person is.”

(Int - Environment 4).

I am also referred to the engineering team, who may be better placed to understand the “technical” issues (Int - Legal 2). The engineering team, however, view themselves as advisors, offering services such as “reviews, technical advice, research and development” (Doc - intranet 2, FN - meeting with engineering team).

The stance of the engineering team reflects that of other actors, who describe themselves as mediators, overseers, or conduits, rather than a backstop for responsibility. Contractor 2, for example, describes himself as an “interface” (Int - Contractors 2 and 4). Design 2 describes his work as sitting in the middle of “a massive web of information flow” (Int - Design 2). The theme is picked up by others:

Project Co. 2: “Yeah we tend to be er mediator, moderator, whatever you like to call it.”

(Int - Project Co. 1 and 2)

“The most amount of my time actually is coordinating and organising on other people's behalf. Getting people to remember to do that, have you done this, where’s that report. Going to the meetings and actually talking, sitting, listening. And directing consultants mainly.”

(Int - Design 3)

Describing your work as mediating and managing may be part of the overall way in which Construction Co. has formulated its organisational remit:
“Remember we’re a systems integrator. We don’t build...we don’t have lots of people going round and you know building stuff. We manage subcontractors to do that for us.”

(Int - BIM 2)

This rationale can be discerned in daily work on site at the hospital, as explained by Construction 1, who whilst he happily accepts responsibility for his “package”, is also clear about his role:

“Well mainly it’s about driving the contractors isn’t it? To finish all the pipework and everything...It’s checking their work’s compliant, and meets the design.”

(Int - Construction 1).

Design 2 is in agreement, as he sees his work as being “a bit like a conductor of an orchestra. You know I don’t play any instruments, I just kind of conduct people” (Int - Design 2). Thus whilst mediation in terms of passing on information and keeping the build on track is valuable, it does not encompass an overall responsibility for coordinating the hospital’s ultimate energy use, nor for the underlying energy detail.

It is possible to track down individuals or departments who do have clearer responsibilities for energy targets, but these are often limited by time or other means. A senior member of the construction site team does identify himself as the source of “90%” of the on site knowledge about energy targets. However, this knowledge is not in the detail, as the philosophy is to follow the consultants’ brief: “it’s quite simple. The design that we procure against delivers the targets” (FN - meeting with construction). The legal liability for the energy targets actually lies with Project Co., but Project Co. 1 believes that he energy targets are not yet relevant to him: “they’re in our monthly reporting but at the moment it’s ‘not reportable/not yet operational’...Until it goes into the asset management phase” (Int - Project Co. 1 and 2). Facilities 3 represents his
department’s interests during construction, but will no longer be involved by the time the hospital is operational (Int - Facilities 3). This means that, once again, there is little incentive for actors to think about energy targets beyond the individual stage of work in which they are involved.

Figure 4.7 shows how the actors that I met defined their areas of responsibility for energy targets. From this it is clear that no individual or department holds responsibility for the targets. Engineering are the only group to engage with targets throughout the building lifecycle through the advice they give, but are not accountable. This analysis of responsibility reflects other research that highlights a lack of “overarching control” over energy performance in construction (Bell et al., 2010:68). Here, it indicates that there is no responsibility for drawing together the multiple enactments of the targets, which remain distributed into different professional areas or phases.
It may be that the energy targets are too new, or too exceptional, to Construction Co. to have clearly-defined practices for managing energy targets. After all, on standard projects Construction Co. would simply “wash its hands” of operational performance (FN - environment team meeting 3). As another member of the environment team explains:

“I mean the way the whole building process is set up is that the main contractor builds it, the main contractor leaves – basically. And there is no follow up about...you know, it’s the whole reason why we have the building performance gap. That buildings are designed and constructed and then operated by someone else. And the two numbers don’t get compared. You know it’s not anyone’s responsibility to do that.”

(Int - Environment 4)

Staff, as already noted, are familiar with the requirements of building regulations, referring to outputs such as the Part L “BRUKL” reports, but are less sure what it is they should review for whole building energy modelling (FN - meeting with engineering team). As Engineer 1 comments, “there are no standards – it’s not like you can go the ISO standard” (FN - conference call on energy targets). Yet much of construction’s day-to-day work seems to rely on following processes, or what Contractor 3 calls “painting by numbers” (Int - Contractor 3). Hence in the absence of developed practices, actors can be left without a clear understanding of what to do, who is responsible, and how overall control of the energy targets is to be obtained.

4.5.2. Convenient distributions?

Whilst there may be a lack of familiar practices relating to energy targets, there are also incentives working against them becoming established. Environment 6 likens Construction Co.’s internal departments to separate “ships”, who, being assessed as profit centres, may be disinclined to work cooperatively (FN - meeting with engineering
team). Engineer 2, for instance, describes how his tasks are bound by his departmental interests: “The JV [joint venture] were down to pick up this penalty, and I work for the JV, so my interest was to just to monitor it for two years, prove it was under target, and then we walk away” (Int - Engineer 2b). This separation of teams and incentives may encourage a distribution of versions of energy targets:

“The main risk for construction is they don’t build it properly. The main risk for us is that …we don’t operate it properly.”

(Int - Facilities 3)

“My job is nothing to do with the operational requirements…I make sure that the BREEAM construction gets done and gets passed. So it’s like at the moment until I spoke to you I hadn’t even thought about down the line… If there were some people from facilities in our team, that would be a bit different.”

(Int - Environment 1)

“Project Co. 1: Although there’s a lot of focus I guess on lifecycle and so on and all those good things. The reality is everyone knows we’re going to divest.”

(Int - Project Co. 1 and 2)

Each of these three participants therefore enacts a slightly different version of the energy targets according to their individual department’s drivers within Construction Co..

For contractors, it is the limits of their assignments that can define the extent of their enactments. As one of the contractors on the office observes, fees tend to be allocated mostly to the design stages, so there is little incentive for consulting engineers to carry out significant work after this point (Int - Contractor Office 3). Moreover, the different hospital subcontractors have conflicting incentives to cooperate with each other on the project, whilst also protecting their own company’s interests, as Contractor 3 describes:
“We do talk quite well but you’ve got to understand that every company’s got its own vested interest to get done, get off site and maximise their profits.”

(Int - Contractor 3)

Therefore professional divisions may be reinforced by commercial incentives, both internally and externally.

On the hospital project, Construction 3 has made attempts to overcome the traditional professional “disconnect” that Engineer 2 referred to earlier (section 4.4) between Facilities and Construction. He tells me that although he knows that Construction “are focussed on capex and Facilities on opex”, he has provided more efficient fans and lighting as “extra benefits”, as although “Facilities 3 hasn’t asked for them...I know he needs them” (FN - meeting with construction). Contractor 3 speculates on the energy targets’ effect on the dynamics of this relationship: “because obviously what Construction 3 and his team want to do is walk away from this place, and then Facilities will look after it … But if things aren’t right and they’re not happy with it, he’ll never get away from the job” (Int - Contractor 3). Hence there is some evidence that the energy targets have helped to incentivise additional coordination efforts to overcome some of these traditional divisions.

However, although facilities and construction may be working in a more aligned way on the hospital, their alignment of practices may not necessarily give rise to an optimally-performing building. Contract incentives could encourage actors to manage the building’s energy use to convenient levels. This is referred to by one participant as the possibility of “smoke and mirrors”, and another suggests that “there’s games played I think”. Another jokes about the possibility of making performance fit the target
precisely, as he discusses how the long-term operating energy target could be made to work with the construction energy targets:

“CW: So the operating target…you set yourself an energy consumption target based on what you’ve actually been using for your [first] two years?”

Anon: Whatever the result is after two years. You’ve got a conflict here between the D&B contractor and the FM contractor. The FM contractor wants it as high as possible and the D&B contractor want it under the target. ”

(Int - anon)

Another participant agrees with him, pointing out that the contract does not offer a good incentive to innovate or out-perform the targets:

“If in fact we don’t operate the building very efficiently in the first initial monitoring period um that means that the energy consumptions are going to be higher um… And in actual fact that’s a benefit for us isn’t it?”

(Int - anon)

The contract causes other divisions in risk and responsibility between parties. For instance, Construction Co. is accountable for carbon emissions from energy use. It is not, however, liable for the cost of energy, which is paid for by the Trust (Doc - construction energy targets penalty clause). Hence Construction Co. is not given an incentive to install renewable energy systems that are cost-effective to run, only ones that help them meet their emissions target, as one of the team admits (Int - anon). The contract also allows for Project Co. to trade any carbon reductions above those required by the target, through allowances in the CRC scheme (Int - Legal 1). One of the contractors believes this could lead to a perverse incentive:

“You know about the [renewable energy] system?…I’m just told they’re going to switch it off after two years because they’re incentivised to use it to burn…you know to get the carbon credits…”
This last point is no longer a possibility, as the CRC scheme is due to close (Department for Business, Energy & Industrial Strategy, 2017a). However, there is a more general point arising from the issues above about the need for careful consideration and communication of contractual incentives, to ensure that parties do not interpret them in ways that promote individual benefits.

As noted at the outset of this section, the consideration of energy targets has now ventured beyond the concerns of Mol, in order to consider some of the commercial reasons why multiple versions of energy targets might not be coordinated effectively that are specific to this empirical case. However, this would not have been possible without the preceding analysis that revealed the different practices by which construction actors enact the energy targets, and how coordination is effected or evaded. The implications of the findings also ultimately return to the question of how reality is made, and what the implications of this might be for the making of energy targets. In Mol’s case, the implications were for the diagnosis and treatment of patients’ health. In this thesis, it is how energy policy incentives are reinvented in the hands of construction stakeholders in their daily work. This will be considered further in the section that follows.

Before continuing, one important point to bear in mind is the nature of the actors who have been analysed. This thesis considers the enactment of energy targets by managers within Construction Co. and some of its subcontractors who direct work, rather than, for instance, the site teams who carry out the physical construction. Mol’s work covered medical professionals who perform physical enactments (such as surgeons), and those who diagnose a course of action for others (such as outpatient
consultants), but also excludes other potentially relevant professionals, such as physical therapists or nursing staff (Law, 2004). The extent to which Mol’s work can stretch to these different empirical circumstances will be discussed in the final section of this chapter (4.7), after the overall conclusions arising from this ontological approach to energy targets.

4.6. Discussion and conclusions: reality is what you make it

4.6.1. Do energy targets “hang together”?

This chapter has explored a number of ways in which the energy targets, and the hospital’s associated energy performance, become multiple. This discussion will consider the potential implications for the eventual energy performance of the hospital. Whilst the building’s energy performance will ultimately be assessed by the apparently simple comparison of a ‘target’ to an ‘actual’ number, such as a “yes/no” on a flow chart (Doc - target flowchart), this belies the variety of enactments of the targets by different actors. As section 4.2 explained, the ‘whole building’ energy targets are enacted mainly at the two points of comparison: targets as agreed at bid, and the measurement of average energy use in the initial period of operation.

Two problems arise because of this. Firstly, the energy use of the building is continuous, and dynamic. It evolves with design, construction, commissioning, and in short- and long-term use it will change from day to day, and hour to hour. Focussing the evaluation of energy targets at two points does not capture this. Secondly, as noted in section 4.3, the deployment of target and actual can act as encouragement for actors to curate compliant versions of energy data at those points, rather than deal with the much harder task of aligning energy use across the full development period of the
building. This means that the enactments of the energy targets do not necessarily “hang together”, and, unlike Mol’s body multiple, do “fragment” (2002:55).

In other studies, multiplying realities of environmental issues may be caused by the specific circumstances of the actors involved, such as experts’ differing time horizons for climate risk (Zegwaard et al., 2014), or the force fitting of carbon data to commercial standards (Lippert, 2016). Section 4.2 showed how fragmentation of energy targets in this case seems to occur most markedly in the construction and commissioning period. The breaking-down of energy-related responsibilities into specialist tasks may be a practical necessity. However, if contractual energy targets are concerned with the whole building, whilst work packages focus on individual tasks, then a fundamental mismatch occurs, in a similar way already observed in the case of BREEAM (Schweber, 2017). It can also lead to a presumption that an energy efficient building can be made by sticking various energy efficient parts together, as when participants focus on particular energy efficient or low carbon technologies. Relationships and trade-offs between enactments are rarely mentioned, with a couple of exceptions (Ints – Contractor 6, Environment 8, Engineer 3). Thus although energy performance requires a balance between “one” and “many” in a dual appreciation of the whole building energy use and the components that contribute to it, this is only sporadically achieved by the construction team in the hospital.

This leaves a huge task of coordinating all the pieces back together again if Construction Co. were to monitor changing projections and measurements of energy use throughout the construction process. As shown in sections 4.4 and 4.5, established practices, including lines of responsibility, are not set up to deal with this. This mirrors the difficulties found by other work, where low carbon technologies require actors to
work across accustomed boundaries (Boyd et al., 2015). The neglect of energy modelling during construction and the failure to track the energy implications of design variations and “VE” exacerbate the problem. Whilst it is not feasible, nor indeed desirable, to suggest that Construction Co.’s managers attempt to align every possible enactment of energy in the hospital project, key points at which coordination efforts could be most effectively deployed could be identified.

In addition, active discouragement is provided by the limits of contractual responsibility. If Construction Co. acts as a “systems integrator”, then it is not necessarily adapted to take responsibility for the energy consequences of design, construction, and operation that are enacted by others. Nevertheless, as the main contractor “at the top of the tree”, as one site manager puts it (FN - site inspection tour), this leaves it exposed to risk, not just from energy target penalties, but from reputational damage, as some previous experiences in other parts of the organisation illustrate (FN - conference call with Engineer 1, Int - Engineer 2a). This is an uncomfortable place for a construction company to be, and is therefore potentially relevant to other large main contractors taking on projects with energy targets.

4.6.2. Constructing good and bad buildings

If the potential multiplicity of energy targets poses the practical and commercial conundrums just raised, it also raises other equally significant questions about the nature of an energy efficient building. Energy performance, both as a number and as a relative assessment, emerges from the analysis in this chapter as a highly negotiable product. The contract that governs the energy targets allows two outcomes: the hospital will either meet its energy targets; or it will not. Yet this bifurcation is likely to obscure many individual ups and downs in performance. The school, for instance, met its gas target but not its electricity, falling foul of a mismatch between static benchmark
standards and the shifting patterns of energy use common to other UK schools (Hong et al., 2013). However, the potentially overlapping reasons for this “failure” are neglected, such as, for instance, the potential relationship between its ‘inefficient’ electricity use and ‘efficient’ thermal performance. Similarly on the hospital, construction team members hope that a concentrated investment in technological magic bullets will cancel out any deficiencies in other areas, which can then go un-investigated. Engineer 2 points out that this need to “get over the line” of the target, can prevent longer-term learning opportunities:

“I suppose the shame about hitting the target is you didn’t have to do any more research. Because we’re home and dry.”

(Int - Engineer 2a)

Construction Co. can therefore be encouraged to avoid investigation of the performance of its buildings. Like the clichéd tree that falls in a forest, if an efficient or inefficient building is something that is made from the data gathered, selected, presented, and interpreted, then a building that is not examined remains in an undetermined state. Engineer 1 likens this to “running a red light that no one sees”, and goes on to observe that there could be “a big dark matter” of buildings out there that no one is pursuing (FN - conference call with Engineer 1). Scrutiny makes performance visible, which is potentially risky for Construction Co.. One participant, for instance, refers to this as “the problem of the informed client” (FN - energy experts meeting 3). Similarly, the scrutiny of another engineering company is also a “danger” as they can criticise Construction Co.’s apparently energy efficient building, disrupting the client’s satisfaction with it, and making it become “inefficient” overnight (FN - energy experts meeting 2).
One of the anticipated benefits of energy targets is to render energy performance more “visible” (Tuohy and Murphy, 2014), but this requires a consistent focus by all the actors in a project to keep them so. Some of the participants in Construction Co. tell me that clients do not necessarily bother to follow up operational energy targets when they do have them, citing a number of other projects, but paradoxically some clients without targets do show an interest in their building’s energy performance. As the hospital’s targets derive from government, not the local Trust, it remains to be seen if the hospital’s management will choose to be an “informed client”. Nor is it clear at this stage how the Trust will negotiate choices such as the trade-off between running costs and carbon emissions savings in the renewable energy supply, for instance. Therefore the coordination of energy targets is potentially relevant beyond the bounds of the construction team.

The “story” of a building can be changed by the selection of data used to construct its narrative (Janda and Topouzi, 2015). Mol’s theory takes this one step further and suggests an ontological flex in the actual building that is created. As the school illustrates, turning a bad building into a good building may combine physical changes to energy systems with changes made by legal or accounting manoeuvres. The reality of the hospital’s operational performance has yet to made, but what we learn from the tools of the ‘ontological turn’ is that, as Woolgar and Lezaun (2013) observe, whatever reality is settled on will be the net result of actors’ practical determination of ‘normal’ or desirable performance. This draws very much on earlier work in STS suggesting that technology does not succeed when a problem is solved, but when social groups accept that it is (Pinch and Bijker, 1987). Therefore whilst energy targets bring the assessment of operational energy performance into construction actors’ daily practices, they do not necessarily give rise to the unproblematic “transparency” to which Cohen and Bordass
aspire (2015). Moreover, there can be an inherent circularity between evidence and policy, in which stakeholders find what they want to measure, and what is measured defines what they were aiming for (Schweber et al., 2015). Thus the data that actors use to produce performance may determine the success or failure not just of the current building, but also establish Construction Co.’s diagnosis of how good or bad energy performance is produced, or what might be an acceptable target for its future projects.

Mol’s work dealt with a known disease, and established treatments. Energy performance in buildings, however, has little yet in the way of normative data or familiar practices. The distributions between enactments, and the lack of coordination that means the energy targets do not always “hang together”, may be symptomatic of this. Thus policy or market incentives to encourage a “collective understanding” of energy (Cohen and Bordass, 2015:535) also require consideration as to how this cohesion is achieved. Aiming for collective understanding should not presume that actors all have ontologically identical versions of energy targets, separated only by poor communications. If actors are indeed enacting fundamentally different energy targets, creating separate realities, it helps us understand why coordination around energy issues in construction might be so hard, even with additional incentives like contractual energy targets.

However, a central characteristic of Mol’s enactments is their fluidity, for as practices generate ontologies, so reality is mutable. Hence, whilst divisions between actors and actions might arise, these can also dissolve if practices are changed. This means that energy targets could “hang together” more coherently if accompanied by changes in working practices to make energy responsibilities clear and consistent, and to support
exchange of information between professions and project phases. For example, arranging review points throughout the building lifecycle, as recommended by Soft Landings (Agha-Hossein, 2018), or agreeing common terms of measuring and comparing different units and calculations of energy use. Emerging insights from domestic low energy construction also suggest that great attentiveness to construction quality and design changes is required (Guerra-Santin et al., 2013). This could go some way to encourage more attention in construction teams to operational energy performance, rather than a short-term focus on avoiding penalties.

4.7. Reflections on the concept

4.7.1. What it offers

As I began this chapter by suggesting, much of the appeal of Mol lies in her blend of the practical and philosophical, and her ability to make clear the ontological implications of routine events. This makes her brand of “empirical philosophy” (2002:4) particularly portable as it helps us to enquire after the fundamentals of everyday practices, and therefore it transplants relatively easily to a new setting, such as construction. The analogy between a building and a body is not unreasonable, both being made of interconnected parts that somehow “hang together” (2002:55) more or less coherently. The energy performance of a building is also, as with atherosclerosis, something that is formed by many specialists. The status of energy performance likewise requires diagnosis and care by these different specialist actors. Finally, a concern with low carbon construction that looks to protect populations from the long-term damages of climate change is as ethically and politically charged as the physical health of the population.
Mol’s approach allowed me to ask basic questions about what it is that actors actually do on a day-to-day basis in response to the incentive of an energy target. These questions helped me to think more deeply about what actors’ practices brought into being, as asking simple questions of individuals can lead to surprising answers, or pauses for consideration. For instance, when I asked one site manager what it was that he produced, he sat and looked at me and replied, “well that’s a strange one isn’t it?”, before concluding that he did not really produce anything, as it was the contractors who produced the hospital’s energy systems. These pauses for thought about everyday actions can add up to a mosaic of enactments around the energy targets, that offers a much more nuanced and situated understanding of what might constitute the energy performance “gap”.

I was initially drawn to Mol for this ability to help me unpick differences between practices in a systematic way, and to assess the extent to which they were brought together. However, in using her theory I also found much more value than I was expecting in her consideration of the making of realities and the normativity of practices, as these held implications for my case in considering which realities of good and bad energy performance become accepted. Her work helped me consider who is constructing goals for energy efficient buildings, what data or processes they are using, and why they might lead to a building being deemed efficient or inefficient. This, I hope, adds some additional import to the pre-existing concern that construction treats buildings as the sum of separate parts (Winch, 2000). They are very valid questions to engage with the wider debate on the need for new policies around the enforcement or disclosure of buildings’ energy in-use, and the implications will be considered more fully in the concluding Discussion (Chapter 7).
4.7.2. What it cannot offer

Using Mol was not without its difficulties. As discussed in the Methodology (Chapter 3) earlier, I could not be everywhere at once, and my interaction with the hospital represents only a particular period of its development. Moreover, and as also noted in the Methodology, the participants that I engaged with were primarily managers of design, construction, or operation, rather than those involved in the physical work of building the hospital. The energy targets that they enact are therefore more intangible in nature, and often performed at arm’s-length when directing enactments to be performed by others. However, other studies using Mol’s concepts have successfully managed to navigate similarly distant enactments, considering the reporting of carbon emissions and pollution (Asdal, 2008; Lippert, 2015; Lippert, 2016).

I was also worried by the prospect that actors’ practices might vary between situations, and that I had the capacity to interact with only a small selection of these. This is a concern that will be partially addressed in the next chapter, in which I consider how energy targets are expressed in different contexts, using discourse analysis. However, there were a few practical steps I took to help mitigate these concerns. One tactic was to ask participants for examples of what they said they did wherever possible. For instance, I would ask someone to show me how they dealt with a design variation enquiry, or a technology specification. I also tried to meet my participants somewhere quiet and neutral so that they could talk about their work honestly, without feeling they were being overlooked by colleagues.

A focus on practices obviously entails what is done by actors, rather than what is not. This leads to a series of questions I have not been able to examine. Law and Lien’s work (2013) has looked into things that are “nearly” brought into being. It would have
been interesting, following this line of thought, to consider in more detail what versions of the energy targets did not get enacted, through rejected designs, potential innovations that were too risky or too expensive, or ideas to which actors could not get others to agree (Janda, 1998). Berker (2013) has also used Ranciere’s concept of the gap between “the arms and the gaze” to explore energy-consuming practices as performed, compared with what actors might aspire to do.

In addition to absent actions, there are many of what I thought of as ‘silent parties’ in the data, or actors who do not get to enact energy targets directly, despite their potentially significant impact on energy use. Two groups I did not meet are the Soft FM contractors, who will provide catering and cleaning in the hospital, and the information technology suppliers. Neither of these parties appears to be included in energy target discussions due to the lack of a direct contractual relationship between them and the construction team (Ints - Legal 1, Facilities 2). Given that this research examines the performance “gap”, which is a story of the apparent failures of low carbon buildings, the question of what does not happen “inside the gap”, or who is excluded, is likely to as interesting as the story of what does, and this could be very usefully researched.

4.7.3. In conclusion

This chapter has dealt with some of the difficulties of coordination in the construction team, as they encounter the sometimes-nebulous demands of energy targets, and bring them into being through their working practices. I have attempted to show that, by focussing on how practices bring different versions of energy targets into being, it is possible to gain insight as to why different enactments of the energy targets could affect long-term energy performance. I have also begun to show how the nature of energy efficiency in buildings may be mutable, and how therefore calls for the gathering and disclosure of more operational data need to reflect on the methods and motives for...
which this is done. However, beyond what construction team members are doing, it is also important to consider what they are saying, and this brings us to the next chapter, which looks at how the energy targets emerge through actors’ discourse.
5. What do actors in the construction team say in response to the energy targets?

Turning from Chapter 4’s focus on practices, this chapter will take an epistemological pivot to consider what it is that the construction team say in response to the energy targets, rather than what they do. The analysis will again be inspired by a single work, in this case Gilbert and Mulkay’s approach to discourse analysis, as set out in “Opening Pandora’s Box” (1984). Gilbert and Mulkay share with Mol a concern with multiplicity, but driven by discourse rather than practice. They argue that concentrating on discourse overturns the researcher’s presumption that there is a definitive account of what “really” happened. Instead they argue that actors’ accounts of events are variable. They may change, for instance, with the context in which actors find themselves, or on whether they are providing a supportive or negative account of what occurred. This adds a further layer of insight to the findings identified in Chapter 4, in considering how events within the “gap” are explained by the actors themselves.

Following the pattern of the previous chapter, I will begin by explaining the particular elements of Gilbert and Mulkay’s work that I have used to inform my analysis. I will provide a brief review of other research that has made use of their work, in order to set my own in context. A central concept of Gilbert and Mulkay’s discourse analysis employed in this chapter is the identification of “interpretative repertoires”. These are
recurrent patterns in actors’ talk, such as contextual variations in accounts of events. Section 5.2 will explore how actors “account” for potential problems in meeting the energy targets, using opposing interpretative repertories of the “theory” and “reality” of energy use. Section 5.3 will explore how actors talk about uncertainties in achieving the energy targets, illustrating how repertoires vary between formal and informal contexts. As in the previous chapter, the findings are firstly derived from the theoretical approach, and then followed by a step back to consider the reasons particular to the case examined that shed light on why they might be observed. These empirical sections will then be drawn together to discuss the overall themes arising and some brief conclusions (section 5.4). As in Chapter 4, the final section (5.5) will offer some reflections on the application of this work to the examination of energy targets in construction.

5.1. An introduction to Gilbert and Mulkay’s discourse analysis

5.1.1. Key concepts

Gilbert and Mulkay’s work began in a case study of biochemistry. The scientists that they studied were working on oxidative phosphorylation, a phenomenon about which several hypotheses were competing for acceptance. As a result, the community of biochemists was engaged in debating the relative reliability of the findings, and of work done by, different research groups. Gilbert and Mulkay had originally intended “to strip away the formal side of science, and show what was really going on” (1984:vii). However, the more scientists they met, and the more data they gathered from interviews, correspondence, research papers, and textbooks, the more they began to question this aim. They found that they had several diverging, and apparently equally plausible, accounts of what was “really” happening. This caused them to abandon their
original research aims, and instead to develop a new approach to discourse analysis that could accommodate this variability.

Although the biochemists talked in multiple ways about their work, this did not lead to chaos. Rather, Gilbert and Mulkay found recurrent discursive patterns, which they termed “interpretative repertoires”. In their case study, there were two predominant repertoires. On one hand, scientists describing their work in a formal context, such as journal papers, tended to emphasise the unproblematic and objective qualities of their findings (the “empiricist repertoire”). On the other, when talking in more informal situations, they qualified their accounts with social, personal, and judgemental motivations and contexts, rendering their research more subjective (the “contingent repertoire”). Therefore, Gilbert and Mulkay’s scientists were “selectively employing” different interpretative repertoires depending on the social context in which they found themselves (ibid:55).

The identification of repertoires does more than suggest that people express themselves differently in formal and informal contexts. As already noted, the case study was one of controversy, and hence the community of biochemists spent time discussing whose work was correct or incorrect. Gilbert and Mulkay found that scientists tended to use the empiricist (objective) repertoire when they wished to promote a particular scientific finding, and the contingent (subjective) when they wished to discredit it. This they termed “accounting for error” (ibid:63). Scientists therefore used the repertoires to “justify and validate” (ibid:64) versions of events, and to suggest reasons for the unreliable work that had lead to such “errors” in scientific knowledge. This allowed them to shore up a ‘correct’ representation of science in their community,
by drawing a dichotomy between good, objective work and bad, subjective results (Mulkay, 1993).

The overall outcome of the work was to show how scientists’ discourse actively “constructed and deconstructed” (ibid:112) the state of knowledge through their discourse. However, Gilbert and Mulkay stop short of the further ontological step taken by Mol, and leave the question of the nature of underlying reality untouched (Woolgar, 1986; Halfpenny, 1988). Their value lies in revealing the crucial shaping role of discourse in making a professional community, delineating what good practice or accepted knowledge is, and sensitising us to the shifts in representation made by actors in different contexts. The concepts just discussed, and which will be used to analyse the findings in the sections that follow, are illustrated in Figure 5.1 overleaf.

Whilst Gilbert and Mulkay’s approach later evolved into a widely used form of discourse analysis (Potter and Wetherell, 1987), the original work has been most often employed in the scientific arena where it began. Research over the years has shown how actors draw boundaries between ‘good’ and ‘bad’ in science, and use discourse to defend controversial positions and undermine their critics (Michael and Birke, 1994; Hedgecoe, 2001). The concept of “accounting for error” has been used to show how scientific errors are excused by implicating external factors (Kerr et al., 1997), and how scientists distinguish between fraudulent research and scientific truth (Augoustinos et al., 2009). However, Gilbert and Mulkay have very rarely been applied to construction research. Sherratt et al. (2013) have, for instance, employed it to explore how the concept of construction safety is understood by site workers amongst themselves. However, Gilbert and Mulkay’s work has not been used to examine how construction
professionals talk about energy use in buildings, despite, as I show in the next section, its potential resonance.

Interpretative repertoires (Gilbert and Mulkay, 1984)

Figure 5.1 Key points of Gilbert and Mulkay’s work used in this chapter
5.1.2. Why apply this work to researching energy targets?

From my early work with Construction Co., it had emerged that actors appeared to be talking about the energy targets in different, and sometimes contradictory ways (section 3.4.3), pointing to a need to explore the nature of their talk in more detail. However, discourse analysis can encompass a very wide variety of approaches and theoretical perspectives (Potter et al., 1990; Alvesson and Karreman, 2000). It can incorporate social systems (Foucault, 2002) or single conversations (Stubbe et al., 2003), language and linguistics (Gee, 1999), or meaning and symbols (Hodge and Kress, 1988). My first consideration therefore was one of appropriate scale and scope. I required a tool to examine the ways in which a single, but diverse, construction community talked about the specific topic of energy targets. I also needed a theory that would allow me to consider the detail of discursive interactions between construction stakeholders, but which was also flexible enough to allow me to make comparisons across the team, and which would fit with the scope of my other two theories. Gilbert and Mulkay’s work fitted these needs.

In the previous chapter, I suggested that energy targets might exist in ontologically-separate forms. Gilbert and Mulkay also claim to “approach the social world of science as a multiple reality” (ibid:188), and so again pick up the theme of multiplicity. The line between what is ontologically distinct, and what is a “polysemous concept” of discourse can be hard to draw (Simon and Randalls, 2016:7). Gilbert and Mulkay’s discourse analysis engages with multiplicity by examining how different versions of events emerge from the way they are expressed. Using discourse analysis in this way allows me to ask if part of the performance gap might be due to the influence of the formats and arenas in which energy performance is presented. It therefore encourages a sensitivity to the shifting and context-driven accounts of energy targets that the
previous chapter did not. The previous chapter also discussed the negotiable nature of an energy efficient building. The analysis of opposing repertoires allows me to develop this theme of negotiability further by considering how language is used to construct good and bad practices and expectations of energy efficiency “inside the gap”.

There are, of course, clear differences between the diversity of professions involved in a complex non-domestic building project and the more homogeneous community of biochemists on which the original work focusses. However, there are also interesting parallels. Gilbert and Mulkay’s discourse analysis reveals how professionals work together on a particular concern, and how they rationalise their differences in the course of doing so. Their approach enabled them to explore the professional frictions between different scientific teams, and the terms they employed to agree or disagree with each other. This has the potential to transplant well to construction, in spite of the differences in the nature of the communities.

Additionally, both Gilbert and Mulkay’s scientists and the construction actors must confront an evolving, technical phenomenon where the causes are under debate: biochemistry on one hand, and the energy performance gap in buildings on the other. Both are also required to “account for error” in presenting interpretations of events and explaining when things go wrong (1984:63). I was interested in how the construction team might explain this discrepancy in their own terms. These parallels suggested fruitful common ground, whilst bearing in mind that it is in the differences between empirical cases that new insights may be discovered (Vaughan, 2014).

5.1.3. This work in context

The words that are used to talk about energy and carbon are important, and so this PhD is far from the only work to take a discourse approach to energy and buildings.
The language in which the environmental performance of a building is assessed, for instance, shapes its “story”, and creates the “mental territory” for stakeholders (Cole, 2005:466). The stories that are told about a building’s energy efficiency frame responses to it, the interpretation of what happened, and how successful it is determined to be (Janda and Topouzi, 2015). Alternative narratives of building performance may affect stakeholders’ judgement, and create disappointment or acceptance (Coleman and Robinson, 2018). The power of gathering energy stories therefore lies in their ability to “change who speaks” and “who gets heard” (Moezzi et al., 2017:8). It has been recognised that exploring how businesses in particular talk about energy can reveal strikingly differences to the way that researchers might frame the discussion (Galvin and Terry, 2016).

Research into societal discourse around low carbon and energy issues has already revealed how language can shape understanding and responses to new policies (Cherry et al., 2015; Ellenbeck and Lilliestam, 2019). These studies reveal valuable insights into the active role that high-level discourse plays in shaping society’s response to energy and carbon reduction. However, they do not explore the ground-level response of communities to energy policies, for whom the glacial movement of societal change may be experienced as immediate and destabilising (Graff et al., 2018). Research that has engaged with the response that energy transitions meet “on the frontline” in local communities demonstrates the value of this approach (Darby, 2017). Thus it is vital to consider how new energy policy instruments are "negotiated on the ground" (Schweber, 2017:302) by the stakeholders whose day-to-day lives they affect.
In addition to providing an “on the ground” perspective on low carbon policy implementation, a focus on localised discourse may also reveal the mutability of the underlying concepts. Picking up on this idea raised earlier in the Literature Review (2.3), discourse analysis can show that “the concept of a green building is a social construct”, meaning a common commitment to “sustainable building” is actually subject to individually varying, and contested, conceptions (Guy and Farmer, 2001). These can be particularly relevant to professional discourse in the built environment (Wade et al., 2018). Moving between high-level shifts in policy discourse and its localised implementation can, for example, reveal how the latter continually re-negotiates the former, amongst the many actors involved in construction projects (Moncaster and Simmons, 2015). Attending to the discourse of professionals charged with the implementation of low carbon buildings policy could therefore reveal much about how they perform these translations.

However, research that focuses directly on construction teams’ discourse around energy, or response to energy targets, is relatively sparse, with a few key exceptions. Gluch and Räisänen, (2009) used critical discourse analysis to examine the dissemination of environmental priorities in major construction projects. They uncovered differences in the form and “culture” of communications between management and project staff, which directly affected the level of engagement by the latter. Ludvig et al. (2013) examined the response of a Swedish organisation that owns and manages a number of large, public buildings to a new regional energy target. Using concepts of organisational sensemaking, the study found how the vague political directive became successfully “anchored” within the organisation, driven by a sensitivity to the appropriate times and forms to engage with stakeholders. These studies indicate that discourse is a vital part of engagement with energy policy amongst built
environment professionals, required to engage “on the ground” with new policies. Thus an appreciation of how a construction team talks about the challenge of energy targets amongst themselves is a vital part of understanding the “gap”. This will be demonstrated by the findings, which will now be set out in the sections that follow.

5.2. Accounting for error: repertoires of theory and reality

This section will discuss a discursive separation between repertoires of the “theory” and “reality” of building energy use. This separation appeared consistently across the data with enough regularity amongst a variety of professionals in the team to be reasonably confident that it represents the “patterned variations” of Gilbert and Mulkay (1984:40). The same words are not always used, and indeed Gilbert and Mulkay’s analysis does not require this to be so (for example, Mulkay, 1993). The interpretative repertoires are characterised by a verbal contrast drawn between a theoretical design or prediction of energy, and what “really” happens. For example:

“One thing is design and one thing is how it really works.”

(Int - Contractor 8)

“Project Co. 1: There will be a difference between what we think and what’s going to happen.”

(Int - Project Co. 1 and 2)

Sustaining this generalised and recurring contrast were a series of activities with which “theory” and “reality” are associated. Each repertoire is also ascribed certain characteristics, from which their relative reliability is derived. Together the contrasts drawn between theory and reality allow the construction team actors to “account for the error” of any potential performance gap in meeting the energy targets.
5.2.1. The theory of energy use

“Theory” is firstly associated with regulations and standards that focus on design, as in spite of the energy targets, these familiar requirements are still often uppermost in actors’ minds when they talk about energy or carbon (Int - Contractor 9, FN - site inspection tour). However, those professionals involved in work directly supporting the requirements of regulations and standards do not necessarily regard their calculations as “real”. Part L is a clear example:

“Contractor 8: We are just in process to re-calculate the energy.

CW: Ah ok. The Part L?

Contractor 8: No...The real energy.”

(Int - Contractor 8)

In my meeting with Engineer 6 he tells me “that he has not often seen an EPC and a DEC which were the same” (FN - meeting with Engineer 6). BREEAM is another example in which participants spoke of “theory” (Int - Contractor 1, Int - Design 3). A BREEAM credit, for example, is awarded for undertaking a thermographic survey of the completed hospital:

It will show, Environment 1 says, leaks and insulation gaps – but they are only required to find them, not actually remedy them, although the theory is they will.

(FN - on site field notes 5)

Compliance with design-based regulations and standards is one of the central reasons behind the performance gap (section 2.1.3). However, as the project’s energy targets are imposed in addition to, not instead of, regulations and standards, these “theoretical” requirements continue to occupy actors’ time and attention. Those involved in the preparation of materials for these, such as design contractors and environment
managers, use “theory” to describe their limitations. However, others with less day-to-day involvement with them may not have enough detailed understanding to separate them from other sorts of energy and carbon calculations.

A related view is that errors in energy prediction arise because it is a difficult, and perhaps even an unreasonable, thing to attempt. As a member of the hospital bid team recalls, there was a “problem” with a “prediction of energy into the future” at the time of bidding for the contract, which was “theoretical”, and very hard to deal with (FN - call with senior bid team member). Engineer 3 believes using energy models as crystal balls is futile:

“So that's the problem. You can theoretically design a building. What you can't do, the one bit of the model you do not possess, is the bit that says how is it going to be used. You don't know that. You can't control that.”

(Int - Engineer 3)

Thus, the repertoire of theory very often appears when actors talk about energy modelling, which activity may also be discursively separated from “reliable” data:

“So we had our energy simulation and we had reliable empirical data.”

(Int - Engineer 2a)

“It's a simulation based on a kind of like a scenario, or what we call normal use. And the only thing we can be sure of, is that it will never, ever occur in reality!”

(Int - Engineer 1)

“Project Co. 2: The design of the building would have to comply with our design requirements, with regards to energy consumption per m², or whatever. And in some way the model has to demonstrate that the building can achieve that. And I think that...that’s where you know real life might be completely different.”

(Int - Project Co. 1 and 2)
There are many criticisms of energy models that were explicitly acknowledged by a range of participants, including: software problems; data omissions; optimistic assumptions; and an inability to predict how occupiers will behave (FNs - conference call with Engineer 1; energy experts meeting 1). Despite this, the energy model remains the principal tool for assessing energy use at the design stage, and hence a key driver of the team’s strategy to address the energy targets (Doc - Energy and Carbon Proposals). Thus the theoretical repertoire can be used to express dissatisfaction with current compliance processes and tools for predicting energy use, by both those who produce them, and those who use them.

As explained earlier, much of the hospital’s detailed design work, and the manufacture and supply of energy-using technologies, is outsourced to specialists. These activities are also tarred with the theoretical brush by members of Construction Co., who rely on their results. Some participants suggest that design consultants can specify “things that don’t actually exist” (Ints - Construction 1, Environment 4; FN - meeting with engineering team), assume the purchase of the “best thing ever” (FN - environment team meeting 3), or use performance criteria under “optimal functioning” without, say, reasonable assumptions about maintenance levels (FN - conference call with Engineer 1). Additionally, suppliers and manufacturers are blamed for exaggerating what they can offer (FN - environment meeting 1), perhaps by giving performance figures that work only “in the factory” (FN - site inspection tour). However, given that suppliers and designers are not liable, unlike Construction Co., for energy performance in practice, it is hard under the current contract structures to incentivise them to produce “realistic” numbers.
Moreover, attempting to push down responsibility for energy use to suppliers encounters problems due to the interconnected nature of the energy systems:

“CW: I was just wondering whether anyone talks to you or you have to provide a kind of...

Contractor 7: A guarantee?

CW: yeah....

Contractor 7: yeah we have to.

CW: Ok and what do you have to guarantee?

Contractor 7: But it will be impossible for anyone to ...like...pin us down on the target... simply because there’s so many sub-parts that cannot be influenced by us. So there’s always an excuse. Which...that’s true for all big sites.”

(Int - Contractor 7)

Construction Co.’s managers explain their role in sense-checking designs for such issues:

“We might have got somewhere near 90% efficiency, but they quite often...try and push it to get the best. Which is fair enough. But some of the things they asked for wasn’t achievable.”

(Int - Construction 1)

These feasibility (or “buildability”) reviews of the design are a standard process in construction. However, because of the introduction of energy targets, Construction Co.’s staff worry about the problems this standard way of dividing work may pose for energy performance of the building in operation.

Those involved in bidding for work also talk about “theoretical” energy being created by client expectations and contract terms (FN - call with bid team member). Here, it is
commercial pressure to win a bid that can encourage ambitious promises about energy:

“The NHS Trust was saying to us we need a figure of at least you know X or whatever [for energy use]…and...the better you can make that figure, like the more favourably it would be evaluated.”

(Int - Legal 2)

With hindsight, some in the energy experts group that I attended speculate that their unsuccessful bidding rivals might be better off, if Construction Co. has won the hospital contract by producing a model that met the energy targets in theory, but might not be possible in practice (FN energy experts group 1). The target that was signed up to for the school project is similarly referred to as “optimistic” (Doc - School Energy Consumption Interim Review) and being subject to commercial pressures that propelled actors towards signing a contract (Int - Commercial 1). Promising clients ambitious outcomes can be a force for change as it provides the impetus to innovate out of necessity. However, it can alternatively lead Construction Co. to “talk a better game than we deliver” (Int - Strategy 3).

Once the bid is won, the contract terms may also encourage theoretical assumptions. For example, a combination of renewable technologies is selected to comply with the targeted carbon emissions (Doc - Energy Statement), but may be expensive to run, as previously noted (section 4.5.2). Some participants suggest that therefore the technologies will not be used for long, and the carbon target will only ever be achieved on paper (Int - Contractor 3, FN - on site field notes 1). Similar scepticism is expressed about the effect of weather data on energy projections, as the contract stipulates a weather file from a different area of the country to that in which the project is actually located (Doc - academic review of design). Luckily, in Engineer 2’s view, this “100
miles difference” actually “made it an easier target…because…it’s warmer in X than it is in Y” (Int - Engineer 2b), meaning that less energy for heating should be required (Doc - academic review of design). As heating degree days can be taken into account when assessing performance against the energy targets (Doc- Project Agreement Payment Mechanism), underestimating heating demand does not penalise Construction Co.. It would, however, underestimate the projected energy use, carbon emissions, and cost of the building in-use being offered to the Trust. Poorly-structured client expectations may therefore contribute to theoretical representations of energy and carbon.

Doubts about the reliability of “theory” are compounded by commercial barriers that separate different companies and different internal departments, and can limit the exchange of energy-related information:

[Design 1] describes it as like an ‘egg timer’ – with the information filtering through a few people from both sides who meet in the middle, and the larger organisations either side.

(FN – on site field notes 1)

“What we're good at in construction is you know building up lots of data, knowledge and information during different stages of the project, but at the end of each stage we sort of press the button and sort of throw that information over the wall...”

(Int – BIM 2)

As noted in section 4.4.1, expert contractors determine how much of the technical detail of their work they transfer to the rest of the team, who in turn may limit how much detail they wish to receive (Int - Contractor 9, Int - Engineer 3). With the introduction of the energy targets, any failure to transfer knowledge relevant to operational
performance between professional groups becomes a risk that critical assumptions or uncertainties are not exposed or discussed. This means that the on site construction team may feel unsure as to whether they have asked the right questions of their contractors:

“You’d like to think you’d involved as many people as you can, but there’s only proof when it starts to work isn’t there?”

(Int - Construction 1)

The lack of common understanding then leads to a further reinforcement of the unreliability of “theory”.

The repertoire of theory is therefore used in association with energy projections that actors wish to present as doubtful, uncertain, or flawed in some way. The repertoire is used by many different professional actors across the construction team. In Gilbert and Mulkay’s case, unreliable work was explained by the intrusion of ‘non-scientific’ factors. In the case of the hospital, it is the poor functioning of industry regulations, contracts, and processes that are positioned as driving unreliable energy expectations. This includes building regulations and BREEAM, whose requirements continue to run alongside the new energy targets, and which can become confused with them. It also includes the contract terms that have introduced the energy targets. In addition, many actors in Construction Co. express doubts about the reliability of contractors’ specialist design tools and processes for predicting performance in-use. However, some of these specialist contractors also express concerns, and use the repertoire of theory to draw attention to the inevitable uncertainties and limitations of their work. This suggests a shared emphasis amongst many members of the construction team, who use the repertoire of theory to present the limitations of existing structures and ways of working in the context of energy targets.
5.2.2. The reality of energy use

As with “theory”, the “reality” of energy use is a repertoire that is also used by a range of different actors across the construction team. A key feature of “real energy”, is that, unlike “theory”, it can be measured:

“All I'm interested in is when the building is fully occupied, what does it use?…Because literally, what else is real?”

(Int - Engineer 3)

Real energy therefore cannot be known until the building is occupied and active: “we'll know when we turn it on and measure it” (Int - Engineer 3). Many participants express the view that calculating real energy is a fairly straightforward process of finding the source of the energy, measuring it, and comparing it to the target:

“So it’s about like finishing the job and having all this information be fed back to you. Then sitting down and reviewing and seeing what the building is doing.”

(Int - Design 1)

Construction 3 tells me that this will be facilitated by the design of the BMS, in which you just “hit a key and it produces reports” (FN - meeting with construction). This view is reflected in government guidance for energy efficiency in the NHS:

“It is relatively easy for an organisation to find out how much energy it has purchased – the delivered energy – by looking at data from the energy supplier, or from on site meters.”

(Doc - EnCO2de A)

According to this logic, energy that is metered is more easily accessed and more reliable than energy that is modelled, despite the potential for each to inform each other.
A more detailed exposition of collecting real energy data is provided by engineers and contractors who will actually be involved in gathering it, through a gradual process of learning about the individual building, as described by Engineer 3 again:

“Normally at 6 and 12 months, you'd be talking to [Facilities] going, how's the energy going? ...They'll start the energy trend running straight away. They'll be looking at it…and it allows them to understand actually what the running of the building is like. ...Because to some extent, you can build everything, you can meter everything, and you can test it on the day you finish. ...But until you put it into use, you don't know…there's always this...one is hypothetical, and one's real.”

(Int - Engineer 3)

A participant from Project Co. echoes this view when he tells me that:

“Project Co. 1: Basically that's why you have this two year bedding-in so you have a steady state of operation. Then you find out what the actual energy use is…So I think a lot of these sort of conceptual models actually work, they’re brilliant, but then in reality they did not work.”

(Int - Project Co. 1 and 2)

The importance of a detailed, tangible understanding of the building in operation is also described by one of the technology suppliers:

“First thing is, find mistakes. There’s always something wrong in the system ok. Then parts...units that fail on a regular basis that shouldn't fail. And next is fine-tweak them, fine-tune them.”

(Int - Contractor 7)

Immediacy is another quality of “real” energy, which is experienced as it happens:
“Project Co. 1: Well you need the granularity and you need the [clicks fingers]. It isn’t any good just looking back at this now… You wanna look at it right at that very moment, and say what is going on.”

(Int - Project Co. 1 and 2)

Real energy use is therefore characterised by a situated responsiveness to circumstance and experience, which is distinct from the more generic assumptions made by theoretical models.

As real energy is strongly associated with the idiosyncrasies of individual buildings, various actors express doubt as to whether designers can envisage these in adequate detail. Engineer 3 explains the difficulties of accounting for a myriad of details and assumptions:

“Unless you want to model every hour of every day of every week of every…throughout the year. And then what do you model it against? Which energy file are you going to use? Which reference file? They’re all different.”

(Int - Engineer 3)

As a visiting consultant observes, even the most intricate of models will find it difficult to simulate the real conditions of a unique building. He uses the example of air flow through ducting, where although the specification might “be in line with design requirements”, when it actually comes to the installed ducting there are so many “twists and turns and changes” that it is hard to tell how it will really work out. Even using computational fluid dynamics will not give you a completely reliable result, he believes: “CfD will get you close but not close enough” (FN - site inspection tour).

Occupiers are often taken to play a significant role in the quirks of “real” energy use. They may use the building in different ways, or to a different extent, than the design
standards assumed (FN - meeting with engineering team; Int - Project Co. 2). As a result, the “human factor” is considered a major, and possibly insurmountable, uncertainty:

“It's the human factor really isn't it? And you just don't know really how people are going to behave.”

(Int - Contractor 8)

The ‘biggest problem is human interface’.

(FN - meeting with engineering team)

It is notable that these worries are shared by professionals from the contracted design organisations, and Construction Co.'s internal construction and engineering departments.

However, there are also some divisions between professions, for example, in the on site experience of real energy. The repertoire of real energy emphasises physically "being there", implying that those who are not present on site cannot understand it. So, for instance, contractors are criticised for being “on their backsides in London” (FN - on site field notes 1), whereas another participant states his credibility by saying that “if you look in the boot of my car, you will find a site bag with a pair of boots in it. And if I need to put them on, I'm on... ” (Int - Engineer 3). Unfortunately, existing divisions between professions and companies do not encourage a cross-pollination of information between those who are there and those who are not. The division between professionals on site and off site is particularly evident in the frequent failure to feedback operational energy data into design:

“I think what would improve the situation if the companies were willing to share...how they run the energy basically, what is measured energy, and you
could really get a real picture… but it’s a very hard information to get, and not many people I suppose are willing to give that information…”

(Int - Contractor 8)

“It is a great shame that we didn’t spend more on our metering strategy. If we had’ve done, I could’ve had a data … A&E [Accident & Emergency] uses this much, theatres use this, outpatients use this… but we didn’t. ”

(Int- Engineer 2a)

Therefore although actors involved in design and operation talk about the value of “real” energy data, it is not often available to them, as construction companies do not regularly collect it on projects without energy targets. This means that those involved in off site design, such as contracted designers and suppliers, primarily have access to “theoretical” energy data, which they cannot test against operational data. Whereas those involved in on site activities, like facilities managers and engineers, have potential access to “real” energy data, but few commercial avenues to link it to design work. This serves to perpetuate the distinctiveness of energy “reality”.

These findings illustrate how Gilbert and Mulkay’s interpretative repertoires act as a lever to open up the construction team’s own problematisation of energy performance. They reveal the professional activities and groups that team members associate with reliable and unreliable energy data, and the characteristics that accompany these associations. Table 5.1 below summarises the qualities that form the two contrasting repertoires, and shows how these combine to impute the reliability of energy data in “reality” and unreliability in “theory”. Attending to how actors sustain these groupings through their talk about energy targets highlights how repertoires of “theory” and “reality” are used to rationalise any potential “error” or “performance gap”. However, it is also important to reflect on why this might be occurring. As explained in the
introduction to this chapter, Gilbert and Mulkay’s approach does not just facilitate the identification of linguistic patterns. It also suggests how repertoires may be used to reinforce ideas of good professional practice.

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<tr>
<th>Repertoire:</th>
<th>Theory</th>
<th>Reality</th>
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<tbody>
<tr>
<td>Association</td>
<td>Designers, suppliers, bid teams</td>
<td>Engineering and maintenance teams</td>
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<td></td>
<td>Generic compliance</td>
<td>Situated, specific conditions</td>
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<td></td>
<td>Modelling</td>
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<tr>
<td>Characteristics</td>
<td>Intangible</td>
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<td></td>
<td>Unclear, complex assumptions</td>
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<td></td>
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<td>Achievable</td>
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<tr>
<td>Implication</td>
<td>Unreliable</td>
<td>Reliable</td>
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</table>

*Table 5.1 Repertoires of theory and reality*

5.2.3. Theory, reality and professional liability

In Gilbert and Mulkay’s original case study, actors used discourse to delineate reliable and unreliable professional practice. Scientists from different research groups used their discourse to either support or undermine particular experimental procedures, and particular models intended to represent the process of oxidative phosphorylation that they were all studying. The construction team’s distinction between reliable and unreliable means of representing the hospital’s energy use, as just shown, also follows this pattern.

If actors distrust existing “theoretical” predictions of energy use, those who are accountable in any way for the targets may become anxious about being blamed if energy performance is not as expected. In response, professional positioning around
who is liable for what is a common feature of actors’ discourse about the energy targets. For example, Construction Co. may emphasise that the responsibility for energy performance lies with contracted designers:

    The M&E consultants have the “contractual obligation” for energy performance.

    (FN - talking with Engineer 3)

    “it’s on their P.I..”

    (Int - Design 1).

Equally contractors themselves may try to limit their responsibility by emphasising that their work offers “recommendations not promises” (Ints - Contractors 2, 6, 7, 8).

Actors responsible for producing design “theory”, or for reviewing it, may also emphasise its limitations. For example, construction managers and engineers criticise designers’ practical experience or the vagaries of energy modelling, and designers and bid teams emphasise the number of assumptions they have been asked to make:

    He admits he has “never had any DEC’s or anything like that, so I don’t really know…”

    (Int - Contractor 8)

    What appears to be “gospel” in assumptions turns out to be “guessing” because a conversational estimate has been input to a model.

    (FN – environment team meeting 1)

Engineer 3 describes a resulting temptation to use professional processes as “an arse-covering exercise” (Int - Engineer 3). Contrasting the reliability of “theory” and “reality” hence allows professionals to account for the potential errors of energy performance, by drawing attention to the systemic problems in construction processes and systems.
This has the potential effect of displacing specific accountability from them or their organisation onto more generic difficulties with the prediction of energy performance.

For Gilbert and Mulkay’s community, and for the construction team, the repertoires that describe reliable and unreliable work are mutually reinforcing, forming two sides “of the same coin” (1984:79). In the case of the energy targets, the more that “theory” is represented as unreliable, the more it forms a contrast to the reliability of “reality”, and the more difficult and risky the task of meeting the energy targets becomes in actors’ talk. This in turn is likely to increase the anxiety about blame for professional errors, and so further reinforce the incentive to emphasise the problems of “theory”. If professionals’ discourse focuses on liability management in this way, they are more likely to shy away from investigating reasons behind energy performance issues. For instance, bringing more of the energy-related knowledge currently vested in contracted designers into Construction Co. itself would increase on site staff’s visibility of data and uncertainties, but it would also bring unwelcome costs and risks with it:

Bringing energy modelling in-house would bring risk in-house.

(FN – environment team meeting 3)

As another example, Construction Co.’s staff often talk about the problems of unpredictable occupant behaviour, for which they are not liable, but rarely mention the performance of the building fabric, for which they are:

“Project Co. 1: Do we do thermal imaging of our projects? Not as a general rule. You know, you can buy a thermal imaging camera for nothing, but do we do it generally? I don’t think we do.”

(Int - Project Co. 1 and 2)
This dialogue around risk could prevent Construction Co. pursuing more sources of “real” energy data, which would increase its ability to mediate between theory and reality.

Successful comparison between theoretical models and actual outcomes requires a significant stream of empirical data from previous projects to improve predictions (Zapata-Lancaster and Tweed, 2016), which will not occur if modelling processes in design are viewed as theory-driven and separate from experience. Furthermore, there is a danger that feedback might also go in separate directions, so that modellers and designers get better and better at producing “theory”, and engineers and facilities managers get better and better at observing “reality”, without a correspondence between the two. Direct experience of previous projects and a “feel” for what might happen in reality are critical when attempting to predict the outcomes of complex and uncertain systems (MacKenzie and Spinardi, 1995). However, what is reported by participants is sometimes a “feeling” for compliance (Int - Contractor 6, FN - attending pressure testing). The valuing of “reality” over “theory” loses the opportunity for each to learn from each other. This is illustrated in Figure 5.2 below, which contrasts an “optimal” feedback process in which design has access to data from previous projects, with the current separation between the “theory” and “reality” of energy use in buildings.
5.2.4. Reflections on the repertoires of theory and reality: what is “real” energy?

The findings so far, drawn from the analysis of Gilbert and Mulkay’s repertoires, raise a question as to how “real” energy “reality” actually is, and whether measuring it is as simple as some participants suggest. This is not often discussed by participants, with a few exceptions from within the Construction Co.’s energy experts group (Int - Engineer 2a, FNs - meeting with Engineer 6, conference call with Engineer 1). Most participants,
however, begin to stumble when asked to describe operational performance in more detail. So, for example, when asked about how practically you might untangle which performance variations are due to design or construction (for which Construction Co. is liable), and which are due to occupiers (for which it is not), Construction 3 cannot be sure, and reverts to telling me, “the only thing you can measure is the energy usage”. Gas and electric are metered and electricity is sub-metered at department level. It is all in the PCPs [Project Co.’s Proposals]” (FN - meeting with construction). Others from different departments are equally unsure:

“I don’t know how that process would necessarily work. But I think usually there’s pretty thorough investigations into rationales and reasons why something hasn’t been achieved, if it’s contractually required… So it’s not something I tend to get so involved with initially…um I think given the fact that the risk sits within ultimately it’s the contractor, in terms of if things haven’t been done properly. I think it would be fairly you know extensive investigations into why, given the money to put things right.”

(Int - Legal 2)

“Um how d’you do…? I’m just trying to think how you would do that. Um I mean Facilities…if I…Facilities – I can’t say it – Facilities must do some monitoring. Because they’d be daft not to go round and look to see is stuff different here? Because in other places, people leave windows open.”

(Int - Design 2)

The challenges of pinning down what affects energy in operation illustrate how difficult participants perceive mediation between the theory and reality of energy performance to be, and how they may not often discuss it.

To add to this, the above analysis has dealt principally with energy use. However, the hospital’s targets also include carbon emissions, which was is one of the most unusual
features of this case study, and also one of the most demanding for the team to deal with. Yet although the contractual penalties for exceeding the target carbon emissions are given equal emphasis to energy in the hospital’s contracts (Docs - construction energy targets penalty clause, Project Agreement Payment Mechanism), the means of mediating its target expectations are not a theme that features in participants' informal discourse, outside the lawyers and engineers who have looked closely at the contract clauses. Once again, this suggests that reconciliation efforts between theory and reality may be incomplete, or unaddressed, and require an engagement with more elements than a comparison of two numbers.

Therefore the discourse around “accounting” for any potential “error” in meeting the energy targets reveals a number of insights. Firstly, it highlights how the introduction of energy targets not only does not completely overcome the separation between the theory and reality of building energy performance, but also perpetuates “the gap” in some instances. One way to discuss the energy targets could have been to talk about how the building’s energy use is represented in a number of different ways from models to measurements. Such a conversation could take account of how expectations of energy (and carbon) gradually change through design, construction, and operation, thus replacing concern with “errors” with an acceptance of evolution. Instead, participants’ discourse separates the ways of representing the building’s energy use into what are effectively two buckets: unreliable design predictions; and reliable measurements in operation. This discursively sets up the problem of a “gap”.

The fear of professional liability for energy use is a key driver, as it encourages actors to ring-fence particular tasks. A lack of information and supporting tools that prevent actors bringing together different representations of energy is also problematic. The
repertoires of theory and reality allow the displacement of why errors might occur onto systemic difficulties rather than specific individuals or organisations, and prevent actors exploring the reasons for any such difficulties in more depth. The consequence may be that opportunities to improve their understanding of energy performance in buildings are lost. However, the division between “theory” and “reality” is not the only repertoire found in the data.

5.3. Constructions of uncertainty: differences between formal and informal repertoires

One of the principal findings of Gilbert and Mulkay was that the community of scientists that they were studying drew “selectively” on different interpretative repertoires “appropriate to the different interpretative contexts they are involved in” (1984:40). The language that scientists used in written, formal sources, such as journal papers, emphasised the impersonal, objective nature of their research. However, in informal settings, the scientists used different language, which acknowledged scientists’ personal impacts on research findings. Therefore, not only did the scientists use formal language to make their findings appear more authoritative, they achieved this by actively “suppressing” what Gilbert and Mulkay call “contingent” influences, such as alternative perspectives, areas of speculation, and social pressures, all of which appear frequently in informal discourse (ibid:47). In this section, I will discuss how construction team actors’ formal and informal repertoires around the energy targets differ.

The data I have used for informal sources are interviews and field notes; for formal sources, I have used documents. This directly follows Gilbert and Mulkay’s approach. However, where appropriate I have made exceptions. So, for example, field notes to a formal meeting have been used an example of formal discourse, or emails between
colleagues have been used as examples of informal discourse. I have also selected the formal and informal discourse around one particular area of significance to the energy targets: that of uncertainty. Partly this picks up on one of the key difficulties just outlined in the previous section, which is actors’ anxiety that something will go awry between design and operation. However, I chiefly selected uncertainty as it emerged strongly from my analysis as a frequent topic in informal data, but was noticeably less frequent in formal sources. I was therefore keen to explore the contrast more systematically using Gilbert and Mulkay, to establish whether construction actors were “suppressing” contingent aspects in their formal accounts of the energy targets.

Before presenting the findings, it is worth making a quick diversion into the nature of “uncertainty”. Signing up to the hospital’s energy targets is like “going into uncharted territory”, as one participant tells me (Int - Engineer 2b). However, this is not a welcome quality in the commercial sector, which prefers predictable outcomes for its projects. As the company cannot be sure that it will meet the energy targets, then “uncertainty” becomes “risk”, whether characterised as financial, reputational, technical, or other. There are of course more rigorous ways of conceptualising environmental risk. Wynne (1992) for instance, in considering policies that address future environmental impacts, breaks down “uncertainty” into components that make it more than a simple doubt about the future. Here, however, my purpose in using discourse analysis is to understand how actors “in the gap” construct the challenges of energy targets, in their own words. Therefore, following Gilbert and Mulkay, I have used the participants’ own terms, in which “uncertainty” and “risk” frequently overlap.

5.3.1. The formal repertoire of uncertainty

One of the main arenas of formal discourse is the bid and design documentation. These are produced with the aim of impressing the client, winning the bid, and
establishing Construction Co.’s proposals for the project. As the PFI tender requires bidders to advance designs to planning readiness, the documents also demonstrate compliance with planning requirements. Together, these documents provide an official account in which confident expectations of the hospital's energy and carbon performance are presented:

“The design has developed a combination of plant and building construction that will deliver a scheme with lower energy consumption, whilst hitting carbon targets. The achievement of these targets will be achieved by use of the [renewable energy] plant. This proven solution has the additional benefit of reducing the risk of increasing energy costs due to the high proportion of renewable energy used.”

(Doc - Site Sustainability Strategy)

“During the dialogue stage we shared with you our journey in arriving at our proposals to meet your requirements. We have confirmed that your targets were challenging, yet achievable. Now we have undertaken a full modelling exercise using IES dynamic simulation, we propose exceeding your expectations in terms of energy usage, carbon production and the renewables content of our scheme. We are confident that we will deliver. This is based on the detailed analysis undertaken to date on our proposal and our proven track record. We deliver quality PFI healthcare facilities which have been shown to operate within the energy predictions from our energy models.”

(Doc - bid team answer plan)

However, there are some hints within these documents of what could go wrong. For instance, the bid team draws the client’s attention to the assumptions made about energy use in operation:

“It is important to recognise that if the energy and summertime temperature conditions are to match the predictions then the new hospital must be designed, constructed and operated within the agreed criteria. Variance on any one of the inputs can and will vary the output.”
This caveat is accompanied by a table dividing up responsibilities between Project Co. and the NHS Trust. However, the neat division of responsibilities, for items such as “room environmental conditions - Trust” or “plant efficiencies - Project Co.”, does not take account of the ways in which these could interact in the eventual energy use of the building, nor does it acknowledge uncertainties within the predictions themselves. Hence, whilst some uncertainty is acknowledged, it is not discussed in detail.

Formal repertoires are also used by the hospital project’s subcontractors, and show similar characteristics. One contractor’s presentation delivered to Construction Co., for example, states their credentials in terms of “Competence”, “Reliability and Quality”, and backs this up with detailed technical specifications (Doc – Design Presentation Contractor 9). Another contractor even offers “project certainty” as a specific part of their branding (Doc - integrated layout drawing 1). The discussion over the expected performance of the renewable technology provides another example. Its efficiency is emphasised not only by Construction Co. to the client, but also by the supplier to Construction Co.:

[The technology is] “extremely efficient in capturing energy and converting it to heat and cool buildings sustainably.”

(Doc - Project Co. Proposals for Energy and Carbon)

“By dynamically responding to the demands of the system in this manner we can optimise the temperature of water returning to the heating plant, thus ensuring maximum operating efficiency at all times.”

(Doc - RE description of operation)

However, the renewable suppliers add a proviso to their document, noting that the quoted coefficients of performance “are approximate and depend on a number of
factors, included the effectiveness of system maintenance" (Doc - RE description of operation). This echoes Construction Co.'s caveats above regarding operating conditions. Any uncertainty in performance is therefore passed on to the user, who, in this case, will be Construction Co.'s facilities and maintenance team.

A further deployment of the formal repertoire is found when participants are reviewed by more senior staff in Construction Co.. This understandably leads actors to put their best face forward on any uncertainties. Engineer 2, for instance, is asked to respond to an internal review of the renewable technology proposals by a senior in-house engineer. He explains his approach to me: "So I gave him the brief, he gave the peer review, and this is so...he's opened a can of worms now, and now we've got to close them. This is our proposals, his questions, we reply and then we close them..." (Int - Engineer 2b). His responses are therefore designed to “close” uncertainties about the design:

“Our consultants have produced a comprehensive energy model. Construction Co. would not normally go into this detail prior to Preferred Bidder award, but as energy and carbon consumption is of particular importance to this Client it is appropriate that we have invested the necessary time and fee into the energy simulation. Moreover this level of detail will assist the quality of our submission. The level of detail also provides Construction Co. the assurance that both energy and carbon targets can be achieved with confidence”.

(Doc - notes to assist internal peer reviewer)

“Reviewer: The view from this Peer review is that the COP`s are optimistic

Response: Point noted and this will be looked at in more detail during the next stage. However; All the performance information has been provided by our [technology] specialists [name] and is warranted by them (subject to design load profiles and ... conditions). The COP`s have been based on simultaneous heating and cooling units, the [technology] proposals, and the desk top studies discussed
in previous comment…The COP’s stated are thought to be reasonable and within acceptable limits."

(Doc - response to internal peer review)

There are other examples of this. For instance, the bid team’s approach to internal Board approval is phrased in a similar way, and, in the exchange of experiences for the webinar on energy targets that I took part in, some participants were initially keen to promote successful projects rather than difficulties. The difficulty of admitting to failure, and the impact on effective learning, is something that will be returned to in Chapter 6. However, here it indicates how the need for commercial approval drives positive views of the energy targets.

Overall, in written, formal accounts of the energy targets, the vocabulary used tends to be positive. Words such as “optimise, maximise, achieve, deliver, will, can, exceed” are used:

“All software shall be fully tested and proven.”

(Doc - BMS specification)

“We set out the results of our detailed studies on energy, carbon and Part L 2010 compliance and share with you how we will exceed your expectations.”

(Doc - bid team answer plan)

“To support this longer-term flexibility and maximize energy efficiency, building information modelling (BIM) is being used.”

(Doc - news 6)

Formal discourse also tends to emphasise new, technical solutions to energy efficiency, such as renewable energy:
“The achievement of these targets will be achieved by use of the [renewable] plant. This proven solution has the additional benefit of reducing the risk of increasing energy costs due to the high proportion of renewable energy used.”

(Doc - sustainability strategy)

Formal documents also deploy tables, and lists of figures and features to support energy projections. The numbers are often quoted as precise figures:

“We will deliver your new hospital which will exceed your expectations in terms of energy use, carbon production and renewable energy content. Your energy target is \(XX\text{GJ}/100\text{m}^3/\text{annum}\). We will deliver \(XX.X\text{GJ}/100\text{m}^3/\text{annum}\)

Your carbon target is \(X.XX\text{ Tonnes}/100\text{m}^3/\text{annum}\). We will deliver \(X.XXX\text{Tonnes}/100\text{m}^3/\text{annum}\)

Your renewables target is \(XX\%\). We will deliver a \(XX\%\) reduction in carbon utilising renewable energy sources …”

(Doc - bid team answer plan)

The vocabulary, themes, and level of positivity of informal talk around energy targets’ uncertainties provide a contrast to this.

5.3.2. The informal repertoire of uncertainty

The vocabulary used in informal discussions includes words such as “might, may, likely, could, depends, affected by” to describe performance against the energy targets:

“There's an allowance in there for the fact that it might have a U-value of X, but actually there's a human factor, there's a bit of slack.”

(Int - Engineer 3)

“But, you know whether it turns out to be reliable or not and accurate, it depends I suppose on your confidence with the modelling process.”

(Int - Engineer 6)
[Engineer 7] says all sorts of parameters affect the results and therefore outcomes are very variable.

(FN - conference call on energy targets)

As in the formal repertoire, the new systems and technologies deployed because of the targets also appear regularly. However, in informal repertoires these can be the source of anxieties amongst the construction team. These are expressed in informal discourse that contrasts with the positive statements made in the formal repertoires:

“Because it’s not something...it’s not a dead cert if you know what I mean?...Because when you got a boiler, it does what it does. You got a chiller, it does what it does. But [the new renewable energy system] seems to be a bit more...um...unstable, if you want?”

(Int - Construction 1)

“I know that is...it does have very high aspirations from an energy perspective, and using things like the [renewable technology], and the interface with the boilers, which will have different energy efficient ways of heating water. That’s fantastic. How does it work? I don’t know yet.”

(Int - Facilities 2)

Technological uncertainty is of particular concern to those in the facilities team, as they do not often have experience in operating low carbon buildings (FNs - talking to Environment 6m; meeting between construction and facilities management). The overall concern is therefore that the renewable technologies might not deliver what has been promised.

In addition to technologies, people come to the fore in informal discussions of uncertainty. Stories highlighting the foolish things that occupiers do with energy systems in buildings are frequent. For instance, “sometimes the caretakers and those
sorts of things will just fiddle around with stuff” (Int Project Co. 1 and 2), or occupiers leave windows open (Int - Design 2), and the lights on all day (Int - Engineer 3). The problem as articulated by Construction Co. appears to be one of a lack of control over occupants. Construction 3 and Facilities 1, for example, agree that changing a set point should require “a permit” (FN - meeting between construction and facilities management). Therefore the operational period becomes a risk for Construction Co.:

“We used to always think that the construction period was the kind of risky period, and I think now …the operational period is actually causing us some losses because of the way the contract’s interpreted.”

(Int - Legal 2)

Users are therefore identified as a key uncontrolled risk to the hospital’s eventual energy performance against the targets.

A solution to the uncertainties around technologies and their operation that is often cited in informal discourse is the introduction of a numerical cushion, or safety margin, between the official targets and the background calculations of what Construction Co. hopes to achieve. This is bolstered by shifting some of the legal responsibility for energy performance onto the client. The dual strategy is summed up neatly in an internal review by the engineering team:

“For previous bids we have modelled energy consumption, linked the annual consumption to the Utility Protocol [which describes responsibilities for energy efficient use of the building] and incorporated a safety margin to protect Project Co. from the risk of surplus energy payments.”

(Doc - internal analysis of NHS Targets)

This approach has also been applied to the hospital. The safety margin is referred to in various ways by participants. Construction 3 and Contractor 6 talk about “headroom”
Engineer 3 refers to “an allowance” or “a bit of slack” (Int - Engineer 3). Design 1 also talks about a “percentage in the back pocket” (FN - on site field notes 1), which is intended to leave “tolerance in there so when everything’s installed and commissioned things go up slightly and down slightly [sic]” (Int - Design 1). There is no mention of the safety margin in the formal documents.

The approach does not appear to be unique to the hospital’s energy targets. Engineer 1, from head office, says that they “tend to use a 10% margin” on the energy modelling for all their projects (FN - conference call with Engineer 1), and an environment manager who predominantly works with commercial projects says that “there is a 3% buffer. One of my building managers won’t accept a model unless it has this” (FN - environment team meeting 3). The concept also appears as a means to manage other energy-related targets. A “margin of safety” is used in energy retrofit estimations (Int - Engineer 6), and for BREEAM:

“we always want to aim if we can to get at least 5% above ...the target score. Because if there is something, if something drops out of the design um then…or at the construction stage something’s not done, then you use your buffer instead of falling below.”

(Int - Contractor 1)

Thus the safety margin strategy appears to have been borrowed from standard projects without operational energy targets.

However, even with the margin of safety, participants do not necessarily feel secure. So, for example, in describing a major redesign of the chillers in the hospital, Engineer 3 tells me that they have emerged with a reduced energy prediction, but that this is
“more by luck than judgement” (FN - talking with Engineer 3). Moreover, as one of the design engineers observes, adding margins to something already uncertain does not necessarily leave you in a clearer place:

“because you just don’t know how a building...because from an energy point of view actually how it performs in real life. But yeah that’s a bit of an er a difficult one where it sort of ends up because this is trying to you know...with the best will in the world you ...the problem is with margins, is there’s margins in...you sort of end up with margins on margins on margins don’t you?”

(Int - Contractor 6)

The safety margin is moreover bolstered by legal protections. These are based on the logic, as one participant describes:

He says see it like a car – they can guarantee what it will do if you drive it at 50, but if you want to speed up or change gear that is your choice.

(FN - talking to Environment 60)

Hence, clauses are specifically included in the contract to put the onus on occupiers to use the building as efficiently as designed, through “good housekeeping” (Int - Legal 1). These clauses protect Construction Co. from some of the liability for unexpected deviations in energy use. Engineer 2 describes how this strategy was deployed on a previous hospital project where the operational energy targets were not met:

“We had to call in some of our mitigations. And the mitigations typically was that the hospital would have to do best housekeeping in accordance with EnCO2de, which we luckily put into the contract. And the Primary Healthcare Trust had been converting a lot of the clinics to wards and there was blatant instances of them not being energy efficient. So we kind of got ourselves off the hook.”

(Int - Engineer 2a)
Legal “mitigations”, however, are a last resort, as they cause damage to the relationship with the client. This is illustrated by an anecdote about another building with operational targets told by Engineer 1. In this story, Construction Co. avoided the full penalty because the client had not understood the guidance issued to them for recording their building’s energy use, and so the data could be dismissed as unreliable by Construction Co.. The cost to Construction Co. was therefore “little” in terms of the immediate financial penalty, but “huge” in terms of harm to the customer relationship and its brand (FN - conference call with Engineer 1). This illustrates some of the potential downside in approaching uncertainty through risk mitigation.

The above discussion has so far analysed what participants talk about when considering uncertainty around energy targets. It has not yet considered what they fail to mention. So whilst users figure frequently in discussions of uncertainty, the fabric of the building does not. This is unfortunate, as research suggests it can be an area of significant uncertainty (Li et al., 2015; Stamp et al., 2017). The energy modellers for both the hospital, and the office that I studied in my early work, tell me that predictions for the fabric performance of a building are much more accurate than the assumptions relating to occupants (Ints - Contractor 8, and Contractor office 2). Engineer 6 also maintains that problems with modelling do not lie in the thermal performance of the fabric as “it’s easy to predict the performance of a building” (FN - meeting with Engineer 6). This chimes with the repertoires of “theory” and “reality” described in the previous section, in which emphasis was placed on occupier activity, rather than the fabric of the building.

In addition, other areas of potentially material uncertainty in meeting the energy targets are mentioned very infrequently. These include the choice of emissions factors used to
convert between energy and carbon, which fluctuate with the national energy mix, and electrical loads from equipment. Only one participant, who has had more contact with the modelling process, brings up the latter, and in doing so, illustrates the potentially significant uncertainty that is inherent in the calculations (Int - Contractor 8). Interestingly, Gilbert and Mulkay also note how insiders, who were also members of the same specialised community of biochemistry as the journal authors, were able to “translate”, or fill in the gaps of contingencies that had been “suppressed” in formal accounts. Those outside the particular community, and hence lacking the technical and contextual background, could not do this (1984:54). It is important to note that those with more direct experience of energy targets also tend to have a more nuanced view of uncertainty.

These more nuanced accounts of experienced professionals appear rarely, but with much more detail offered around uncertainty when they do. For instance, an external expert review of the energy targets is the one of the only documents to note the underlying uncertainty of all inputs to the modelling, possible effects of variations over time, effects of maintenance schedules, and to recommend the use of CIBSE’s TM54 (Doc - questions from external reviewers). Other examples come from participants in the energy experts group, and a few members of the environment team who have been required to think more strategically about energy performance. For example, Engineer 6 tells me that:

“Everyone uses the language of targets and guaranteed performance but in reality it should be predicted energy performance. It’s very important to manage expectations of what a guarantee is.”

(Int - Engineer 6)
He is also willing to admit that the assumptions made in modelling are “massive” and “unpredictable”. Environment 6 is also aware of the complexity of “overlapping dependencies” and “what ifs” (FN - talking to Environment 6 a and h), and the many details of uncertainty comes up as a key theme in the webinar of energy experts (FN - notes from webinar dry run). However, like the rest of the findings above, these more subtle considerations of uncertainty appear to be confined to informal discourses.

Table 5.2 below summarises the characteristics of the formal and informal repertoires.

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<th>Repertoire:</th>
<th>Formal</th>
<th>Informal</th>
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<td><strong>Contexts</strong></td>
<td>Bid &amp; design documents</td>
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<td>Precision</td>
<td>Mitigation</td>
</tr>
<tr>
<td><strong>Uncertainty</strong></td>
<td>Suppressed</td>
<td>Acknowledged</td>
</tr>
</tbody>
</table>

*Table 5.2 Formal and informal repertoires of uncertainty*

5.3.3. Reflections on formal and informal repertoires: why might they diverge?

Following Gilbert and Mulkay’s approach, the findings indicate that formal and informal discourse construct different representations of the uncertainty relating to meeting the energy targets. The distinction does moreover appear to be “selectively” deployed, as discourse appears to vary consistently between formal and informal contexts. There are obvious commercial incentives for the differences, given the motivation to present optimistic views to more powerful stakeholders, whether internal or external. In these
findings, such stakeholders include clients, planning authorities, and senior management in Construction Co., as well as subcontractors presenting their plans to Construction Co.. Therefore the formal repertoire does appear, in Gilbert and Mulkay’s terms, to “suppress” issues that make the achievement of the energy targets uncertain when talking about them in formal contexts.

However, there are also differences between this case, and that of Gilbert and Mulkay. One of these is around the question, raised by Gilbert and Mulkay, as to what extent actors are able to translate between formal and informal repertoires. In Gilbert and Mulkay this is a relatively minor issue, as they were largely studying a homogeneous community of biochemists. The construction community is much more professionally diverse. As already described in Chapter 4, construction teams are divided by, amongst other things, profession, project phases, and contracts for packaged works. This renders translation or an insider view of the energy targets much harder to achieve. For instance, as shown above, the few participants who are exposed to the details of energy modelling or monitoring are much more aware of the potential areas of uncertainty when they talk about it. By contrast, others stakeholders are unlikely to appreciate what complexities underlie formal discourse around energy use:

“His clients have a perception of accuracy – but do not understand it is only a simulation.”

(FN - conference call with Engineer 1)

The significance of this for energy targets is that there may be far from a uniform understanding of what it is that is being promised by the energy targets, and the potential challenges of meeting them.
A key driver is provided by the contracts. The original ethos of PFI (section 3.5.2) is that:

“each risk should be carried by the party best able to manage it. This will depend on each party’s ability to accurately predict and control the issues representing the risk.”

(Doc - information for bidders)

Thus the hospital contract passes the risk of energy use onto the construction company. The worry expressed informally by many participants is that the energy targets represent a risk that they will struggle to predict or control:

“CW: Do you feel fairly comfortable with this?
Facilities 3: No! [laughs]
CW: [laughs] What bothers you about it?
Facilities 3: It’s just where the risk lies. I mean um there’s a pain/gain share mechanism um and we’re not quite sure what the risk is around that.”

(Int - Facilities 3)

Whilst managing various sorts of uncertainty is a familiar, if not a comfortable, part of many aspects of construction, data on energy in-use is still “quite poor” so it is much harder to “risk profile” it (Int - Environment 8). Construction Co. may therefore need to present a confident view of the energy targets to win the bid for the hospital, but express concerns about their feasibility in private.

This pressure for expressing confidence about energy and carbon in formal situations can be discerned in the formal bid documents for the hospital’s tender:
“Bidders should produce and submit an energy model with their commercial bids. The model should *predict* Energy consumption based on the design and Trust output specification requirements.” [my italics]

(Doc - government guidance provided to contractor)

The contractual definition of the targets does not allow for uncertainty, beyond a small percentage allowance either side of the target figures given. Therefore it provides little tolerance for the contractor:

“Cos the only question that you've got to answer, is will you achieve the energy use. The rest of it around it is almost fluff. You need to know, will we achieve that target. And it's a yes or a no. It's completely binary.”

(Int - Engineer 3)

The penalties for exceeding the hospital’s construction energy targets, whilst offering an incentive, could also be conducive to encouraging a legal debate about who is to blame, rather than productive energy management:

“If … there is any indication that the thermal and energy efficiency of the Facilities causes energy use exceeding X Giga Joules per 100m$^3$ per year, the parties shall investigate the matter to determine the cause of such failure either in the manner agreed between them or in such manner as may be determined in accordance with Schedule 26 [the Dispute Resolution Procedure].”

(Doc - construction energy target penalty clause)

It is therefore often down to the relationship with, and personality of, the client as to whether divergences in operational energy use and carbon emissions are treated collaboratively or with acrimony. Some participants, who have been involved in previous projects with energy targets, attest to positive experiences:
“In some projects they have meetings every 6 months – they gather data and discuss the variation, so by the 2 year inspection the client already knows everything and there are no surprises.”

(FN – conference call with Engineer 1)

“At X for example...the hospital employed their own energy manager, as did we, so they worked together.”

(Int – Engineer 2b)

However, if the relationship is less positive, the net result of being asked for formal certainty about energy use whilst expressing fears of its uncertainty informally, is that actors may feel resentment for the perceived risk that the targets represent:

He doesn’t see why they take on the risk for all the energy use— he doesn’t think all of it is ‘in the gift’ of the contractor. Surely it should be shared?

(FN - meeting between construction and facilities management)

“They put the risk onto us. We carry it all.”

(FN - meeting with construction)

“A warts and all target. Absolutely everything. Which is a bit unfair because if you take operating theatres, pharmacy, pathology, laundry, kitchen, sterilisation, you’ve got process loads there that is nothing to do with energy efficiency.”

(Int - Engineer 2b)

The solution for Construction Co. can be to draw boundaries of control, and manage uncertainty by passing off some of the perceived risks. The object is to avoid anything too “onerous” (Int - Legal 1). Design 1 puts this more practically:

“Onerous in terms generally of the interpretation of it. Or whether some things that they are trying to put on ourselves which are not necessarily applicable for this type of project.”
This is also a concern for the bid team, where a manager tells me they were wary that "we didn’t sign up to something that might trip us up" (FN - call with senior bid team member). Rather than investigate uncertainty, or tackle it head on, the urge could be therefore to avoid accountability for it. This echoes the discussions of professional liability in the previous section around “theory” and “reality”. Once again therefore, analysis of divergent repertoires in actors’ talk has helped reveal some of the underlying drivers that operate on actors “in the gap”.

To summarise, using Gilbert and Mulkay’s repertoires reveals how the construction team are prone to discuss their work in more confident and certain terms in formal contexts than they might in private. In construction, commercial pressures, contracts, and lack of access to information drive the discursive separation. Contract terms, whilst forming a major part of the rationale of energy targets, in making the construction company responsible for the performance in operation, also provide an odd perverse incentive to over-represent the certainty of meeting it, whilst covering your back with legal “mitigations”, and hedging the numbers in the background. In addition, the diversity of professions and tasks in the construction team makes the difficulty of translating between formal and informal repertoires much more difficult. This raises the possibility that uncertainty is not perceived or tolerated by stakeholders when it should be, such as by the client. Conversely, a lack of information or understanding may make construction actors unduly wary of committing to energy performance in operation. The implications of this, and of the previous repertoires of “theory” and “reality”, will now be drawn together in the conclusions for this chapter.
5.4. Discussion and conclusions: separate conversations

5.4.1. What has been learnt

This chapter set out to explore what can be learnt about a construction team’s response to energy targets through their talk. Using Gilbert and Mulkay’s interpretative repertoires it has examined two aspects of the construction team’s discourse around the energy targets: one in which they verbally separate the “theory” and “reality” of building energy performance; and another which contrasts their formal and informal discussions of the uncertainties surrounding the energy targets. There are likely other repertoires that could have been examined. However, even these two demonstrate that construction professionals’ discourse can reveal how they construct the challenge of operational energy targets in their own terms, and their sometimes-unexpected responses to them.

In section 5.2, repertoires of “theory” and “reality” revealed actors’ scepticism about the ability of existing tools and processes, such as energy models or design specifications, to help them manage the hospital’s energy in operation. Actors use the repertoires to distinguish between reliable and unreliable professional practices around energy, and in doing so attempt to limit their liability for any problems that might emerge, and their willingness to investigate underlying reasons for any “gap”. Section 5.3 explored contrasts between formal and informal repertoires around the targets, using uncertainty as an example. This revealed how formal accounts of the energy targets are more positive, “suppressing” aspects of uncertainty that could affect energy use. Furthermore, the ability to perceive uncertainty is potentially affected by the individual actors’ level of previous experience in dealing with operational energy efficiency or
energy targets. Once again, contracts were shown to encourage caution, or defensive attitudes, to understanding energy use.

5.4.2. Grappling with new forms of uncertainty, risk, and liability

Using the concept of interpretative repertoires to analyse the empirical data allows a few common themes to arise from both sections. The first of these are the occasionally perverse effects of contractual terms, acting between the client and Construction Co., and Construction Co. and its suppliers. Contracts can promote the allocation of blame between different parties, and hence encourage the control of risk. The emphasis on liability management promotes an arguing of the ins and outs of energy target definitions, rather than tackling underlying difficulties in energy use and associated carbon emissions. Corporate pressures can also discourage conversations with clients around exactly what it is feasible or sensible to ask builders to guarantee in terms of energy performance. If construction companies are asked to envisage uncertain futures in definitive terms at the risk of penalties, they may baulk and look for ways around.

A second theme is the limited adaptation of standard ways of working to the energy targets. As raised in the Literature Review (section 2.2.1), energy targets are sometimes promoted as providing an incentive to collaborate. However, they are not automatically accompanied by any new framework or changes to ways of working, such as, say, in integrated design. The construction processes in this project do not necessarily facilitate the exchange of information relevant to energy performance in operation, due to commercial barriers between companies and professional teams. For instance, although significant efforts have been made to advance the design beyond where it would be on a standard project, the technical design is not completed until after the contractual energy targets are signed off. As another example, data from Construction Co.’s, or its subcontractors’, previous projects are not uniformly fed back
into designers. This may impede Construction Co.’s ability to monitor energy expectations through the construction phase, and hence to make important links between design “theory” and operational “reality”, and address areas of uncertainty. Each building is unique, and no design prediction can be expected to foresee exactly how much energy will be used in a building’s future. Nevertheless, there are some practical means, such as the ones just mentioned, which could help improve the current processes.

A final theme that emerges from this chapter is that the construction team actors appear to value the familiar, the controllable, and the tangible. They talk about their understanding of energy use in situated and embodied terms, being linked to projects they have worked on, people they trust, and data that is measured and monitored. Yet energy targets are unfamiliar, intangible, and uncertain for much of the building’s development. The concept of the targets may therefore generate anxiety, or sometimes resistance, amongst construction actors. Dichotomous representations of truth and error, guaranteed delivery and “uncharted territory”, which reflect the possible performance gap between design and operation, hence persist, rather than dissolve in this case.

5.4.3. Implications: alternative discourses

The separate conversations around theory and reality, or formal and informal constructions of uncertainty, have the effect of displacing alternative discourses about the energy targets. The opportunity for conversations with clients, regulators, and suppliers that acknowledge uncertainties about energy use does not therefore appear always to be taken. This could impact on the potential of all stakeholders of the building to investigate and learn from mistakes, and so to improve energy estimates in design. If more attention is not paid to discussion of why there are differences between design
and operation, opportunities for collaborative learning may be lost. Tools that could help, such as TM54 (Chartered Institution of Building Services Engineers, 2013), and the Soft Landings framework (Agha-Hossein, 2018), have either not been used, or not used to their full potential. This means that a more detailed and more widely circulated discussion of energy modelling in particular, and what it can offer, is not achieved.

The dialogue between construction and suppliers instead seems to concentrate on the allocation, rather than the sharing, of responsibility. Continuing to talk about the uncertainties and difficulties of energy targets may also encourage actors to translate targets into risks to be managed, rather than opportunities for individuals and their organisations to develop experience in better-performing buildings. It may even discourage the construction company’s willingness to undertake more projects with energy targets, as has been found elsewhere (Janda and von Meier, 2004). Innovation could also be compromised, as although the energy targets do encourage Construction Co. to think more creatively about how to ensure performance in-use and to reduce carbon emissions, the risk of the penalty for failure could push them towards safer, established solutions where possible. However, further work would need to be done to establish if these consequences do occur.

The focus on discourse taken in this chapter also uncovers issues with the management of information around the building’s energy in-use. It shows how participants struggle to cope with the inherent uncertainties and fluctuations in the hospital’s energy use. Actors sometimes push uncertainty under the general umbrella of “risk”, and avoid further consideration of the question by the use of safety margins, or by the control of specifically identified problem areas, such as users. The few participants who have more experience of energy targets are aware that these gaps in
information and process exist. However, the percolation of this awareness of into project priorities, and beyond the circle of energy experts, appears limited. This is a theme that will be picked up in the next chapter.

Overall, these findings contribute to the literature cited earlier that illustrates how the construction of stakeholders’ conversations around energy targets can be as important a process as the physical construction of the building itself (Cole, 2005; Janda and Topouzi, 2015; Coleman and Robinson, 2018). Incentives for more low carbon buildings may not produce the results expected if they act on existing professional ways of working in ways that exacerbate existing divisions, rather than overcoming them. If Construction Co. and its contractors felt able to discuss the grey areas of energy performance openly, such as key assumptions and sensitivities, then they might shift away from the black-and-white contrasts of opposing repertoires. A clearer, more nuanced understanding of the eventual energy use of the building could result. For this to be achieved, contractual terms and working processes need to be reconsidered. However, alongside this, more thought about ways to change the conversation about energy targets in construction teams is also needed. Revealing how construction actors problematise the energy performance gap themselves in their conversations about energy targets is one step towards a better understanding of this.

5.5. Reflections on the concept

5.5.1. The value of discourse analysis

Employing discourse analysis has accented the multiplicity of energy performance in a different way to that of Mol in Chapter 4. In the latter, actors’ practices link them to particular realities. By contrast, discourse shows that participants emphasise varying
qualities of reality depending on the context in which they find themselves. This approach indicates that the nature of energy performance can be constructed just as much by the way that stakeholders talk about it, as by their actions in measuring or recording it. Discourse can be a “performance” by which information is deliberately made visible or invisible to other stakeholders (Hilgartner, 2000). Exploring how actors use the discursive spotlight selectively in order to create or undermine credibility helps us consider their motivations to do so, through a sensitivity to the social contexts through which they move in the course of a construction project. This case therefore offers further contextual understanding of discourse around energy targets, or aspirations, in construction (Gluch and Räisänen, 2009; Ludvig et al., 2013). Moreover, the response of actors to these contexts helps us understand more about how a “gap” can arise.

Examining discourse in construction also allows us to bring out the voices in a construction team. It emphasises what is said within the construction team, rather than focussing on the words of civil servants, economists, academics, and others involved in energy policy. Instead of considering the inputs and outputs of design and energy performance data, it allows us the space to ponder how the people themselves characterise energy performance. This permits us to understand how the “negotiation on the ground” takes place (Schweber, 2017:302). In doing so, we appreciate more about how easily actors in this case assimilate the uncertainties of energy targets, how they deploy means of communication to deal with any difficulties, and how they respond to the targets’ contractual imperative to bring together design intent and operation and to increase the reliability of buildings’ performance.
This does more than indicate that the actors use particular terms or concepts to discuss energy performance (Galvin and Terry, 2016). Energy use is recognised by discourse analysis as a subjective presentation of what might “really happen”, mediated through the actors involved. It is these actors and the professional pressures acting on them that really give us insight into what might be happening “inside the gap” between energy target and performance. However, the approach does have a number of limitations, and a short reflection on these is required before turning to the final chapter.

5.5.2. **Imposing discursive order**

Gilbert and Mulkay’s approach sets up repertoires in deliberate contrast to each other. I originally found this an appealing device for its potential to extract differences in the way in which participants spoke about energy targets. This, I hoped, would allow me to grasp the contradictions and communication failures that might contribute to the performance gap. Nevertheless, it may also incentivise the researcher to push the data into either this or that bucket of repertoire, when there may be shades of grey. Both this and the previous chapter illustrate how boundaries may be socially constructed, such as in the distinction between good and bad energy performance, or between theory and reality. A lens of discursive contrasts therefore runs the risk of perpetuating participants’ own dichotomous views of error in energy performance. However, I do believe that the value of Gilbert and Mulkay’s contrasting repertoires lie in their ability to show us how these boundaries are discursively constructed, and why participants want to do so. It is perhaps this that is more valuable than the construction of the dichotomies themselves.

One of my concerns was around the use of interview data to represent informal discourse, which I used in replication of what Gilbert and Mulkay had done. Whether a
recorded conversation, carried out expressly for inclusion in written research, represents an informal interaction could be debated. However, all interview data is unavoidably “mediated” through the participant (Potter and Mulkay, 2007). Yet there is a further danger that, given what has been said in this chapter about the fear of blame or liability in construction, my interview participants were a self-selecting group willing to discuss problematic topics. Without covert research or more intense ethnographic immersion though, these concerns are difficult to overcome. Overall, I felt that this risk was outweighed by the practical considerations of gathering data across different actors in the hospital project and Construction Co. itself, described in 3.4.

I felt that the principal weakness of Gilbert and Mulkay’s work lies in the treatment of reconciliation between repertoires. Their work shows convincingly how repertoires are kept apart, but is more vague about how actors negotiate between the two, as others have observed (Will and Weiner, 2014). For the purposes of this thesis, I have tried to consider the implications of reconciliation more. For example, in the consideration of why actors might want to keep representations of the theory and reality of a building separate, or to consciously or unconsciously obscure uncertainty in energy predictions. In doing so, I have tried to use the repertoires to help reveal the reasons why discourse might influence the eventual energy use of the hospital.

5.5.3. Things unsaid

Discourse analysis is self-evidently based on what is expressed in written or verbal forms. However, my fieldwork indicated that there were many other forms of communication on site. I noticed, for instance, that much communication between professionals revolved around drawings. In the site office, paper drawings are piled up on desks, in the drawing hanger, and pinned on walls. Electronic drawings, in pdfs and BIM, were often given to me when I asked for information or examples of someone’s
work. However, drawings may not even be as formalised as this on the site itself, with notes being made by site workers on the materials to hand, such as a wall (Figure 5.3). Additionally, as workers often may not have English as a first language, the location and management of each area is physically marked by a laminated, coloured map of the building, and also by a large photograph of the Construction Co. manager for that area. Physical examples in the forms of “mock-up rooms” and “benchmarks” are used to show how something should be installed (Figure 5.3). Whilst Construction Co.’s corporate offices seemed to rely more on recorded information, there were still non-verbal messages being conveyed, such as the prominent displays of organisational branding on everything from screensavers to the entrance hall of the building.

This raises the question of what data might be gathered from other types of communication that are not recorded or verbalised. This is of particular relevance to construction, as much of the communication on a construction site is non-written (Mäki and Kerosuo, 2015). The latter work draws on previous research suggesting that on site construction learning takes by place by doing and seeing, and that written sources
of information can be regarded with scepticism by construction workers (Styhre et al., 2006). An analysis of discourse might therefore misrepresent the team’s response to energy targets. However, the focus of my work, as I set out earlier, has not been on the on site construction workers, but on the management of construction (section 3.6.2). The managerial nature of most of my participants’ work made them more likely to be responsible for communicating between different groups of stakeholders that was an area I was particularly keen to investigate.

Lastly, it is important to consider those things which are absent as well as those which are dissonant, as, unlike some other work in STS, such as Star (1991) or Law (2004), Gilbert and Mulkay’s method does not emphasise the importance of marginal points of view or the “messiness” of the findings. This is a theme that runs quietly underneath some of the discussions already put forward, but is not dealt with by Gilbert and Mulkay. When considering uncertainty, I have primarily used the concept of repertoires to explore what is said about uncertainty in energy performance, but I have also branched away a little from Gilbert and Mulkay in considering those types of uncertainty that are not discussed. Similarly, when discussing enactments of a building’s energy performance, I raised the issue that Mol’s focus on practice cannot help us understand what is not enacted, or who is not enacting. Although clearly this is relevant because the enactment of a building creates a parallel possibility of its alternative (Law and Lien, 2013), and, as raised in Chapter 4, there may be strong commercial reasons for avoiding drawing attention to those alternatives. However, the proper examination of these absences would require a different research approach from the one selected here.
5.5.4. In conclusion

I will now pass on the final empirical chapter of this thesis. Chapter 5 has just revealed a lack of trust between actors, a lack of faith in models and predictions of energy, a reliance on personal experience that is challenged by energy targets, and a failure to share mistakes and uncertainties with other stakeholders. In Chapter 4, I also considered how divergent practices lead to different realities of energy performance and targets, and how difficulties arose in the coordination of these. My final chapter will take up some of the questions raised by these issues, by exploring how information about energy targets is shared between diverse professionals. It will consider what systems currently collect energy information, and the differences between formal and informal knowledge. It will also return to the theme of residuals, in the form of missing information, and consider energy targets in the light of other business priorities. In this way, the third and final empirical chapter seeks to build on and link to the questions already raised, but to tackle these through a contrasting and informative analytical framework.
6. How do actors in the construction team share information about the energy targets?

This is the last of the empirical chapters, and considers how actors in the construction team share information about the energy targets. In doing so, it picks up on the themes of information exchange, work processes, and coordination already raised in previous chapters, whilst also adding a final set of insights as to “life inside the gap”. The concept employed is that of the boundary object, as originally developed by Star and Griesemer (1989), but also drawing on Star’s later reflections (2010). The concept retains the interest in multiplicity in professional environments that runs through the two previous chapters, as it describes how actors from different “social worlds” may share (“trade”) information in a common venture, whilst retaining their own identities and objectives. Star and Griesemer’s boundary object thus achieves a delicate balance, facilitating cooperation, yet without enforcing consensus on all its many contributors. The concept has a wide appeal, serving as an inspiration for Star’s later work (Bowker and Star, 1999; Bowker et al., 2015), and for others in STS to develop it further (for example: Fujimura, 1992; Guston, 2001), as well as researchers in many other disciplines. As a result, Star and Griesemer’s work is by far the most cited of the three works that I have used. It is also, as I will argue below, highly relevant to the efforts of heterogeneous construction actors to work together on energy targets.
This introductory section will introduce the characteristics of the boundary object used in the findings, selected for their relevance to the sharing of information amongst diverse actors. It will also, as in previous chapters, provide an overview of other research, in which I will pick out the most relevant material to this thesis, rather than offering a comprehensive literature review of the boundary object concept. The findings will use three aspects of the boundary object to explore how the diverse actors of the construction team share information about the energy targets. Section 6.2 will begin by setting out the social worlds of the construction team. Section 6.3 considers if the energy targets form a common venture for the construction team that can be translated into specific actions. Section 6.4 will then set out in detail how, when, and by whom energy information is being shared (“traded”), and draw attention to “residual” information that is not being consistently captured. Section 6.5 will reflect on why differing boundaries of actors’ priorities might adversely affect the sharing of information about the energy targets. As in the preceding chapters, the concept will be used to reveal insights from which the particular circumstances of the case and the practical implications will be drawn. The overall implications for the construction team’s sharing of information in relation to the energy targets will then be discussed in section 6.6, and, once again, the final section 6.7 will be used to reflect on the usefulness of the concept.

6.1. An introduction to boundary objects

6.1.1. Key concepts

Star and Griesemer’s research began with a “central tension” (1989:387) as to how scientific knowledge could be advanced by the heterogeneous work of many disparate individuals. Their investigation was based around a single case study of the Museum of Vertebrate Zoology in Berkeley, California, and its development during the first half of
the 1900s, and draws on social worlds theory. “Social worlds” form through actors’
collective actions, common sites of work, shared perspectives, and commitments
(Strauss, 1978; Clarke and Star, 2007). The museum involved a potentially
incompatible assortment of social worlds, including “professional scientists, amateur
naturalists, patrons, hired hands and administrators” (ibid:388). Nevertheless, these
actors were able to contribute their own specialisms to the overall development of the
new museum in a way that produced coherent scientific research. The presence of a
number of boundary objects, acting as “bridges” between social worlds (ibid:414),
provided the conceptual explanation for this successful balancing of heterogeneity and
cooperation, and underpinned the eventual success of the museum venture.

A boundary object “exists at junctures where varied social worlds meet” (Clarke and
Star, 2007:121). In order to facilitate negotiations between worlds, it must be “plastic” to
allow actors from each social world to mould it to their specific tasks. However, it is also
“robust” enough to retain “a common identity” across the different groups (Star and
Griesemer, 1989:393). The boundary object therefore operates as “a means of
translation” between social worlds (ibid:393). As a result, participants are able to collect
and “trade” relevant information with others who need it, whilst continuing to pursue the
majority of their work autonomously. Actors are therefore able to “tack back-and-forth”
between the specific and common forms of the object (Star, 2010). It is also important
to note that this is an “analytic concept” (Star and Griesemer, 1989:393) that deals with
the “multiple interpretations of objects”, rather than a theory of “multiple objects” in the
way of Mol and ‘the ontological turn’ (Law and Singleton, 2005:334).

Boundary objects may take many forms, and are best illustrated by some examples
from Star and Griesemer’s case study. One important boundary object for the
development of the zoology museum was the geographical designation of a Californian “nature preserve” (Star and Griesemer, 1989:409). This met many social worlds’ aims, being variously: a “laboratory in the field” for scientists; a political convenience for university administrators; and a conservation goal for amateur naturalists. The physical boundary of the nature preserve was common to all, but the specifics that they hoped to achieve within it were different. So, the founding scientist wished to pursue his work on evolution, the university administration wanted a local mandate for attracting additional funding for the institution as a whole, and amateur naturalists wished to conserve the state’s flora and fauna. Each therefore had a slightly different, strategic goal that was met within the boundaries of the nature preserve. In this flexibility, the nature preserve provides an example of a boundary object formed by “coincident boundaries” (ibid:409-410).

Another crucial boundary object was the development of standardised information systems for the recording of zoological specimens collected in the nature preserve. The structure of such systems is important, Star later observed, as it may “shape and squeeze out what can be known and collected” (2010:607). In particular, “residual” information that does not fit the system structures will not be captured (ibid:609), and indicates that the boundary object is either not well-established, or no longer fits actors’ needs (ibid:613-14). In the museum, however, the standardised systems worked well, and captured information in a format common to all the different social worlds that contributed to them, from professional scientists to local animal trappers. As such, they facilitated “common communication across dispersed work groups” (ibid:411). Thus the development of the museum overall was achieved through a combination of boundary objects, enabling a variety of actors to establish it as a centre of scientific excellence.
A final consideration is the lifecycle of a boundary object. In the original case study, the museum “matures”, as methods and protocols for collaboration become increasingly established between social worlds, even leading to a “common coin” in which to exchange information (1989:413). Star later elaborated on this, describing the “growth and death” of boundary objects (2010:613-4), through their origins from organic alliances between social worlds, increasing standardisation and maturity (as in the case of the museum systems), and final demise through inflexibility. A summary of the characteristics of the boundary object that will be used in this chapter, drawing on both the original and later papers, is shown in Figure 6.1 overleaf.

6.1.2. Why apply this work to researching energy targets?

Star and Griesemer’s case study describes the establishment of “a management system in which diverse allies could participate concurrently in the heterogeneous work of building a research museum” (1989:393). In this final chapter, I wanted to explore if, despite their differences, actors in the hospital’s construction team were still able to share useful information on the energy targets. This is an important consideration as the construction industry often struggles with the “effective diffusion of information” (Harty, 2005:514). Moreover, as already discussed in previous chapters, the difficulties of aligning the interests of the many professionals in construction has often been given as a contributing factor to the energy performance gap (section 2.1.6). Star and Griesemer’s contention that consensus is not after all a prerequisite for successful cooperation is therefore intriguing. The boundary object was the last concept that I chose for my research, and it appealed to me precisely because of this ability to consider how information and actors could brought together in construction, and to explore to what extent the energy targets formed an effective common venture for the case study team. Like the preceding two works, it therefore emerged from my early
work in the PhD (section 3.4.3), which had highlighted differences between professionals' interactions with energy targets “inside the gap”.

**Boundary objects and the sharing of information (Star and Griesemer, 1989; Star, 2010)**

1. Diverse actors work together in a **common venture**, supported by boundary objects that facilitate **translations** into specific work. Actors **tack back-and-forth** between the common venture and their specific work;

2. **Information systems** may form boundary objects for the **trading** of information relevant to the venture. The trading is not effective if there is a large amount of uncaptured **residual information**;

3. **Coincident boundaries** may also form boundary objects to facilitate collaboration.

**Boundary objects form organically over time between actors, and tend to gradually standardise information collection.**

*Figure 6.1 Key points of the boundary object concept used in this chapter*

The boundary object approach also seemed likely to yield practical research insights for the industry around sharing energy information in project teams. I wanted to assess how effectively information flowed back-and-forth around energy in the hospital, to what
extent the actors were “trading” energy information, and what might be encouraging, or discouraging, this movement. As I gathered data on the ways that Construction Co. dealt with information relevant to the energy targets, I found that I was following links outside the hospital project to the company itself. This means this chapter will focus a little more on the construction actors’ experience of other buildings’ operational energy performance, the impact of the company’s wider priorities, and how these might impact on the hospital project. This is unlike the previous two chapters that dealt primarily with energy targets in the project itself.

As in the previous chapter, in which uncertainty required some prior definition (section 5.3), so here it is worth discussing the distinction between knowledge and information, as these could be constituted in a number of different ways, depending on the theoretical perspective employed. When Star and Griesemer refer to “knowledge” it relates to generalisable and coherent scientific findings. “Information” they use as something that is “gathered”, “recorded”, “managed”, and “processed” in steps towards the generation of knowledge. It is the latter activities that they are interested in. In this chapter, I have also taken information as my key concern (except in the case of internal experts and subcontractors discussed in section 6.4.2). In my case study, I use it to mean something that could be shared amongst the social worlds of the construction team, and that is potentially relevant to the eventual performance of the hospital against its energy targets. Once again therefore, the intent is to use the theoretical concept to practical ends. Moreover, the conclusions will reflect on how effective information sharing might foster greater knowledge of operational energy use in buildings in Construction Co., and the implications of this.
6.1.3. This work in context

Boundary objects have already attracted attention from researchers in energy and carbon, perhaps because the climate change debate brings together huge numbers of stakeholders from diverse social worlds in search of agreed knowledge and a clear pathway to mitigation. Randalls (2010) and Taylor et al. (2014) have explored how the details of uncertain and complex energy futures can be gathered into targets and models. Both offer successful examples, in which the targets were flexible enough to draw together very diverse participants, and embody what it might mean to meet climate change objectives. However, both deal with the long-term, intangible goals of energy policy, around which it may be easier to overcome differences, rather than the pressures of immediate action.

By contrast, case studies from the hands-on industries of construction or engineering have uncovered difficulties in cooperation. Bechky (2003) and Henderson (1991) applied the boundary object concept to engineering teams, in two classic works focussed on how information is shared in multi-professional workplaces, collaborating on technical projects. Both emphasise how a failure to translate specialist language and the adoption of inflexible technological systems can impede effective collaboration. This was particularly pronounced where professional knowledge was situated and practical in nature, as it is often held to be in construction (Carrillo et al., 2013). This could lead boundary objects to encounter problems if high-level objectives are vague or poorly expressed, and hence fail to translate into individual goals for construction actors (Fellows and Liu, 2012).

In construction research, one interesting application of boundary objects is to assess how they might catalyse changes in working practices. Bresnen (2010) investigated
partnering in the industry, exploring the difference between the discourse of collaboration and the difficulties of embedding it into daily work. He found some means of collaboration failed to suit the needs of all stakeholders, and recommended simpler systems that fitted construction actors’ existing practices. Wahedi’s investigation of drawings as boundary objects in construction (2016) also found mixed success, where some objects failed due to their technical specificity, or to site workers’ preference for physical reference points. Zapata-Lancaster and Tweed (2016) found that designers were reluctant to alter accustomed ways of working when energy modelling tools were introduced as potential collaborative boundary objects. These studies indicate that Star and Griesemer’s concept, originating in the social worlds of science, may be tricky to apply to the “unruly” and evolving nature of building design (Ewenstein and Whyte, 2009).

However, these negative examples are countered by Gal et al. (2005) and Naar et al. (2016), who found that boundary objects could be active in driving disruption and innovation in construction. In domestic buildings, Lovell et al. (2017) found that new energy technologies acting as boundary objects can even drive redistributions in power and the control of energy, through the ability to foster local tailoring by individuals. Moreover, new digital systems can act as boundary objects to produce greater standardisation and visibility of information amongst construction actors (Whyte and Lobo, 2010). Bharathi and Nicol (2013) also suggested that it is possible to bring together diverse professionals using standards and “knowledge transfer groups” to drive sustainable construction. However, what is notable about these examples is that, with one exception, they relate to technologies or objects. This suggests a challenge for an intangible instrument such as energy targets, unless linked to specific information sharing systems.
Other work has assessed boundary objects’ success through their fit with existing working practices and stakeholders’ needs, and their ability to encourage change. Styhre and Gluch (2010), for example, showed how better knowledge management in construction resulted from a good balance between standardisation and local tailoring that accommodated familiar practices. Black and Andersen (2012) also emphasised that encouraging staff input to a boundary object’s development contributed to its success. Berker and Kvellheim (2017) relate a success story of collaborative research in sustainable buildings. Here, they find that more than one boundary object was required, enabling the different groups to pull together around the focus that they found most relevant, and that once this was achieved, the objects then worked together in a reinforcing loop to achieve the aim of low or zero carbon buildings. Overall, the research suggests that the energy targets’ success in improving the exchange of energy information between professionals could depend on the impact they can have on existing information management processes, and on their ability to translate a high-level aim into action.

### 6.2. Setting out the social worlds

Before beginning the analysis, the social worlds of the construction team will be described, as it is the intersections between these that boundary objects inhabit. Strauss originally suggested that a social world shares: an activity; a site and technology for carrying out the activity; and, eventually, more formal organisational structures to further the activities (1978). A social world moreover constructs the boundaries of its own identity and concerns, which members represent to others (Clarke and Star, 2007). Social worlds may correspond to professions or organisations,
but do not have to. Moreover, they are not mutually exclusive, and actors may participate in several simultaneously (Strauss, 1978).

The aim in this chapter is not to provide a substantial analysis of each social world relevant to the energy targets, but to lay the groundwork for the analysis using the boundary object concept. I will therefore focus on introducing some of the groups that intersect in the overall venture of building a hospital that is energy efficient and low carbon in its operation. Some of these actors are familiar from the previous chapters; others, such as Construction Co.’s strategic staff and the client (in various forms), come more to fore through this chapter. Consistent with the analysis elsewhere in the thesis, and with the practical research question to assess construction actors’ response to energy targets, my emphasis is on human actors, although social worlds theory allows for both human and non-human.

One social world is formed of the staff physically on site at the hospital, forming, in the largest sense, “the construction team”, the mutability of which has already been discussed. These actors all inhabit the same physical space within the construction site boundary, and collectively they partake in the same general activity of building a hospital. However, this complex social world has underlying “segments”, or subdivisions (Clarke and Star, 2007:119). Firstly, it breaks down into activities such as: design or construction management; construction site work; environment advice; commercial and administrative support; and others. It also segments along organisational lines, separating Construction Co. staff and subcontractors (“the trades”). Another division occurs along the lines of technological, or administrative, specialism. These can be focussed, for example, on the delivery of a technological
“package” (Int - Contractor 9), or the quality control of information and documentation for the whole project (Int - Support Staff 2).

Actors overlap several social worlds. Whilst the actors in the on site construction team share a vision to build a hospital, they also belong to several underlying segments. Each of these social worlds also has its own “vision” (Star and Griesemer, 1989) of priorities and activities for their work on the hospital. So, for instance, a manager from the lighting contractor belongs to the worlds of management, subcontractors, and the lighting package, each of which have differing but overlapping membership, and different priorities. Moreover, an attribute of social worlds is that they are fluid and evolving (Strauss, 1978). This is very much reflected in the nature of on site work, which is characterised by impermanence and an evolving focus of activity and actors, complicating the social worlds further.

Other social worlds exist away from the hospital’s site. These include contracted designers and advisors, senior managers of site workers who only visit the site periodically, or technology manufacturers. These actors may occupy their own social world related to particular tasks in the building’s design or construction that they perform, and the organisation or profession that they belong to, but will also participate in other social worlds, such as being part of the hospital’s multi-professional design and bid team. For example, a manager from Construction Co. describes himself as providing “a bit of direction and leadership” and acting as a “link” between parties (Int – Design 2). Whereas an architect describes his job as not only to meet the client’s needs, but to “challenge” these through his depth of experience (Int – Contractors 2 and 4). These two actors therefore belong to the differing social worlds of management and of architecture, but both also belong together to the off site design team.
In addition, there are important social worlds off site composed of Construction Co.’s own staff. Of particular relevance are a small number of company “energy gurus” (Int – Facilities 3), who provide expert advice to the on site team. The gurus are themselves a subset of an advisory department in Construction Co., whose role is “to capture and transfer research and development, innovation and knowledge to the benefit of our project teams and clients” (Doc – intranet 2). They are also simultaneously participants in a company-wide energy experts group. (Note that for ethical reasons, these experts will not be identified individually given that they are so few in number).

There is also the Facilities team, who will be responsible for the hospital’s operation, and whose primary concern when I engaged with the hospital is for “mobilising” (Int – Facilities 2) towards this, and who eventually will have their own long-term energy and carbon targets (as described in section 3.5.4). Finally, there are strategic and management staff in Construction Co. whose interest in the hospital’s energy performance is part of a wider picture of the company’s capabilities, product offerings, and market positioning, and whose vision is focussed on Construction Co.’s corporate “mission”, as Strategy 1 describes (FN – notes webinar dry run).

Elsewhere, there are other social worlds, such as the client, itself segmented into medical staff, patient groups, the local Trust, national government policymakers, and others. There are also city planners, building regulators, and local residents’ groups. Each of these social worlds outside the construction team (in its widest sense) not only have their own activities, but also “visions” of what they hope for the hospital to be, that may overlap, support, or conflict with each other and with the energy targets (discussed in more detail in section 6.5). Even in the very brief description of social worlds above,
it is clear that there are very many intersecting groups potentially concerned in the hospital's energy targets, raising potential challenges for the sharing of information.

6.3. Tacking between the common venture and specific work: problems in translation?

As already described, a successful boundary object has an identity common to all but can also be moulded to fit the needs of very different social worlds. This balance of the general and the particular allow actors to “translate” overall aims into specific actions for them to carry out. A successful balance also allows actors to “tack back-and-forth” between the aims of a common venture and their own work. To do so, all relevant actors need to be recruited so that their specific work can contribute to the overall venture, as in the mix of scientists, administrators, and local stakeholders involved in the museum. In this section, I will explore whether the energy targets themselves are able to rally the disparate social worlds of the hospital project around a common venture to make an energy efficient and low carbon hospital, and whether actors are able to “tack back-and-forth” between this general aim and their own work.

6.3.1. Grasping the common aim

Understanding what the energy targets are in principle seems fairly straightforward for actors across various worlds. The incentive is quite simple, as a construction manager explains, “if we don’t hit our carbon target, we will be fined” (Int - Construction 1). Nor does it take long on my first site visit to the hospital for me to be informed that in response to the targets the team have to “monitor energy consumption and emission levels”, that “there is a financial penalty”, and for someone to unearth the relevant clause of the contract (FN - on site field notes 1). Facilities 3 is also able to offer me a hospital site plan, with a solid, red line all around the outside denoting Construction
Co.’s responsibility for energy use (Doc - Site Plan). It is therefore clear to him what the energy targets cover:

“It means the whole project. Whether that’s inside the building, outside the building. Whatever is within the footprint of the project…There’s a drawing with a red line on it that shows all the areas that are within the project boundary.”

(Int - Facilities 3)

It is also possible for actors to pinpoint where energy in operation will come from: either from the grid or on site generation. Thus the incoming power and the plant room form two identifiable, physical landmarks on the site visible to all the on site actors (Figure 6.2 overleaf):

“Contractor 3: that grey building there is the main intake for the site [pointing out of the window]. So all the ….I don’t know if you can see it?

CW: Oh yeah [looking] I can see it.

Contractor 3: all the water comes in there, the gas, the electricity.”

(Int - Contractor 3)

This means that it is not hard for actors from various social worlds to understand in principle where the boundaries of responsibility for the site energy use are, which will correspond to the target, and where the total operational energy used on site can be found. Therefore, the two comparative points of target responsibility and actual energy use that form the target mechanism do appear clear.
Moreover, the terms of the contract also appear unambiguous:

"Energy Consumption" means the total number of Units of Energy actually consumed at the Facilities during a relevant period."

(Doc - Project Agreement Payment Mechanism)

“During the period of two (2) years…the parties shall monitor the actual energy consumption at the Facilities…ascertaining whether and to what extent the thermal and energy efficiency of the Facilities is in excess of X Giga Joules/100m³ per year.”

(Doc - construction energy targets penalty clause)

The energy targets therefore provide an apparently easily-understood common aim to ensure that the energy used in the hospital, and the resulting carbon emissions, are less than the two target numbers.

Because the aim for the hospital to be highly energy efficient is clear, this can provide motivation to diverse actors in their own work. Actors from both Construction Co. and its contractors express a sense of pride in working on the hospital project. One
Construction Co. employee for example refers to his aim to make the project “exemplar” (FN- meeting with construction), a contractor says that the intent was to take the design “one stage beyond” (Int – Contractors 2 and 4), and another refers to it as “a flagship job” (Int - Contractor 3). The targets therefore provide the basis for a common venture that motivates actors to make efforts to minimise energy and carbon in the hospital project. They therefore appear to possess some of the characteristics of a functioning boundary object in themselves.

6.3.2. Confusion in translation

Yet when considering the targets in more detail, ambiguity starts to emerge. This can be illustrated by returning to the example of the solid, red line around the site plan, shown to me by Facilities 3. The drawing seems to indicate that all sources of energy use on site are included in the targets (Doc – Site Plan). Alongside the site drawing, Facilities 3 has also produced his own energy flowchart, which summarises the requirements of the energy targets from various official documents, and translates them into responsibilities and action points for his team (Doc – target flowchart). The flowchart includes some items such as “medical gases”, “energy consumables”, and a requirement to measure “the thermal efficiency of major plant and equipment”. However, when asked, Facilities 3 is not sure of their meaning, and suggests it may be negotiated at a later point (Int - Facilities 3). This single example illustrates how the apparently simple mechanism of the energy targets can quickly become unclear when an actors attempts to “translate” the common targets into specific work and individual responsibilities.

This is not an isolated example. For instance, it is also unclear to what extent Construction Co. is responsible for the energy use of the large amounts of equipment in
the hospital. This includes specialised medical technology, and small power items, both of which will be plentiful:

“Because there is a lot of stuff that the client will bring in. They are bringing in quite a few of their PCs and monitors and medical equipment and things, and our FM partners are bringing in washing machines, and the cleaners, and the medical cleaners and the nightshift…”

(Int - Design 3)

I receive different accounts as to whether these different sorts of equipment will fall under Construction Co.’s energy targets or not, and therefore whether their efficiency should be a concern of its procurement or facilities staff. In another example of ambiguity, I discuss with one of the energy experts how generating renewable energy on site, or bringing it in from elsewhere, shifts inefficiencies of supply in and out of the hospital’s site boundary:

“So what we had to do was to displace some of the electrical, because that carries the highest carbon...So the best way to do that is put in a bit of [renewable energy]. Now it all depends on how you read EnCO2de. If you put [renewable energy] on site, you introduce some of the inefficiencies...So if you put [renewable energy] on site, that’s within your site boundaries, you now carry that inefficiency on site.”

(Int - Engineer 2b)

Thus defining what the energy targets actually cover can quickly become fuzzy when talking about the details of what will be done to address them. This means that actors may not be able to “tack back-and-forth” between the common venture and specific work, as they are either not sure what they should do, or are aware, like Engineer 2, of how it may be negotiable.
These problems appear to have been experienced in some of Construction Co.’s other projects with energy targets. During the webinar on energy targets in which I participated, one case study showed how energy modelling at the design stage failed to take account of distribution losses, lighting in common areas, and the shared mechanical room of a project (Doc – webinar slides). Engineer 7, from a different department, presents a slide making a very similar point, which he simply entitles “energy confusion!” highlighting the problems he has experienced defining energy targets in practice (Figure 6.3). Similar problems were experienced by the school that I studied in the early stages of the PhD, in which apparently clear contractual terms, such as “baseline” energy or “core hours”, proved very difficult to define in practice (Docs - internal meeting notes school, commercial report on school performance).

<table>
<thead>
<tr>
<th>Energy confusion!</th>
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</thead>
<tbody>
<tr>
<td>- Net energy...</td>
</tr>
<tr>
<td>- Delivered energy...</td>
</tr>
<tr>
<td>- Calculated or measured...</td>
</tr>
<tr>
<td>- Methodology</td>
</tr>
<tr>
<td>- Primary energy...</td>
</tr>
<tr>
<td>- CO₂-emissions...</td>
</tr>
<tr>
<td>- Weighted energy...</td>
</tr>
</tbody>
</table>

*Figure 6.3 Energy "confusion" can characterise translation of energy targets into specifics*

*(From Engineer 7)*

This suggests a more widespread problem for construction teams in “translating” general requirements to control overall energy use or carbon emissions into the specifics of energy use in the buildings they work on. In Star and Griesemer’s terms,
the energy targets are therefore not as “robust” as they appear to be in the contracts for the project, as they do not have an identity that is common to social worlds. Moreover, they are also too “plastic” in their individual interpretation by different social worlds. Hence when actors try to translate the overall targets into specific tasks, they may run into difficulties, as illustrated by the uncertainty around the specific meaning of the contractual terms. Whilst legal contracts cannot define every eventuality, and conditions may be expected to vary between projects, the net result may be confusion amongst actors in navigating the terms of the targets.

6.3.3. Difficulties in translating targets into specific work

For the energy targets to be a successful boundary object, an awareness of the common aim also needs to recruit relevant social worlds, so that they contribute relevant information and tailor their work effectively. Awareness of the energy targets, however, can be limited. They either fail to reach some actors at all, or are confused with the other energy-related targets referred to in section 3.5.4, especially the BREEAM target. Some actors from the design team, for instance, immediately assume I mean BREEAM when I mention energy targets (Ints - Design 3, Contractors 2 and 4). Contractor 9, who is a technology specialist, assumes that I mean the energy efficiency thresholds defined by Part L (Int – Contractor 9). Additionally, whilst those most closely involved with the energy targets are clear that embodied carbon is not part of the target criteria (Int - Engineer 3), for others on site this is not always the case, despite their potential to contribute relevant information (FN - site inspection tour).

It moreover appears that those who do deal with energy targets more directly, either in the hospital or other projects, such as the experienced engineers in the webinar, understand the difficulties in translating between a goal to make a building energy efficient, and all the underlying aspects of individual work that need to be undertaken to
achieve it, reflecting the findings in Chapter 5. Those who have less previous experience or direct exposure to energy targets are not so aware of the underlying ambiguities or implications of energy targets for their own work. So, for instance, those in construction management may rely on following contractors’ specifications, in order to make the “translation” into specific works for them:

The thermal performance is based on temperature bands from the contract. The fabric all has a set specification – so the building envelope has a minimum U-value and the glazing has a certain U-value and reflectance. So you know what the thermal performance will be because it is determined by the design – so ‘if you build it to the design’ you will have a certain level.

(FN - meeting with construction)

Relying on others’ expertise is often appropriate in a multi-professional project. Hence not all social worlds may need to “tack” between their work and the overall targets. However, the energy targets’ success is dependent firstly on contractors fully understanding what needs to be produced to help meet them, and secondly on Construction Co.’s managers’ ability to perform an informed review of their outputs. The latter may not always have the confidence or information to do this. For instance, when asked about judging the energy performance of technologies, Construction 1 suggests that, “what’s most important for the project, the consultant would know” (Int - Construction 1). This may inhibit his “tacking back-and-forth” between the general aim of the targets for which his company is responsible, and their translation into specific outputs, such as specifications or other work that should help meet them.

In summary, the findings in this section suggest that the hospital’s energy targets could successfully create a common aspiration for energy efficiency and carbon reduction amongst the diverse social worlds of the project’s construction team. The principle of a
target appears easy for many to grasp, and could lead to common venture to build an energy efficient, low carbon hospital. However, not all of the relevant social worlds have the same awareness of the energy targets, and they can become confused with other energy-related requirements. More critically, a boundary object must facilitate translations of the common venture into specific, local actions that help achieve it. It appears that difficulties are arising in this translation process, as actors are unsure as to what exactly is covered by the targets, and what this means for their own day-to-day work. This will inhibit their ability to “tack back-and-forth” between the own tasks of their particular social world, and the overall venture. Hence the energy targets do not currently appear to have fulfilled all their potential as a boundary object towards the common venture of an energy efficient hospital.

6.4. How energy-related information is traded

If the energy targets are not in themselves a boundary object to produce an energy efficient hospital, this does not mean that actors are not able to share information through other boundary objects, as in the museum, in order to improve the eventual energy performance of the hospital. Both Star and Griesemer’s original case study (1989), and others that followed it, such as Bechky (2003) or Berker and Kvellheim (2017), have considered multiple boundary objects. This section draws on boundary objects’ ability to facilitate the collection of relevant information that can be “traded” (in Star and Griesemer’s terms) between different social worlds, using a common information system, or systems. It will therefore consider if, despite the limitations of energy targets as boundary objects, there are other functioning systems for the sharing of energy information relevant to the targets.
This section will also consider to what extent there is “residual information” around the energy targets, or information that does not fit standardised systems and methods of capture. As noted at the outset of this chapter, a high degree of residual information indicates that boundary objects are not functioning effectively. I will firstly discuss some of the formal processes of energy information exchange that I have identified, and then move on to informal means, and the existence of residual information. In doing so, it is important to bear in mind that processes for capturing energy information in the hospital project often overlap with information systems in Construction Co. more generally.

6.4.1. Do formal information systems accommodate energy targets?

The early design stages of the hospital project do appear to have facilitated the exchange of information around the targets, as already described in Chapter 4’s consideration of coordination (section 4.3.1). The different professional groups of the design team met regularly in workshops, in which the energy targets, and the outputs of the energy model, were discussed and design proposals debated (Ints - Contractors 2, 4, 6, 8):

“I mean we were having these workshops and we were writing…we were writing these bodies of text as well, so we were sort of defining it in written word and sort of discussing that at meetings so yeah so things like these sort of graphs and stuff [shows on screen] were presented. This sort of thing would be worked through on the team.”

(Int - Contractor 6)

At this stage of the project there was also the ability to exchange information in common units of kWh, tonnes of carbon, and GJ, so that totals could be compared to the target requirements, and design adjustments made accordingly. Whilst they do not represent an “information system” as such, the workshops do appear to be an arena in
which information could be traded with other social worlds in the context of the overall aim of the targets, and in which the energy model played a significant role.

However, as also observed in Chapter 4 (4.3.2), once the design work was complete and the translation of the technical elements into specifications made, the energy model faded from view and design workshops ceased. After this point, there appear to be very many different systems for sharing information on the progress of the hospital's detailed design, construction, and commissioning. A variety of these were suggested by participants when asked how they might share information with others in the hospital's construction team, including: the architects' design database; coordination of drawings in 3D; the project's document management system; BIM; daily and weekly site meetings; a Last Planner system for scheduling works; the BREEAM tracker; the construction programme; and cost and financial indicator reporting. However, these information systems only rarely accommodated energy targets. Instead, they were often focussed on other aspects of design, or more pressing priorities, such as work scheduling, the construction timetable, or money. The connection to the energy targets of these many information systems that run during the construction phase is therefore marginal at best, and none focus directly on them.

Following the completion of construction and commissioning, there are other systems for gathering information, focussed around gathering feedback and learnings from the project. Energy performance features more often in this than in the construction and commissioning phases. For the hospital, this stage has not yet been reached. However, insights on how it might be treated can be gained from Construction Co.'s work on previous projects with energy targets. Participants were hence asked to reflect on how they had shared information on prior projects with energy targets to prepare for
their work on the hospital, and to suggest how they planned to do so from the hospital once completed.

When asked about how they might collect insights related to the hospital’s eventual energy performance, many participants mentioned Construction Co.’s “Lessons Learned” system (Ints - Commercial 1, Construction 1, Design 1, Design 2, Engineer 2b, Engineer 3). Lessons Learned is a specified part of Construction Co.’s processes (Doc - company review processes). It can involve written feedback tips, or face-to-face meetings and visits, and covers many aspects of construction. Design 1 explains how he used it to consider how he might manage the hospital:

“What we did here we actually went up to [previous hospital] and sat with the team… It were just like - here we are, we’re here for the day, open your heart out and tell us what the pitfalls were, we don’t want to go in ‘em”.

(Int - Design 1)

The system also successfully includes the engineering experts, as described by Engineer 2, who has gathered feedback on energy targets from other hospital projects:

“I went to all the hospitals [with targets]…all the people that were involved in it. I said tell us what you would do again, what you wouldn’t do again.”

(Int - Engineer 2b)

These personalised experiences of Lessons Learned appear to have been positive and useful for the individuals involved.

However, others have reservations about the extent to which actors absorb the Lessons Learned:
“We done it from the [last hospital] I believe. But something we quite often find, is it doesn’t really work that. We all talk about it, all these lessons learned, but no one seems to take it on board. And we quite often do the same mistakes we do on every job. …we do see a lot of things going on, and we think oh they made that same mistake at [the last hospital], and they’re doing it all over again!”

(Int - Construction 1)

“Yeah well it’s a noble thing, and it’s probably mostly better than not doing it. Um ...but then ...they get lost you know? … it’s probably helpful to codify it at that point, but then people don't really read it and absorb it for the next project.”

(Int - Strategy 3)

The lessons may also reflect the perspective of the social world that gathered them. For Design 2, the problem with Lessons Learned is that they are written by construction, and therefore “it tends to be about things you know that gave the construction people issues rather than perhaps design-related” (Int - Design 2). Commercial 1, on the other hand, is not planning on a Lessons Learned report for the energy targets on the school, as it is no longer relevant to his sector (Int - Commercial 1). This view of individual project experiences as being “too different” to be worth comparing is also expressed by other actors (Ints - Construction 1, Strategy 3; FN - meeting between construction and facilities management). Lessons Learned may therefore facilitate the collection of information, but not necessarily its “trading” between social worlds, particularly if not delivered in person.

In addition to Lessons Learned, projects with energy targets, or which have made particular innovations in energy and carbon, may be written up into case studies. These appear externally in corporate communications, and also internally on the company intranet. As a source of trading operational energy information between groups they have some major limitations. Firstly, they often appear to be primarily designed for
marketing purposes, and secondly they may re-tread the same few low carbon exemplar projects (FN - induction). The company’s priority may therefore be around collecting case study exemplars:

“We are increasing our Green communication focus that energy and carbon efficient products and services is good business, both for us and for our customers. We have developed internal and external marketing material to support this.... We have also produced the internal report “Lessons learned from our most ambitions Green projects” aiming to share experiences from our greenest building projects”.

(Doc - company carbon disclosure)

Therefore as practical means to share information on how to build a low carbon building they are not especially effective, although they could well be motivational.

Therefore, the findings indicate that there are very few established systems for the trading of information relating to energy targets and operational energy performance, for the hospital, or indeed for other of Construction Co.’s projects with similar targets. Whilst there are many systems for the trading of other sorts of construction information between social worlds, these relate to the wider common venture of getting the hospital built, not the subsidiary aims of making it energy efficient or low carbon. This is illustrated in Table 6.1 overleaf, which also shows how the trading of energy information is concentrated at the beginning and end of projects. However, my findings did also indicate there is in fact quite a lot of information being shared about the energy targets, but that this is being done through informal or personal channels. This will be discussed in the sections that follow.
### Table 6.1 Formal information sharing systems and their relevance to energy

<table>
<thead>
<tr>
<th>Project phase</th>
<th>Information sharing system</th>
<th>Extent to which includes energy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design</td>
<td>Design workshops</td>
<td>High</td>
</tr>
<tr>
<td>Design</td>
<td>Energy model</td>
<td>High</td>
</tr>
<tr>
<td>Design</td>
<td>Architects’ database</td>
<td>Low</td>
</tr>
<tr>
<td>Design, construction</td>
<td>BIM</td>
<td>Low</td>
</tr>
<tr>
<td>Design, construction</td>
<td>BREEAM tracker</td>
<td>Medium</td>
</tr>
<tr>
<td>Construction</td>
<td>Document Management system</td>
<td>Low</td>
</tr>
<tr>
<td>Construction</td>
<td>Financial indicators</td>
<td>Low</td>
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<tr>
<td>Construction</td>
<td>Construction programme</td>
<td>Low</td>
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<tr>
<td>Construction</td>
<td>Site meetings</td>
<td>Low</td>
</tr>
<tr>
<td>Construction</td>
<td>3D drawings coordination</td>
<td>Low</td>
</tr>
<tr>
<td>Construction</td>
<td>Last Planner (work scheduling)</td>
<td>Low</td>
</tr>
<tr>
<td>Post-completion</td>
<td>Lessons Learned</td>
<td>Medium</td>
</tr>
<tr>
<td>Post-completion</td>
<td>Case studies</td>
<td>Medium</td>
</tr>
</tbody>
</table>

### 6.4.2. Trading information via energy experts

One important social world, as introduced in section 6.2, are Construction Co.’s internal energy experts, or “energy gurus” (Ints - Construction 1, Facilities 3, Legal 1). Much of the knowledge of how Construction Co.’s buildings perform, and energy targets in particular, appears to be concentrated not in any system, but in these specialist engineers. During my fieldwork, I found that when I mentioned energy targets I was repeatedly referred to the same three individuals. Their status is also recognised by contractors (Int - Contractor 3; Int - Contractor 7), and much of the assessment of the
risk and requirements of the hospital’s energy targets is performed by these individuals, and it appears, on other projects with energy targets. Not only are they involved actively in reviewing the energy targets; they are also a resort for others in Construction Co. in search of help. One engineer, for example, keeps a folder of questions raised from around the organisation on energy performance (FN - energy experts meeting 2). These individuals are a focus of experience from prior projects, and expertise derived from their professional training and this practical experience. As such, they may be considered to embody much of Construction Co.’s knowledge about energy performance in-use.

Information from these individuals does appear to be circulating around the organisation, through personal contacts. However, these specialists do also produce written materials. For example, some have been in charge of investigating previous projects where energy targets have not been met, for which they produce formal reports, including the school that I studied, and other hospitals. These are produced in a formal format, in which “the objective of the audit is to establish the actual electrical and thermal performance of the ...Facilities and confirm compliance or otherwise against contractual obligations” (Doc - internal energy audit former project). The reports contain many valuable details on operational performance, and reasons for the variations between target and actual energy use. However, they are not intended to be practical guides for on site staff.

In another example, one of the energy experts has produced a checklist for energy models that details the assumptions and methods used to produce them (Doc - modelling checklist). This seems to be an extremely useful means of capturing some of the technical data and parameters that could otherwise cause unexplained variations in
energy use. However, although the checklist appears well-used in the region in which it originated, it has not spread more widely through Construction Co. Therefore, although experts do make efforts to codify some of their extensive knowledge, the trading of these written materials with other social worlds to whom they might be relevant is not always extensive.

Additionally, locating the detailed knowledge of energy targets in a few people has some risks. The most obvious is that the knowledge may leave Construction Co. with them. Commercial 1, for instance, has significant problems re-tracing the original calculations of the school’s energy targets:

“We have been scratching our heads between us all going, why? Because there's no one in the business that was involved with the original agreements.”

(Int - Commercial 1)

However, it can also paradoxically be risky if experts do stay. As one participant suggests, the company could be “held to ransom” by certain people in the organisation who are considered irreplaceable (FN - anon). This suggests that their status as “gurus” could prevent their knowledge being codified and shared around the organisation, as it becomes identified with them in person, rather than being a company asset. As one of the specialist engineers explains: “you can't distil what's in your head" (Int - anon). In addition, I found expertise on different aspects of the energy targets elsewhere in Construction Co., in places such as the legal team, the environment team, and Project Co.. However, far fewer people appeared to be aware of them. This suggests that the trading of energy knowledge may be restricted by its identification with “gurus”, preventing other social worlds from contributing to the general pool.
However, there is one way in which the knowledge of specialist engineers is intended to be traded. This is the company-wide energy experts forum, of which both the “gurus” and energy experts group that I attended are a subset. The aim of this forum is to “filter” energy knowledge out of the engineering team into the rest of the organisation “via webinars and things like that” (Int - Project Co. 1 and 2). However, despite its aims to diffuse knowledge, those from other social worlds may view it as highly technical:

“Project Co. 1: Most of that is highly technical stuff…It’s more about you know what innovative solutions are being used round and about Construction Co.. You know the heat storage stuff – ‘it really needs spiral coils or something around it’ and yadda yadda yadda…because virtually everyone on the group is technical.”

(Int - Project Co. 1 and 2)

Engineer 1 is also sceptical about the forum, for different reasons. He sees it as populated by senior staff, who say “oh this is very important... and we should do this, and we should do that” to improve energy performance. Yet senior staff are often preoccupied with other priorities, meaning that by the time of the next annual meeting “11 ½ months has passed, and you haven't done anything” (Int - Engineer 1). The energy experts group can also fall prey to internal marketing, with individual contributors wondering what they can bring along to “showcase” on behalf of their department (FN - energy experts meeting 1). Hence the knowledge captured by the experts’ forum may be limited, and squeeze out some of the practical know-how that could otherwise be traded. It may also fail to capture non-technical actors’ relevant energy and carbon experience.

6.4.3. Residual knowledge in contractors

In addition to Construction Co.’s own energy experts, there is likely to be a significant amount of knowledge relevant to the energy targets in sub-contracted organisations,
who also have both practical experience of previous projects and professional expertise. A failure to capture knowledge can lead to “residual” information, in Star and Griesemer’s terms. In the hospital, Construction Co. continues to rely on a high level of energy-related expertise vested in its contractors. In the case of the hospital’s renewable energy systems, for instance, the technology is unfamiliar to Construction Co., and hence they depend on the contractor. When I ask for information on how the whole energy system will work, I am given the contractor’s schematic, and told, “they’re very good at what they do. And probably can explain their system far better than anybody else” (Int - Construction 1). The contractor himself views his company’s capabilities as a selling point:

“Contractor 7: It’s experience.

CW: Ok?

Contractor 7: It’s ...actually that’s what we bring to the table...

CW: So if I was the facilities manager for this, and I had never worked a system like this before, would it be easy for me to do?

Contractor 7: No. Almost impossible. If you are not experienced, it will be hard...they cannot operate it without the inside view.”

(Int - Contractor 7)

This reliance on contractors’ expertise extends to other aspects of the hospital’s energy systems. Much of the overall design responsibility for the energy targets falls to the expertise of the M&E contractors, who have worked on projects with energy targets before. They are responsible for specifying and making recommendations on the procurement of key technologies, and balancing energy and carbon against other performance criteria (Doc - Email re boilers). This principle of devolving knowledge also applies to the specific technologies themselves. Contractor 3, for example, explains
that there is limited review of the details of his design: “they’re engineers but they’re not consulting engineers on site...they wouldn’t necessarily comment on a design” (Int - Contractor 3). The BMS contract is another illustration:

“The BMS specialist is required to bring his expertise to bear in this respect to ensure that a fully coherent and energy efficient BEMS controls system is realised for the project.”

(Doc - BMS specification)

The decision to leave knowledge in subcontractors is not so much an omission as part of Construction Co.’s business model. Its own selling point is the ability to link together other companies with knowledge to produce energy efficient buildings: it is, as mentioned before, a “systems integrator” (section 4.5.1). Whilst this sort of model is common in the industry, it poses problems when construction companies have to address new and more complex issues, like energy targets:

“We outsource about 80% of what we do...that's certainly typical for a Tier 1 contractor [a large main contractor]. And I think that we should be looking to reduce the amount of outsourcing we do because new capabilities are complex. And they work as complex systems. And to try and bolt together a complex system using a lot of ...a number of external organisations is a...level harder than developing the capabilities internally. In my opinion.”

(Int - Strategy 3)

Residual knowledge in subcontractors is relevant not just to design and construction, but also to the trading of feedback from completed projects. This trading is variable. Contractors cannot, for example, access the company intranet. Sometimes contractors may gather feedback themselves, such as Contractor 7 who tells me that he continues to monitor the performance of all his previous projects (Int - Contractor 7). Another indicates that his company intends to gather their own learnings internally, but that
Construction Co.’s interest is limited: “It’s kind of very much like once the project’s done and they’ve got a certificate, it’s like oh great thanks yeah we’re off….“ (Int - Contractor 1). Another contractor is sceptical about the feedback process, suggesting that:

“It usually goes through the guys at the top. They kind of…yeah…maintain the relationship. It’s more of a marketing thing isn’t it?”

(Int - Contractor anon)

By contrast, others are more positive about having had a useful exchange of information with Construction Co.. Contractor 6 acknowledges that feedback on standard projects without energy targets is rare, but that on projects that do have them, he feels that “you do get a bit more” (Int - Contractor 6). Contractors 2, 4, 7 and 9 also think they have received useful feedback on previous projects’ outcomes:

“I did the design for those two hospitals and we worked closely with Construction Co. on those …what we did after first phase was completed… basically we had a meeting…What have we learned from this phase, what went wrong, and what can we do to make things better. And this was almost like the self-assessment of what we’d done, and we got feedback then from the various construction teams and you know it gave a real insight to what we could do to make things easier, to make things better.”

(Int- Contractor 9)

There are two potential problems with residual knowledge vested in subcontractors. Firstly, Construction Co. may not be aware of issues that could either affect the energy performance of a current project, such as the hospital and its targets, or of those that could affect the performance of future projects that it takes on. Secondly, it prevents actors from being able to review inter-linkages between the individual works of specialist social worlds that could affect energy performance, and to trade energy information between the worlds of different contractors. So whilst Contractor 7, for
example, holds specialist details about the renewable energy system’s ability to help meet the energy targets, he is also not in a position to take a view on its interaction with the rest of the building, due to the commercial barriers of information management between organisations.

### 6.4.4. Residual information in gossip

A further means by which information about the energy targets and energy performance is traded between different social worlds is the circulation of the gossip, which by definition falls outside Construction Co.’s formal systems. A participant telling me tales of what had happened on this project or the other was one of the most common elements of my fieldwork, and was used across social worlds. Often these were cautionary tales and provided an interesting counterpoint to the official case studies discussed earlier, by spotlighting failure. So, for instance, I was given many examples of recalcitrant users (FN - meeting between construction and facilities management). Another theme was also poor quality installation, where I am told about un-insulated pipework, buildings that “leak like a sieve”, and BMS equipment being damaged by having bolts drilled into it or sensors lagged over (Int - Project Co. 1 and 2; FN - commissioning). Also featured in gossip were renewable energy technologies that were never turned on, or did not work:

> “There was another place where the boiler was supposed to be half bio-diesel, half gas – they were supposed to use both but they never bothered with the diesel. Construction Co. came back and it had gone off - they had to empty the tanks and pour it all away.”

(FN - attending pressure testing)
The stories provide unofficial insights as to some of the reasons for poor performance against energy targets in the past:

“And I’ve heard of a hospital in X that was steel framed and was incredibly energy efficient, and that was because, when we build, we build structurally with flat slabs, so they had the flat slab there [he is drawing again] and the steel frame, and then they had to have a service void, so they had extra volume, because of the steel frame... So whereas our void would be typically a metre, theirs was something like I don’t know 1400... Just a little story I picked up along the way.”

(Int - Engineer 2b)

Tales can also encompass warnings of mistakes to avoid, or worries about errors already made. Design 3, for instance, uses a past experience to remind himself and his team not to make the same mistake again:

“So going back to [other hospital], I think at procurement stage... something happened in the specification and the one with the lower environmental rating got selected and almost procured, and we found out at [the] last minute. And the impact of that would have been we didn’t get LEED Gold...So it’s every step of the way, you have to keep that in mind, and we do.”

(Int - Design 3)

These tales all contain potentially useful information about what not to do with an energy target, and they seem to be traded informally amongst the different worlds of the construction team. As is clear from Design 3 above, some actors do pay attention to these stories, with one admitting that he had heard about what happened on other hospitals and so was now going to make sure he did not fall into the same trap (FN - meeting between construction and facilities management). Engineer 1 also observes that whilst some of his information is gained from meetings, the rest is gathered “round
the coffee machine” (FN - conference call with Engineer 1). However, the circulation of information outside the official systems also poses some risks.

One of the potential pitfalls of gossip is that it might exclude actors, such as staff who have not developed informal relationships with actors from other social worlds. Facilities 2 for example, is worried about knowing who he should collect information from to help him run the hospital:

“There are a lot of people I have to talk to, because each of them, each of the guys over there [on the other side of the site office] is in charge of a different package of work…I have to draw all the information, all of it … to feed it into the plan. So yes there are a lot of people, and I don't know nearly as many of them as I should, which is part of the learning curve. It's like that, the learning curve [makes a steep shape with hand]”

(Int - Facilities 2)

Information that travels from person-to-person may also come too late in the process. So, for example, it may not reach design and bid in time to improve energy efficient designs (FNs - energy experts meeting 2, meeting with construction). Informal information may also fail to reach subcontractors, who even if they do receive formal feedback on projects, are still not part of the internal gossip networks.

Another problem for those actors it does reach is that, whilst gossip can provide an unvarnished honesty, it can be hard to establish if it is reliable. On the hospital, for instance, an innovation has been made to enhance the efficiency of the fans. I am told this by many individuals, indicating that this story has travelled widely between social worlds. I am told that this innovation may receive an internal award (FN - meeting with construction). However, I am also told, variously, that the supplier suggested it because they “wanted to show it off” (FN - site inspection tour), that Engineer 3 suggested it (FN
- commissioning), or that Contractor 3 suggested it (FN - energy experts 3). Alternatively, the fan solution is not innovative and has been done already elsewhere (FN - talking to Environment 6o; Int - Engineer 3). I am told that whilst Construction is keen, Facilities do not like it (FN - talking to Environment 6m). I am told that it was not the energy target but Part L that induced the innovation (Ints - Engineer 3, Contractor 8), or that it was actually because of the energy target (FN - meeting with construction).

I received a similarly diverse selection of stories around the renewable energy systems. It is therefore challenging to work out the impact of exactly what it is that has been achieved, by whom, and how.

From the many stories circulating, actors may select a particular version, meaning that gossip can further facilitate ‘silver bullet’ solutions to energy efficiency (section 4.2.2 earlier). For instance, in one of my very first environment team meetings, I am told that doors were a key problem for energy efficiency in a previous hospital project, being frequently left or propped open, and that preventing this has therefore been worked into the design of the new hospital project (FN - environment team meeting 4). Whilst this is a good use of feedback to improve design, it also illustrates how stories help circulate these silver bullets. As with the fans, the diagnosis may contradict itself between different social worlds. So, for instance, on the school that formed part of my early work, Commercial 1 tells me that the main problem was late contract changes (Int – Commercial 1), whilst a senior member of the engineering team thinks it was a mistake of confusing units of carbon (C) with carbon dioxide (CO$_2$) (FN - meeting with engineering team). As these diagnoses are used to inform later design, as in the case of the doors, they are of importance in the development of energy knowledge.
In summary, whilst there are few developed, standardised systems for trading energy-related information in Construction Co., there is much that is potentially relevant vested in informal communications, and in people. As just described, this often involves individuals, specialised groups, or information transmitted in person via advice, or gossip. Energy information may therefore circulate in unpredictable ways around Construction Co., untracked by formal systems. Additionally, feedback links to its contractors, a social world who potentially have much specialist knowledge to contribute to the management of energy targets in Construction Co.’s projects, seem to vary in effectiveness, and face significant commercial barriers. Thus the level of “residual” energy information outside formal systems of information appears high.

The lack of processes specifically adapted to capturing energy information provides a significant contrast to the zoology museum’s standardised systems. In the case of the museum, Star and Griesemer used the analogy of a “mixed economy” (1989:413), in which diverse participants meet to trade relevant aspects of their own work. Instead, what sometimes seems to occur in the hospital, or Construction Co. more widely, are gaps in official information trading, leading to a reliance on gossip, with professional expertise partially blocked behind commercial, personal, or technical barriers. This could affect the eventual energy performance of the hospital, or other projects with targets, in two ways. Firstly, the significant technical knowledge vested in experts is not being diffused, so other social worlds do not develop the expertise to make autonomous decisions in relation to energy targets. Secondly, if energy information is traded informally it is not clear whom it has reached, nor whether the message is consistent.
6.5. Reflections on information sharing: do actors’ interests in the energy targets have coincident boundaries?

The previous sections considered the detailed aspects of how actors from different social worlds share information about energy targets and energy performance, and to what extent the energy targets effect a common aim. They have also raised some difficulties. As in the previous two chapters, and in the interests of drawing out practical insights, this section will consider some of the commercial reasons why these difficulties might be occurring. In Star and Griesemer’s zoology museum, the creation of a “nature preserve” established an arena with boundaries common to all of the museum’s stakeholders, but within which they pursued individual priorities. Thus, the social worlds shared “coincident boundaries”. This was key to the success of the common venture of the museum.

Given that the energy targets in my case study do not exist in isolation, but are part of a much larger common venture of the hospital’s construction, it is important to consider how the boundaries of other commercial pressures may affect the sharing of information around the energy targets. This requires consideration of the priorities of some of the social worlds referred to in section 6.2, who are responsible for the strategic direction of the hospital project, but who have not yet been discussed. Firstly, there are the priorities of the client, as perceived by the construction team. Secondly, there are the internal priorities of Construction Co. itself in relation to developing knowledge around operational energy performance in its projects. Thirdly, there is Construction Co.’s external corporate identity. In considering these, I will explore
whether these three different sets of priorities share “coincident boundaries” with the energy targets.

6.5.1. Boundaries of client concerns

The perceived priorities of its clients are a significant concern to Construction Co., around which it arranges its approach to the hospital project. Although the energy targets originate in the NHS Trust's Construction Requirements, many different actors in the construction team believe that, as a hospital, they are not the most important of the client's needs. Facilities 2 acknowledges this when I ask him whether energy targets are a priority for his work:

“So long as it doesn’t impact on patient safety, it’s very important, because it becomes part of the financial aspect of it. But the fundamental driver is patient, staff, public safety… Everything else follows that.”

(Int - Facilities 2)

This view is shared by participants in other teams, who often emphasise clinical design:

“The start is getting the clinical design. Making sure that whatever we design does clinically function.”

(Int - Design 3)

Participants involved in design explain, for instance, how levels of daylighting and the solutions to reducing solar gain and glare were constrained by the Trust's clinical requirements in patient rooms (FN - talking with Engineer 3, Ints - Engineer 2b and Design 2). These clinical concerns can impede the energy targets, and innovations to meet them, as one of the technology suppliers explains:
“They didn’t want to be the test bed so to speak. And the NHS certainly wouldn’t want to be that, so any products we put forward are tried and tested products…to ensure the client that you know what we’ve given you isn’t something that’s going to fail, especially in hospitals…The risk is too great.”

(Int - Contractor 9)

The other important concern of the client that is described to me is a desire to impress local stakeholders with a “visual statement” that was “going to stand out”, and to create a “distinct” and “iconic” building. One of the architects combines the two, believing that Construction Co.’s consortium won on the combined excellence of the “medical planning” and “striking building design” (Ints- Contractors 2 and 4, Design 2, Engineer 3). Design 2 views these client concerns as “immovable”, as other construction priorities have to fit around them:

“It was almost you’ve got to build it, you’ve got a shape or a form, now how do we deal with the energy?”

(Int - Design 2)

Whilst it is quite understandable that the client would want a visually attractive building that provides excellent medical care, the trade-offs with the contractual energy targets may be unclear:

"In order that the development achieves the carbon emission targets as detailed above, the building services engineering design must embrace energy efficiency where practical and cost effective" [my italics]

(Doc - TCRs)

Hence, unlike the zoology museum, the client’s priorities to make the hospital a landmark and centre of excellence tend to overshadow the energy targets, rather than coincide with them.
The final perceived priority of the client is to ensure that the hospital is built on time and to budget. This is made clear by the contract for the hospital: as one participant observes, the energy targets may have a financial penalty attached to them, but the value of it pales into insignificance compared to that for completing behind schedule (Int- Legal 1). Hence this is an overriding priority for the team:

“programme... that’s the thing that weaves everything together.”

(Int – Design 3)

Because the programme is a core part of the construction contract delivery, it has fully-fledged information systems, an easily-understood aim (to reach Practical Completion on time), and significant attention from management to junior staff. When walking onto site, the “Information Wall” of progress towards completion is immediately visible (Figure 6.4), and forms a focal gathering point for staff from all on site groups (Int - Support 1). There is no overall “information wall” for progress towards delivering a low carbon hospital, nor even within specific social worlds (such as, say, the environment team, or energy experts).

Figure 6.4 The "information wall" of programme progress
The perceptions of client needs in the hospital’s construction team raise inconsistencies with the boundaries of the energy targets. Conflicting priorities may arise because “the client” is not a single social world. The hospital’s energy targets come from the government, but its other design needs are directed by the individual NHS Trust and its senior clinical staff, and are additionally heavily influenced by local stakeholders. So for example, whilst the government’s strategic drive towards energy efficiency is clear (Doc - government guidance provided to contractor), the information for bidders produced by the local Trust has only one mention of sustainability or energy efficiency (Doc - information provided to bidders). This suggests that, in the construction team's eyes, different stakeholders within “the client” have priorities with boundaries that do not necessarily coincide with the energy targets. Moreover, the relative importance attached to these other perceived client priorities by the construction team may eclipse the targets’ aspirations.

6.5.2. **Boundaries of internal knowledge development**

In terms of its internal priorities, Construction Co. states that it is keen to be a “learning organisation” that shares information between its different members (Doc - Website 3). This aspiration has the potential to coincide with gathering information and the development of knowledge on how to build more energy efficient or lower carbon buildings. However, in an industry where competition is fierce and margins are tight, time spent on learning can get in the way of the core business of getting buildings built. As Engineer 6 explains when we talk about making time off site for sharing energy information with others, “the business gets paid when I'm on site. So that there's where I spend time” (Int - Engineer 6).

Moreover, commercial pressures to move on to the next project can limit the extent of information gathering. Once a building has been finished, and if the energy target is
met, there may be no more commercial imperative to share information with other social worlds. For instance, Engineer 2 explains how, in previous hospitals with energy targets, he used to visit the facilities team once the buildings were operational:

“Engineer 2: Certainly on [Projects] X and Y I was regularly seeing them [Facilities] and getting all the figures from them.

CW: Oh yes of course…then what happened?

Engineer 2: Well then we passed [the energy targets] and there was no…as much as I enjoyed going down there …You've passed. End of. Move on.”

(Int - Engineer 2b)

The rotation of staff onto other jobs as their specific role on a project finishes can also inhibit learning:

“I'm not normally on a job this long. I'm normally… moved onto another job, and start the design on another job…But I've stayed on this job a bit longer. So I've actually learnt quite a lot and seen things I don't normally see and I'm oblivious to because I've never been there. And you get feedback but it's nothing like being there and living it is it? You know…when you're living it, it has more effect.”

(Int - Design 2)

The same concerns affect feedback from subcontractors. Environment 1, for instance, tells me how he cannot get information from a supplier as “they’ve already been paid and they don’t care anymore” (FN - on site field notes 5). I have a similar experience with another contractor, who I am keen to interview, but who has finished their work on the hospital, and is unwilling to commit time to talk to me (FN - speaking with Contractor 10). Thus the boundaries of learning from projects with energy targets and getting on with core business may not coincide.
Part of the problem is that learning about energy performance in Construction Co.’s projects is couched in terms of profitability. Although Construction Co.’s intranet links together collaborative learning and commercial advantage by suggesting “together we can help each other by sharing knowledge to beat competition” (Doc - Intranet 6), this link can both foster and deter knowledge acquisition across the various departments of Construction Co.. Strategy 3, for example, explains that any innovation, whether energy-related or not, would need to show a clear “return on investment” and preferably have a “steady flow” of income to support it (Int - Strategy 3). Engineer 1 relates a story where he is able to negotiate more time and money to investigate why a building had not hit its energy target. He does this by appealing to the potential value of brand damage (FN - conference call with Engineer 1), which seems to make the business case for learning rather effectively. As a result, whilst enhancing knowledge across diverse actors is an internal priority for Construction Co., it must also demonstrate quick commercial results, which do not necessarily coincide with understanding long-term or future energy performance.

If learning and profit are balanced in a trade-off, then they may conflict rather than coincide. Therefore processes for capturing information about energy targets and operational energy performance may be limited by the perceived opportunity cost to more immediate “paid work” and profit:

“I mean I know we do try …and be energy efficient and provide energy efficient buildings, but up to a point…We’ve got to be a viable company, we’ve got to stay in business… Honestly if Construction Co. can do it, and still win the bids…and still build it on time, still make a profit, and also deliver that, they’ll do it, but if they can’t do all those other things, they wouldn’t risk those just to deliver an energy target to a client. Would they? Nobody would.”

(Int - Design 2)
This balance is of course normal for a commercial entity. However, if the balance tips too far in favour of immediate profitability, it risks failing to capitalise on the opportunity to learn how to produce better performing buildings for Construction Co.’s clients.

6.5.3. Boundaries of external corporate visions

Despite the issues just noted, Construction Co. does have a strong emphasis on sustainability as part of its external identity. This again has the potential to coincide with the energy targets for the hospital project, and therefore to pull together social worlds:

“Construction Co.’s a business that's very proud to be seen as being a green company… I think a lot of what we do, is to be a differentiator. I think that's the association of green with the brand, and if you ask anyone what they think about Construction Co., I think most often it comes up as a company that's very environmentally aware and responsible...So that's important and that is very much cultivated…”

(Int - Engineer 6)

Being green can be a way to win work in a crowded market, acting as a “differentiator” (Int - Strategy 2), a “selling point” (Int - Design 2), and by casting the company in a “leadership position” (Int - Environment 9). Reputation can certainly be a motivation to improve, as for example, when the experts group are notified of a project that has received a low DEC rating, one engineer comments “we can’t allow that to happen. We can’t have F on our buildings” (FN - energy experts meeting 2). In a similar way, once the school’s excess energy use has been reduced to a reasonable amount, the problem ceases to be energy use, and becomes about “the brand – we don’t like to put our hands up and say we missed the target” (FN - call with Engineer 2 on the school), providing an incentive to make sure future targets are met.
The brand imperative is present in the hospital project, where bid materials reiterate the ambition that “Construction Co. is determined to be [a] leading green project developer and contractor” (Doc - Initial Sustainability Statement for hospital bid), and external publicity emphasises its energy efficiency (Doc - News 2). However, a focus on reputation could possibly lead to an emphasis on managing the brand itself, rather than underlying actions to bring together the various social worlds of the construction team around energy performance, although, given the timing of this research, the outcome of the targets was still unknown. Another danger is that if being green is driven by perceived market value or demand, it can also be abandoned for the same reasons if it no longer seems “to be on the radar” (FN - energy experts group 1, FN - site inspection tour, FN - talking to Environment 6e). Notably, operational energy performance does not feature in the strategy team’s priorities for Construction Co.’s market development or innovation plans (Ints - Strategy 2 and 3).

If green reputation is a key issue to Construction Co. it can create an impetus for success stories that may be used as marketing, such as the use of case studies discussed earlier in this chapter. The hospital project follows this pattern as, for example, the bid materials for the hospital highlight a previous hospital project that is now operating at 25% below its energy use target (Doc - Project Co. client presentation). Once the contract was won, exciting new technological innovations, whether energy-related or not, become the basis of promoting the hospital (Docs - News 2, 4, 6, Website 2). Although useful for providing inspiration and information on what can be achieved, the focus on success means it may be harder to talk formally about failures in energy efficiency aspirations, or indeed even unremarkable projects, unlike the informal gossip networks discussed in the previous section.
A reluctance for actors from diverse social worlds to talk openly about failed projects is unfortunate, as there could be much to learn from them. At one point, I am myself told to de-emphasise the case of the school I looked at which had not met its energy targets, in case the director whose project it was feels like he is being “kicked” for it, and to make my insights more “positive” (FN - meeting with engineering team). It can be difficult for staff to admit publicly to failure:

“Actually the things you want to know are the things you did wrong. But how often - it's a human trait - sorry how many people do you know would stand up in a room of their peers and tell them what they did wrong?”

(Int - Engineer 3)

Engineer 1 explains how he has managed to set up a discussion forum on energy performance in his team, but that even with a small number of participants, they have to be encouraged to speak up:

“and the people who are listening, it's important that they ...have to be quite nice. ...You have to be um...humble. Not criticising...I think it's also an important question, you know, to... create a space where people are allowed to ask questions.”

(Int - Engineer 1)

A focus on success and external branding tends to capture exceptions from actors, and squeezes out day-to-day examples and problems that could help others develop their knowledge of energy in-use in the buildings they work on. It also seems to push failure into the informal channels of communication, such as gossip, that were discussed earlier. Thus there are a number of potential inconsistencies between the green vision of Construction Co. presented externally that unites its employees and contractors, and energy targets on projects such as the hospital.
This section has considered how the boundaries of the hospital’s energy targets do not necessarily coincide with other commercial priorities of either Construction Co., or what actors perceive its clients’ to be, as illustrated in Figure 6.5 overleaf. In Star and Griesemer’s case study, the creation of an exemplary museum was a central concern to the principal founders, funders, and local stakeholders. The “coincident boundaries” of the “nature preserve” fitted this common venture as well as each social world’s particular vision of success. In the case of energy targets, boundaries are not the same as other, larger aspirations belonging to Construction Co., or to the various incarnations of the client. These larger priorities may sometimes squeeze out or overshadow building energy performance in-use. This means that once again the energy targets do not appear to form effective boundary objects. Therefore, unlike Star and Griesemer’s zoology museum, the differing visions of stakeholders’ social worlds, both perceived and direct, do not always pull together within coincident boundaries to advance the development of overall knowledge about energy targets and buildings’ performance in-use.
Figure 6.5 A lack of coincident boundaries

6.6. Discussion and conclusions

6.6.1. Do boundary objects exist to facilitate sharing of energy information?

As discussed at the beginning of this chapter, one of the qualities of boundary objects is that they provide “bridges” between heterogeneous social worlds for the sharing (or “trading”) of information (Star and Griesemer, 1989). The aim of this chapter was to explore if the hospital’s energy targets do have the potential to help diverse professionals, from different social worlds, to collaborate on operational energy performance. In doing so, it returns to the idea of multiplicity, by investigating whether
diverse social worlds, with diverse aims, may nevertheless achieve a balance of heterogeneity and consistency in working on the hospital project’s energy targets.

Section 6.2 showed that the targets provide a common aim to make the hospital energy efficient, and to minimise its carbon emissions, that is easy to understand in principle, and which many - if not necessarily all - actors appear to be aware of in general terms. However, actors can lack confidence in translating the general aim of the targets into specific actions. Literature has suggested that a key problem for energy efficiency is the division of construction into many different actions performed by specialists (see section 4.2), yet Star and Griesemer’s work shows that this could be overcome. In the case of Construction Co., the boundary object concept helps uncover a more subtle issue beyond the diversity of specialists. It indicates that there are problems in understanding the unfamiliar energy targets, and in the transmission of energy expertise and experience between social worlds, which can in turn hinder them translating the targets into local actions. Unlike the low carbon policy goals in the studies quoted at the beginning of this chapter (section 6.1.3), energy targets have not proved to be a goal that this particular construction team rallies round consistently.

Section 6.4 examined the extent to which the information needed to help actors increase their knowledge about energy performance in-use is collected and traded between social worlds. It also considered what sorts of potentially useful information about the energy targets is not captured by existing systems, and hence is “residual”. This indicated that few systems currently fit the needs of information on energy targets, and that current formal means of trading information may not be not effective at producing practical expertise to help actors implement energy targets. Instead, there is a high degree of “residual” information either uncollected, or circulating unpredictably
via informal means. Energy expertise is rooted in a small group of engineering experts who provide a consistent recourse for questions, but may also keep energy performance pinned into a specialist, technical corner, from whence it is harder to circulate to others. This further hampers the development of practical knowledge about how to handle an energy target amongst other social worlds. Overall, the failure of information to flow evenly between actors inhibits the development of an internal economy of energy information. This contributes to the literature quoted in section 6.1.3 that described how new information sharing systems or standards could create change in construction, as here the difficulties appear to arise from the imposition of targets without sufficient supporting work processes.

Finally, section 6.5 showed how the boundaries of the energy targets fall within the larger venture of building the hospital. As a result, other commercial goals have significant effects on sharing information around energy. The targets can be subsumed by more pressing priorities for success, such as patient safety and local prestige, or by emphasis on reputational and branding issues. The boundaries of these priorities do not necessarily coincide with those of long-term operational energy use in buildings. The focus of the client itself, in its various subdivisions, can also confuse the priority associated with energy targets. Therefore, this chapter has underlined the uneasy fit between energy and other incentives in construction, supporting other research (for example, Janda, 1998).

6.6.2. Are boundary objects at an immature stage?

The final concept introduced from Star’s work in section 6.1.1 was that of the “lifecycle” of a boundary object (2010:613-14). From heterogeneous social worlds, boundary objects grow at first out of informal alliances between stakeholders. From these links, systems are formed that balance cooperation and individual work, and produce
“economies” that trade information. From the previous sections, it is clear that developed systems to collect information about the energy targets throughout the hospital project do not yet exist. Those that do exist are subject to limitations. Moreover, there is a high level of what appears to be “residual” knowledge about energy targets and energy performance in operation that is not incorporated into any formal information management systems. It is therefore possible that if energy-related boundary objects do not function well, it is because they are at an immature stage of development.

The relative immaturity of the systems of information sharing around the energy targets is particularly apparent when they are compared to those around more established commercial priorities, such as the construction programme, or branding concerns. This supports other research findings quoted in the introduction to this section around the challenges for boundary objects in disrupting embedded working practices. The overshadowing of energy and carbon by other, larger priorities with greater perceived importance in the construction team may impede the further development of knowledge around dealing with operational energy use in Construction Co.’s building projects. It could be argued that Construction Co. does not need to share information or increase its own knowledge about energy use or carbon emissions in operation, as it manages building projects rather than participating directly in design or construction activities. However, it is exposed to the outcome of the targets, both in terms of the direct financial penalty and its reputation. Moreover, if its role is to facilitate the cooperation of others engaged in design and construction work, then there are potential benefits for the company in improving information sharing processes around energy.
6.6.3. What has been learnt?

If information and knowledge about energy performance in operation is to mature further, there are a number of learnings for Construction Co. to take on board. Making a meaningful cultural shift to more sustainable buildings does pose significant challenges for construction companies (Wingfield et al., 2008; Boyd and Schweber, 2012; Morrell, 2015). This research has shed more light on why this might be. One reason is that there is an internal ambiguity as to whether energy targets are really worth making the shift. Participants express some doubt, as section 4.6.2 showed, as to how committed clients really are to the concept of energy targets, or what guise energy performance guarantees might assume in the future. Thus the market demand for operational energy targets is uncertain. As discussed, other industry preoccupations, of which there is a bewildering set, from wellbeing, to offsite construction, or fire safety, could further inhibit a focus on energy efficiency and changes to working practices. Energy targets might therefore suffer from a lack of consistent priority from Construction Co., its clients, and policymakers, which hold them back from inducing real change.

However, if further market demand does arise for energy performance in operation, whether voluntary or regulatory, Construction Co. will need to consider how it can prepare its information management better to meet it. It should consider the level of in-house energy experience or expertise focussed in the teams, particularly on site, but also in design and operation, as detailed knowledge in this case seems to be either out-sourced or confined to internal “gurus”. This implies that Construction Co. would need to make a decision as to what extent it wishes to move from being a green “systems integrator” to offering its own knowledge about energy efficiency. It would also require Construction Co. to make an active choice as to how it balances professional heterogeneity and cooperation through designating what information it
requires to be shared by staff and subcontractors, and what can be left to specialists. This theme of managing the specifics of cooperation also crosses the other chapters, and will be picked up again in the Discussion and Conclusions that follow (Chapter 7).

The analysis here gives some ideas as to how information on building energy performance might be exchanged better, based on the specific case examined. Information needs to be consistently collected, but also seems to benefit from personal delivery. Knowledge management systems need to give more practical guidance on what actors should actually do in response to energy targets. These examples should include both success and failure, rather than encouraging the promotion of “hero” stories (Janda and Topouzi, 2015). This should also provide a benefit in capturing some of actors’ informal experiences, currently circulating in the form of gossip, for the use of the company and its contractors. The findings also suggest that energy targets as a policy instrument cannot be applied on top of pre-existing industry structures and practices and expected to induce collaboration. Moreover, the importance of the trade-offs they will require from other policy objectives, such as improving specialist medical care or leveraging funding and risk from the private sector, should be considered.

6.7. Reflections on the concept

6.7.1. A concept to broaden the picture

The boundary object concept encouraged me to widen the net of my research to encompass different people and processes from those I had examined in Chapters 4 and 5. I found that I was now talking to other individuals, from senior staff engaged in the high-level strategic concerns of innovation and knowledge management, to junior administrators involved in document and information systems. Taking this perspective allowed me to step back from the hospital project to consider the potential influence of
the company, its systems, and its priorities on the energy targets, and their influence on “the gap” itself. It was therefore both academically interesting and practically useful for Construction Co., to consider the hospital project in the context of the company itself.

In considering the trading of energy information, I have pursued additional angles of the original boundary object concept beyond its familiar concern with interpretative flexibility. I felt that these directions were useful to addressing my underlying concern of the energy performance gap, and responded to some of Construction Co.’s own concerns, as it admits to knowledge sharing as one of its weaknesses (Doc - Intranet 4). However, in considering general aspects of feedback and information, I risked following leads that took me too far away from the topic of energy targets, or even energy performance. In order to keep on track, I have had to employ my own version of “tacking back-and-forth” between my research question and the specific data I was gathering, to ensure that they continued to tie together. Avoiding too much focus on different interpretations also avoided re-treading ground on cooperation already covered by Chapter 4.

6.7.2. Challenges of boundary objects

The boundary object is in principle easier to grasp than Mol’s ontological philosophy, or Gilbert and Mulkay’s discursive repertoires. However, I found that the apparent simplicity of the concept, and its sheer flexibility, made it the hardest of the three concepts to apply. The boundary object is a slippery concept, as balancing heterogeneity and cooperation is just that: a delicate balance that is hard to pin down. I found it challenging to determine what the characteristics of a successfully balanced boundary object might be, or how to judge the integrity of information that should result. As a lone researcher, I was also concerned that I would miss information transfers and conduits through an inability to cover enough ground in the time available. Practically
speaking, the issue of how exactly to balance general and specialist knowledge is one of the main questions that this work raises for Construction Co.. Although I have been able to make some suggestions in the conclusions to this chapter around better feedback and the balance of in-sourced and out-sourced knowledge, I am not able to provide the details, which will require further examination by the company, and others in the industry.

A more conceptual implication of relevance to construction lies in the boundary object’s lifecycle, and its tendency to gradually increase standardisation of information as it matures (Star, 2010:613-4). The original case study of the zoology museum suggested that mature, standardised information systems were key to its success. This success derived from the links the systems forged between the common venture and stakeholders’ specific work, and because of the consistent gathering of information in forms recognisable and accessible to all (Star and Griesemer, 1989). However, Star’s later paper (2010) emphasised that increasing standardisation eventually leads to inflexibility, and the resulting exclusion of potentially useful information from the common system. For energy targets, this raises a question as to how much standardisation is currently desirable. If construction teams, like the one in this case study, are still learning how to manage energy and carbon in-use, flexibility may still be beneficial whilst determining better means of identifying and sharing information about energy targets.

6.7.3. Stones unturned

Despite some of the challenges in applying the boundary object concept just outlined, it contains a wealth of ideas with which to explore the cooperation of multi-disciplinary teams around energy targets, and energy performance in general. There were very many other themes that I would have liked to pursue, but did not have the capacity to.
These would make fruitful areas of further research. In particular, it would be very interesting to explore information standardisation, as just noted. Another related idea would be to consider the “common coin” that guides information exchange between social worlds, and which is only glancingly referred to in this chapter. Given some of the difficulties in representing future energy use in recognisable units that has been highlighted in various parts of this PhD, I would have liked to investigate this.

A further area in which I would have liked to collect data is the client. In Star and Griesemer’s original paper, the vision and momentum behind the museum is created by its patron, providing funding, and its scientific director, providing the academic impetus. In my case study, the energy targets have come from government via the local NHS Trust, meaning that these actors are critical in shaping the sustainability vision for the hospital. Other emerging research in non-domestic projects suggests client commitment to energy targets might be key to operational outcomes (Cappuccio et al., 2018). Actors within the client body are therefore worth much more analysis than the brief paragraphs I was able to provide in this chapter.

By contrast, there were data which I gathered, but which I could not justify as academically interesting enough to include in this thesis. For example, participants talked a great deal about Construction Co.’s corporate values, and these featured prominently in my own observations in the field. The values seemed to have significant relevance to the way that participants discussed sustainability, and how they chose to translate it into action. Whilst this does have relevance to the energy targets, it was too marginal to the boundary object concept to include in these findings. Yet the topic is likely to be of great interest to Construction Co. itself. The solution I have therefore
provided is to include this, and other similar topics, in the separate outputs for the
sponsor that can be found in Appendix I.

6.7.4. In conclusion

Chapter 6 is the last of my empirical chapters. In turn, I have now examined the
practices, discourse, and sharing of information in relation to the energy targets in the
hospital case study, and, where relevant, in Construction Co. more generally. It is now
time to draw together the findings across all three of the chapters, considering linkages
and inconsistencies between them, and what learnings for construction, policy and
academic research arise. It will also allow me to return to the opening of this thesis,
and to consider what has been contributed to the academic knowledge on energy
performance in non-domestic buildings, and to think more about how the methods and
concepts adopted have been effective in addressing the original research questions.
As set out in the introduction to this thesis, the chapter that follows has been kept
relatively brief in view of the emphasis on discussion that has already been taken at the
end of the empirical chapters.
7. Discussion, learnings and conclusions

At the outset of this thesis, the Literature Review suggested that the failure of construction teams to collaborate effectively across disciplines, and to engage with the operational performance of buildings, played a significant role in perpetuating the performance gap. A number of authors have suggested that new incentives, such as operational energy targets, could pull together design and construction teams around the common aim of energy efficiency in-use (section 2.2.1). However, prior experience with energy targets indicates that construction teams may still not produce buildings that perform against their design promises (section 2.2.3). This suggests that a more detailed understanding of what happens “inside the gap” when construction professionals interact with energy targets is needed. Without such an understanding, a disconnect between the strategic aspirations of non-domestic building policies and practical implementation is likely to persist. The aim of this thesis has been to contribute just such a situated exploration of one project team’s engagement with operational energy and carbon targets.

This final chapter will summarise what has been learnt. Findings have now been presented in three empirical chapters, each drawing on a separate theoretical or analytical basis. This has allowed them to contribute distinct insights, sensitising us to different aspects of what energy targets might mean to construction actors “inside the gap”. However, the three different STS concepts are also intended to complement each other. They share a concern with multiplicity, whether through actions, communications, or collaboration, that both fits with the challenges of energy...
performance in complex buildings produced by a variety of professionals, and reveals the mutable nature of targets intended to control it. As stated in Chapter 1, the aspiration was to contribute to research conversations around policy for energy use in buildings, and to do so by using STS to frame the analysis of communications and collaborations in this specific case study of construction. It is therefore important to return to these expectations. Consequently, this chapter will include reflections on how the findings contribute to the literature in the discussion that follows.

However, the purpose of this research, again as stated at the outset, is also to provide findings that are helpful for stakeholders in industry and policy, and for whom theoretical distinctions between academic theories are less relevant. This overall discussion will therefore summarise what has been learnt from each chapter, and then draw together overall themes from across the theoretical divides to consider what has been learnt in combination. It will also consider what implications these themes might have for both industry and policy, based on the insights from this specific case study.

Therefore, this chapter will start with a brief summary of the findings of the three empirical chapters in section 7.1. It will then bring together the overall themes emerging from the thesis in a general discussion in section 7.2, followed by the implications that arise for construction and policy, as well as for future academic research in section 7.3. It will then present some reflections on the research approach, covering both methodological limitations and the utility of the three theories used in this PhD in section 7.4. Finally, section 7.5 will complete the thesis by summarising the main conclusions.
7.1. Summary of findings: what has been learnt about “life in the gap”?

7.1.1. What do actors in the construction team do in response to the energy targets?

The contention that reality is enacted (Mol, 2002) was used in Chapter 4 to investigate what actors in the construction team do in response to the energy targets. Using this ontological approach allowed the analysis to reveal how the hospital’s energy targets become multiple in the hands of different professionals during the various phases of its development. It found that the “coordination” (or bringing together) of these diverse enactments of the targets was not consistent, with particular fragmentation occurring during the construction period. This was compounded by a lack of overarching responsibility for the energy targets across the project lifecycle. The structuring of contracts, work packages, and responsibilities were found to be a major reason behind this. The consequence was that the hospital’s energy performance sometimes appeared as the sum of various individual parts, and hopes to meet the energy targets were often invested in specific silver bullets. Therefore the energy performance of the hospital did not “hang together” as a holistic team endeavour.

Chapter 4 also showed how considering reality as made by practices also reveals its malleability. Actors’ efforts to ‘make’ an energy efficient building were most obviously focussed on the points of developed design (target setting) and initial operation (target assessment). This differs from a more dynamic enactment of the building that could acknowledge the energy implications of the many changes in design and construction through the building’s development. Using Mol’s work to frame the data indicates how the determination of ‘good’ or ‘bad’ performance in low carbon buildings is not
objective: because it is made by stakeholders. The reality of whether energy targets are met is therefore negotiable. Thus greater disclosure of buildings’ operational energy data, through targets or other means, is not as simple as it seems, because it will not of itself overcome the ontological differences between different versions of energy performance.

As shown in the Literature Review, some authors advocate more “transparent” information on the operational performance of buildings, (Cohen and Bordass, 2015; Cohen et al., 2017). This view assumes that opening a window onto the underlying reality of actual energy use will ultimately help to reduce it, by providing a lever to focus design and construction actors on achieving better energy outcomes. The findings in Chapter 4, however, suggest that there is no singular reality of energy use to uncover. A key question is therefore what version of the building and its energy use, is being enacted in the assessment or reporting of performance against targets.

7.1.2. What do actors in the construction team say in response to the energy targets?

Chapter 5 considered how actors in the construction team spoke about the energy targets, employing Gilbert and Mulkay’s approach to discourse analysis (1984). Using their concept of interpretative repertoires, it first explored how actors rationalised any potential energy performance gap through a discursive contrast between energy “theory” and “reality”. These repertoires were used by actors to deem certain professional practices unreliable, and also to deflect their liability for any “errors” that arose from these practices. Secondly, it considered differences in actors’ discussions of uncertainty between formal and informal contexts. It found that uncertainty about the hospital’s energy use was “suppressed” in formal accounts, whilst being acknowledged informally.
Underlying both sets of contrasting repertoires were the effects of commercial contracts. The contractual terms of the energy targets require Construction Co. to guarantee a level of energy use and carbon emissions based on design projections. Inevitable fluctuations in energy use from changes in design, construction, commissioning, or operation that then arise may produce “errors” in meeting the target projections. This encouraged actors in this case study to evade the formal recognition of these uncertainties, and to deem design work “unreliable” in respect of energy and carbon. The contracts also appear to encourage the allocation of blame, and hence initiate a retreat by construction actors into defensive risk management. The defensive conversations displaced discussions that could recognise uncertainty, and the difficulties of predicting energy use at design.

Overall, the findings in Chapter 5 illustrate how actors’ talk may reveal their problematisation of the energy targets, and “the gap”, in their own terms. It therefore indicates how the performance “gap” may be manifested in words as well as actions. As such it contributes a new perspective to the small pool of empirical research on construction teams’ discourse around sustainability (Gluch and Räisänen, 2009; Ludvig et al., 2013), and supports the wider body of work that already highlights the shaping power of language on energy (or sustainability) outcomes in the built environment (Guy and Farmer, 2001; Janda and Topouzi, 2015).

7.1.3. How do actors in the construction team share information about the energy targets?

The final empirical chapter used specific aspects from the concept of the boundary object (Star and Griesemer, 1989; Star, 2010) to consider how actors in the construction team share information about the energy targets. It found that the
incentive of the energy targets could form an effective common aim across the construction team, but that awareness did not percolate far enough through the relevant stakeholder groups. Moreover, actors found it difficult to understand what the introduction of energy targets meant they had to implement or adjust in their day-to-day work. Chapter 6 also revealed the limitations of company systems in “trading” (sharing) information that could help actors respond better to the energy targets. It indicated that significant amounts of “residual” energy-related information was either circulating informally, or evading capture entirely.

The chapter concluded that the boundaries of energy targets and other, larger commercial priorities do not necessarily coincide. This includes both Construction Co.’s own commercial imperatives, and what it perceives to be its clients’. Thus there is not enough drive to enhance the priority of energy targets within the organisation or the construction team, and to make deeper changes to existing professional processes. The energy targets and associated systems that could capture information relating to them therefore appear immature and under-developed. Construction Co. might not therefore capitalise on the full extent of available energy information, which it could use to grow its knowledge in building low carbon projects further.

The boundary object, as Chapter 6 noted, is a well-used concept. The analysis in this thesis used specific aspects of it concerned with information sharing (or “trading”) to examine how energy targets interact with communications around energy in the case study construction team, and company. The aim is to feed into conversations that highlight communications as a key “barrier” or concern for energy performance in buildings, including both industry and academic research, (for example, Zero Carbon Hub, 2014; Zapata-Lancaster and Tweed, 2016; Hietajärvi and Aaltonen, 2018), by
highlighting the ways in which energy information travels (or fails to travel) between the diverse social worlds of the construction team.

7.2. Discussion

7.2.1. Energy targets and the challenge of managing multiplicity

From the three empirical chapters some overriding themes emerge. These are:

1. The control of, and responsibilities for, energy targets;
2. Company priorities and ways of managing energy information; and
3. Dealing with the energy targets as a risk.

Each of these will be discussed briefly in turn, drawing together findings from all three empirical chapters. Additionally, the findings also raise other questions for discussion. Firstly, they help assess to what extent the energy targets have fostered a sense of responsibility for operational performance in the construction team. Secondly, they suggest that understanding the fundamentals of what an energy efficient building is might be more complex than it appears. Together, these themes and questions form the response to the original research question of how the practices and communications relating to energy targets in a construction team might contribute to the phenomenon of the performance gap.

7.2.2. Controlling energy and the responsibility for energy targets

This particular hospital's energy targets originally derived from several policy principles: an ambition to reduce carbon emissions from the NHS; the devolution of risk and responsibility for ‘delivery’ of public projects to the private sector, as embodied in PFI; and the pursuit of more ‘output-based’ policy metrics (sections 3.5.1 and 3.5.2). Other authors have warned that policy in the built environment often misjudges the means of inducing change in construction (Whyte and Sexton, 2011; Foxell and Cooper, 2015;
Loosemore, 2015). This thesis supports that, indicating problems in imposing high-level energy efficiency or carbon emissions targets onto building projects and expecting better performance to ensue. The findings indicate not only the difficulties of inducing “change” in construction practices and discourses, but also the ambiguous nature of energy targets themselves.

Energy targets may indeed appear simple in principle, but are much more slippery to get hold of in practice. As shown in the introduction to the case study (3.5.4), the hospital’s targets are numbers in a contract, which represent an expectation of ‘good’ energy and carbon performance, to be compared with actual measurements taken at a defined time in the future. However, the details of how this level of performance is to be achieved through day-to-day practices during design, construction, and operation is left to the team’s discretion. An energy target is hence amorphous in origin: it is “not the kind of object you can drop on your toe” (Law and Singleton, 2005:331). As Chapter 6 observed, whilst the general aim of a target may be easily understood, its translation into actions is much less certain. Yet these translations are critical, as how energy is materialised affects the priorities and decisions attached to it (Shove, 1997). Indeed, Chapter 4 showed how different actors’ enactments of the targets leads to problems in coordinating the multiple versions that arise. This suggests that there are difficulties in maintaining consistent and coherent control of the project’s energy targets.

The contract for the hospital places legal responsibility for the energy targets onto Construction Co.. The company, however, is made up of many diverse, and sometimes competing, groups. Moreover, the construction team charged with the hospital project is also an amalgam of many professions and contracted organisations. This is not in itself problematic, if there are systems to ensure the coherence of the overall output
(Chapter 6). However, as energy targets are an unfamiliar, and still unusual, construction requirement, there are no established procedures to follow, as shown in Chapter 5. This is a significant problem as many of my participants emphasise the importance of process and “compliance” in directing their day-to-day work (for example, see section 5.2). The introduction of the targets may meet with confusion in the many different parts of the team. Thus an operational energy target does not automatically unite actors around a shared aspiration, as some have suggested it could (UK Green Building Council, 2016).

Uncertainty about how to approach the energy targets, and who is responsible for them, could lead to an uncoordinated response. The findings in Chapter 4 suggest that during the construction phase practices around the energy targets become particularly fragmented. The design energy model provides an overall vision of the building energy and carbon in-use. However, as shown in section 4.2, one of the outputs of design is also to translate the targets into specifications for the various systems and materials that should together deliver the required energy performance. These specifications, in which energy is measured in a variety of different units, from U-values to seasonal efficiencies, are followed by individual specialists who have no direct stake in, and sometimes little awareness of, the eventual energy performance of the building. The BMS provides a focus point to draw together energy information during operation, but this is a separate system from the energy model, and only functions once the building is complete. As section 6.4 reveals, there is simply no system to monitor information on energy expectations in the current construction process, leaving it to the varying attention of individual team members.
This situation is exacerbated by the lack of an individual or a team with overall responsibility for energy performance. As Chapter 4 observed, there are many actors who have partial responsibilities for energy performance, and a few who have in-depth experience of energy targets, but there is no one who appears to have an overall responsibility for the targets from design, through construction, to operation. The solution is a mix of different measures to be delivered by specific actors, such as the renewable energy supplier, the lighting supplier, or the legal team (for example, sections 4.2, 4.4). This does not represent a holistic strategy leveraging knowledge from outside the organisation and drawn together by a guiding vision from within. The overall result is an inconsistency of energy information occurring between design and operation that the team’s processes and responsibilities have failed to straddle, despite the presence of the energy targets as an incentive to link them.

7.2.3. Company priorities and the management of energy information

How Construction Co. does business and handles information also affects the ways in which actors engage with the energy targets, as show in Chapters 4 and 6. Other research has previously made the point that construction actors’ “institutional” ways of working may prove resistant to sustainable construction ambitions (Bueren and Priemus, 2002; Fedoruk et al., 2015; Palm and Reindl, 2016). This thesis supports that in general terms, but more specifically contributes to literature on the management of information in construction, which operates through “loosely-coupled” organisational connections and reactive decision-making (Gluch, 2009; Gluch et al., 2013). The findings reveal contextual detail around the ways in which Construction Co.’s own information management processes structure responses to the imposition of energy targets in the hospital, in ways that make it difficult for actors to ‘change’ in response.
As initially observed in section 4.5.1, the company is primarily structured to be a “systems integrator”. It therefore often relies on the expertise and judgement of its supply chain to address the challenge of energy targets. This is problematic for the hospital’s energy targets in a number of ways. Firstly, awareness of the targets does not appear to have spread uniformly across contractors (section 6.2). Secondly, contractors may not wish to share all of their energy-related knowledge with Construction Co., either because it represents valuable intellectual property for them, or because they are wary of exposing their company to liability (for example, 5.2.3, 6.4.3). Finally, Construction Co. itself may also shy away from suggesting changes to subcontractors’ work for reasons of legal liability. The company is therefore liable for the eventual energy use of the hospital, but not necessarily able to judge if it possesses sufficient information about what might affect it.

Figure 7.1 overleaf illustrates the difficulties arising from choices as to what information “gets thrown over the wall” (to use one participant’s analogy quoted in Chapter 6) between project stages and contractual parties. Different groups of actors, whether from different departments of Construction Co. or, as shown in the figure, from different organisations, hold specialist information that will affect the project's eventual energy use. Not all of this information will be transferred for obvious practical reasons, and for the commercial reasons just described in the previous paragraph. Yet if relevant information is not transferred, parties on either side of the commercial “wall” will have to deploy strategies to deal with the resulting uncertainty. It is not practical to suggest that each party involved in a construction project should have complete information about every possible aspect of its eventual energy use. However, what Construction Co. could consider is what particular sorts of information it would be most beneficial to share over the “wall”.

In addition, the ways in which Construction Co. handles information internally also has a potential impact on its ability to respond to the energy targets. Energy knowledge, as Chapter 6 showed, often appears to be treated as a technical specialism confined to a few. Information that is circulated formally tends to be in the form of case studies, often packaged in marketing terms. Experience or expertise that could be valuable from non-technical staff and from informal communications is not captured effectively (section 6.4). If energy is seen as a technical risk to be managed by outsourced experts and internal “gurus”, then non-technical knowledge that does exist in the business is not capitalised on. Restrictions in the internal channelling of energy information could mean that actors in the construction team are not aware of the impact of their day-to-day
decisions on eventual energy performance, or do not take the decisions to improve
energy performance that they could.

Previous research has noted that a rearrangement of contractual boundaries and ways
of working facilitates innovation in construction (Walter and Styhre, 2013; Boyd et al.,
2015). However, to make this change, motivation is required, and the “salience” of
energy may not be great enough to induce this (Mallaburn, 2016). As noted in Chapters
4 and 6, actors in Construction Co. are unlikely to make any fundamental changes in
their ways of working to adapt to operational energy performance without clear demand
from its clients and commitment from senior management. In the case of the hospital,
its energy targets originate from government, and are not necessarily a priority of the
local NHS Trust (section 6.5.1). Moreover, such contractual targets are still a rarity.
Construction Co. does not appear to be convinced of the long-term interest in
operational energy and carbon performance from UK government or the commercial
market (section 6.5). This deters it from making significant changes to its usual
procedures, given that this would incur significant disruption, time, and cost. In these
circumstances, there is little incentive for the company to treat energy targets as
anything other than exceptional requirements. As a result, it is perhaps strategically
and practically more attractive for them to confine adaption of working processes to an
assessment of the risks, some tweaks to existing ways of working, and a focus on
managing liability.

7.2.4. Dealing with a different type of risk

Energy targets are also often acted on and spoken about through a prism of risk (for
example, sections 4.2, 5.3). This is again linked to Construction Co.’s positioning as an
integrator of others’ skills, and its partial adaptation to the demands of operational
energy targets, both of which have just been discussed. It also links to a more
widespread theme around the general “risks” of delivery to the hospital project that appear to characterise other aspects of project management besides energy. Consequently, Construction Co.’s primary activity sometimes seems to be managing risk, rather than building buildings. However, the risk represented by energy targets is potentially different to other project risks that Construction Co. regularly deals with. The construction team actors may therefore be less prepared to deal with it.

Making energy predictions involves envisioning how a building that does not yet exist will operate at a point in the future (de Wilde, 2014). Whilst design is inherently a conjuring process, energy targets must guarantee a fairly precise level of energy use that is subject to complex and changeable interactions. As explained in Chapter 5, Construction Co. does not always have enough information to judge either the odds or the parameters that may determine the energy performance of the building. Nor can it control uncertainties arising from the “human factor”, such as the building’s users, and the particular client's tolerance of failure. In addition, the contract framework places the risk fully onto to Construction Co., encouraging them to take evasive action, to avoid what participants describe as an “onerous” or unfair burden (section 5.3.3). This prevents a sense of shared responsibility for energy use amongst client, main and subcontractors, and instead promotes a sort of musical chairs for risk management, as parties try to evade it.

A focus on risk also discourages innovation. Construction Co. is willing to take on challenging targets to win business, but is also keen to minimise responsibility. For instance, it ring-fences particular areas of energy that it can control, or suggests protective contract provisions (section 5.3.2). More innovative solutions to the energy targets may be ruled out. For example, an option to connect the hospital to a district
heating system is rejected early in design on the grounds that Construction Co. cannot control its timetable for completion (Int – Engineer 2b). Whilst it should be acknowledged that healthcare might not be the best sector in which to attempt radical innovation for reasons of patient safety, the level at which this energy target is set is in fact something Construction Co. has delivered on a few previous hospital projects. The findings provide mixed evidence for the targets driving further efforts towards energy efficiency. For instance, the efficient lighting is to a great extent the result of technological improvement since the original bid, and the efficiency of the fans appears to have been a response to revised Building Regulations rather than the energy targets (section 6.4.4). It is only in the introduction of a specific carbon emissions target that the construction team is stretched. Thus a focus on risk may not help push the boundaries of what can be achieved in low carbon design, as it might encourage Construction Co. towards where it feels comfortable.

7.2.5. Do the energy targets make the construction team more responsible for the performance of their product?

The policy aim of the hospital’s energy targets is to make the construction company responsible for energy in-use. This thesis aligns with the conclusions of other qualitative case studies that targets for energy or sustainability may have unpredictable consequences when they encounter the actors they are intended to motivate (Moncaster and Simmons, 2015; Palm and Reindl, 2016; Jain et al., 2017). The findings in this case do indicate that this new incentive has engendered a sense of responsibility in many participants. The financial penalty is most often uppermost in participants’ minds, and some are also aware of potential reputational damage (sections 5.3.2, 6.3.1). These dual drivers of contract and reputation align with the motivations suggested by advocates of Design for Performance, or other initiatives in the mould of NABERs introduced in the Literature Review (section 2.2.1). Much time
and effort appears to have been taken in the design stages, particularly by the M&E contractors, to meet the targets and balance out the demands of both energy efficiency and carbon emissions (section 4.2.1). Senior members of the construction and facilities teams are also aware of the need for additional monitoring and management in order to track energy use, and are prepared to invest more budget to achieve this (section 4.5.2). Significant attention has also been given to various commercial, legal, and engineering reviews of the targets’ implications (section 4.2.1). There is a sense of pride attached to working on a project with such high sustainability aspirations, evident from some participants’ comments, and from documents (section 6.2). Finally, this PhD would not exist were there not an internal concern in Construction Co. around the implications of energy targets for its business.

However, the target incentive does not always act optimally. The concern for liability does not, for example, work evenly on actors. Thus although facilities and construction teams may both care about monitoring energy, their motivations for managing it diverge. They may even work against each other, as a few participants point out in Chapter 4. Thus the energy targets do not necessarily overcome professional divisions. Additionally, there are omissions or uncertainties in the contractual responsibilities of Construction Co. that present issues for eventual energy and carbon in-use. As energy costs, for example, are excluded from Construction Co.’s responsibilities, the carbon target does not necessarily encourage them to focus on the long-term cost-effectiveness of their renewable energy proposals (section 5.2.1). It is also unclear how responsibility will be untangled for a number of areas that could be significant sources of energy use, such as occupiers’ activities and electricity use from medical equipment (sections 5.2.4, 6.3.2). Construction Co. is also unable to manage energy use from activities over which it has no contractual control, such as information technology and
Soft FM services (section 4.7.2). These gaps in energy responsibility can potentially obfuscate the assessment of actual energy use against targets, provide convenient scapegoats for any problems, and prevent a holistic approach to the building’s eventual energy use.

Critically, the energy targets can also have the unexpected effect of continuing to encourage what Cohen et al. have called “design for compliance” (2017), but through alternative means. As raised in Chapter 5, actors continue to talk about the two apparently irreconcilable points of “theory” and “reality”, indicating that the promised links between design and construction have not been fully forged. The energy targets thus fall into the representational trap of taking snapshots of a moving object (Latour and Yaneva, 2008), because the bidding process for the project explicitly requires a guaranteed “prediction” of operational energy use and carbon emissions (as quoted in section 5.3.3). This fails to recognise the dynamic nature of buildings and the actors that use and shape them.

The overall effect can be to foster the skills of target management, rather than energy management. Therefore construction teams may be made more responsible for energy use, but perhaps not in the ways anticipated. This engages with literature on the pitfalls of target setting as a means to induce changes in the behaviour of particular groups, both in general, and in reference to energy in-use (Gann and Whyte, 2003; Meacham et al., 2005; Love et al., 2017). The findings here also indicate that whilst some positive innovations have taken place in the design of the hospital, there is also an opposing temptation to manage the target by other means. This reflects Murtagh et al.’s study of architects and design engineers (2016), which concludes that the introduction of new mandatory “motivations” can encourage actors toward sustainability, but also produce
negative effects, such as seeking out means of avoidance or taking the route of minimum compliance. This brings us to the final question for discussion, of how the energy efficiency of a building is determined.

7.2.6. Do energy targets help make more efficient buildings?

Targets for operational energy performance are intended to address concerns that design predictions are not “realistic” enough. However, the findings from this PhD show that this supposition is not as straightforward as it might seem. Chapters 4 and 5 have shown that the reality of the measured building energy can be negotiable, and may be assembled in a number of ways. Chapter 6 has also shown that the way in which information is channelled promotes some project outcomes and types of information above others. The result is something of a paradox. Both the assumption of the targets, and actors’ conceptions, suggest that energy use in design and operation are too often different and the challenge for the hospital is to ensure that they are the same. Indeed the discussion above indicates that the construction team have struggled to adapt to this challenge. Yet the findings also indicate that what is counted in design targets or operational measurements, both in the contract and in subsequent discussions, is flexible. The gap between target and actual may therefore be closed by negotiation between parties, as they reach agreement on what is an acceptable reality for the building’s performance. This then forms the agreed “story” of the building (Janda and Topouzi, 2015).

Barry (2015) has argued that the measurement of energy creates the object it purports to represent. Shove (1997) has likewise drawn attention to the “proxies” in which we may come to “know” energy in various forms. This thesis indicates how the stakeholders in this particular case produce an ‘energy efficient’ building. The hospital (and indeed the school discussed in Chapter 4) is a performance of both practice and
discourse, as construction professionals formulate strategies, and collect and assemble evidence, to meet energy targets. Once the building is complete, client and construction contractor will reach an agreement on what meeting the targets means to them in practice, as illustrated in section 4.3.2. The paper by Love et al. quoted earlier uses mathematical techniques to reveal how operational energy measurements may be manipulated (2017). This thesis offers a reflective perspective from a different research tradition, showing how the reality of a building’s energy use will always be a construction of the actors involved in reporting it. The question raised here is therefore not what actual measured energy really is, but what we would like it to be.

The negotiable nature of the building’s energy performance can sometimes represent an opportunity for a proactive and open discussion between client and contractor about energy in-use. Indeed, some members of Construction Co. had had positive experiences on previous projects (section 5.3.3). However, if the negotiations focus on controlling liability, accounting adjustments, and an unwillingness to investigate the underlying details of energy use (as in section 5.2.3), the result will not help increase Construction’s Co.’s understanding of how its buildings perform in-use. The hospital project offers the potential for either approach in the assessment of its targets, the results of which are as yet unknown. Therefore ensuring that negotiation is as positive and open a process as possible is important.

The contractual targets also run the risk of simplifying the causes of energy under- or over-performance. Technological failure, as Latour reminds us, can be the result of a “collective assassination” (1996:10). However, the hospital’s contract penalties require that fault is clearly allocated to one party or another. This is despite the potential for complex interactions of actors and technologies underlying energy use. Internally,
Construction Co.’s staff can also favour explanations that focus on particular factors. This includes, for example, proposing that one specific technology is the solution to the hospital’s overall targets (section 4.2.2), or circulating stories of previous projects that attribute overall failure to meet energy expectations to one particular cause (section 6.4.4). Moreover, if the targets are met at a total level, there is no remaining incentive to explore in further detail how the system is working. The placing of target boundaries of acceptable energy use makes the performance of the building appear more easily knowable, but such determinations are highly normative (Mol, 2002). Thus the level at which the energy targets are set and investigated is critical, as it forms a standard below which a building is deemed efficient and no further work is required.

However, even making a judgement on the efficiency of buildings that meet their targets is problematic. Literature that promotes greater disclosure of operational energy use emphasises the power of rendering it “transparent” (Cohen and Bordass, 2015; Cohen et al., 2017). However, this thesis indicates that the many contractual ins and outs of what is included in energy use or carbon emissions may be individual to each project (section 6.3.2). Variation in these provisions can therefore make it challenging to compare between buildings, even though to do so is part of the targets’ intent. As explained in Chapter 4, Construction Co. has indeed run into exactly these problems when trying to compare between its previous projects with energy targets (section 4.3.1). When added to other idiosyncrasies of non-domestic buildings, such as their many varieties of form and function (Hong et al., 2013; Morgenstern et al., 2016), the question of obtaining an overall picture of ‘good’ performance becomes even more complex. This impacts on Construction Co.’s ability to learn how to build more energy efficient, lower carbon buildings, and on clients, regulators, and government in their
attempts to set realistic but demanding targets to improve the performance of the building stock.

As observed in Chapter 5, in judging energy performance it is vital to pay attention to what is not being made transparent, as well as what is. The nature of what is disclosed or determined about energy and carbon clearly affects any assessment of whether targets produce buildings that are more likely to perform in operation. In terms of reporting policy outcomes, and drawing up construction specifications, a binary yes or no as to whether a building is ‘working’ is convenient. However, it obscures the informative subtleties behind this simple answer. Therefore whilst having an energy target is a helpful step towards energy efficiency in operation, it may not tell us the whole story about why a building uses the energy that it does, because, as Janda and Topouzi have previously observed (2015), there are instead many and varying stories that can be told about it.

7.3. Implications of the research

7.3.1. Implications for construction

One of the main findings of relevance to the industry has been to pinpoint ways in which the construction team’s knowledge of buildings’ energy in operation is still developing. Particularly problematic are the number of inconsistencies in what is included or measured between different projects with targets (Chapters 4 and 6), as well as the general uncertainties inherent in making future assessments of energy use (Chapter 5). This suggests some form of standard guidance around setting, implementing, and measuring energy use in projects that are subject to energy targets would be very useful. There are unfortunately no current industry standards that do this, although CIBSE’s TM54 (Chartered Institution of Building Services Engineers,
2013) and BSRIA’s Soft Landings framework (Agha-Hossein, 2018) do partly address this need, and could certainly be used to greater effect by the construction team.

Construction Co. could also take steps of its own. For example, tools such as the modelling checklist used locally (section 6.4.2) could be adapted to other departments, or other tasks. Team workshops on energy targets for specific projects could also supplement those that tend to be held on contract terms and BREEAM. As another example, one of Construction Co.’s requests for this research was for short, practical guidance for project teams, covering “top 10 things to consider if you have an energy target”, and which is included in Appendix I. Working energy performance more explicitly into the company’s standard project review processes would help alleviate anxiety amongst actors about the targets, and help reduce omissions and blind spots.

Diffusing energy knowledge into project teams, and beyond engineering and environment specialists, will also be required to control operational energy use more effectively, as raised in Chapter 6. This is particularly relevant given the “troubleshooting culture of construction” (Gluch, 2009:966), where decisions have to be made quickly on site, and where therefore, energy efficiency can be compromised if the decision-maker is not aware of the impact. Difficulties in understanding energy impacts can also be compounded by the technical jargon in which it is often expressed, as described in Chapter 4. Section 6.4 indicated that feedback seems to be more positively received when delivered informally, or face-to-face, so Construction Co. should not rely only on formal, technically-focussed means of knowledge management. For example, employees with experience of energy targets could be embedded into all stages of the building development, not just at contract review or post-occupancy stages. It is important that the facilities teams are also routinely involved in energy
decisions through the construction process, as has been done in the hospital (section 4.5.2). Thus change will involve focusing on the people and processes that support energy efficiency, as well as its technical aspects. This would likely require Construction Co. to invest more time, and hence budget.

The dialogue about improving experience of energy in-use needs also to encompass the client more effectively. Clients should certainly be clear on what they require from construction companies, and should make sure that they enforce energy targets. Clients do not necessarily do either of these, as the conclusions to both Chapters 4 and 6 observe. However, a collective emphasis on blame needs to be avoided. Clients’ role in the outcome of their buildings is not just as a source of inconvenient variation from design, but as part of an integrated system of technology and actors. As Chapter 5 suggests, there is an opportunity for a better ongoing dialogue between the client and Construction Co., including through its facilities team, over the life of the building. As noted earlier, a few participants did indeed have positive experiences on other projects in which this had been achieved (section 5.3.3). This could benefit both the client, by helping them understand how to get a better-performing building, and Construction Co. by increasing the value their services are able to offer.

In addition to learning from experience, developing coordination between actors’ communications and practices is important. Construction Co. needs to identify priority areas where better coordination is needed. As can be seen from Chapter 4, design variations, procurement, and value engineering are part and parcel of construction, but can cause the energy implications of decisions to be lost. Lack of insight into the main sensitivities and assumptions of the energy model would be another example, as raised in Chapter 5. In the longer term, Construction Co. is investing in collaborative,
digital systems, such as BIM, which aims to produce a “single source of truth” about projects (Int - BIM 2). Care needs to be taken that energy is built into these developments. As suggested in Chapter 4, a significant need is for an individual, or group, to take overall responsibility for energy performance through the various phases of building development in order to provide a strategic direction and consistent focus, or at least an effective relay system of handovers between phases.

“Mainstreaming” sustainability in construction requires companies to move beyond a reactive response to customers and the production of exemplar projects (Boyd and Schweber, 2012). If Construction Co. regards energy targets as a niche customer demand, then change in the organisation is unlikely to happen beyond a superficial level, perpetuating the problems described in Chapter 5 in particular. To guarantee its customers levels of operational energy performance with confidence, Construction Co. would not only need to re-consider its internal processes as already described. If the company were to specialise in energy efficient buildings, it would also need to decide whether it continues to view itself as an “integrator” who directs others to build a high-quality product, or whether it would prefer to develop and offer its own expert knowledge on sustainable buildings. This in turn would drive strategic decisions as to what knowledge and skills it recruits in-house, as opposed to out-sourcing them.

A decision such as this requires Construction Co. to consider energy targets as more than an immediate goal of achieving or failing a particular project goal, and to take account of the costs and benefits of time, skills, and brand implications that arise from addressing operational energy performance more holistically. However, in order to make fundamental changes to its ways of working, Construction Co. would need to see a real business case for doing so, and would encounter some significant barriers to
change, given that its business model is reflective of wider industry trends. There could therefore be a role for government to play in a long-term policy commitment to the in-use performance of buildings, which could in turn stimulate a market for buildings that are energy efficient or low carbon in operation.

7.3.2. Implications for policy

There is a potential role for public procurement to play in projects such as the one examined here. The findings have indicated that commercial structures, often embodied in contracts, can hinder the construction team’s collaboration around energy issues. These include the PFI contract terms discussed in Chapter 4, the structures of professional liability in Chapter 5, and the priorities of clients highlighted in Chapter 6. These issues are harder for Construction Co. to deal with alone, as its influence over the form of contracts is limited. The contract for the hospital follows the PFI model, which, despite its aims to foster better relationships between public and private actors, has not always done so (Leiringer and Schweber, 2010). Contracts for public sector buildings that encourage a more effective sort of collective responsibility could go a long way towards promoting collaborative working (Lloyd-walker et al., 2014). This needs to include subcontractors, as well as the main contractor and the client. Attention needs to be given to iron out perverse or contradictory incentives, such as those between construction and facilities’ targets (section 4.5.2). The hospital’s energy targets originate with government, which has therefore begun to drive some change, but public procurement could do much more to evolve the development of such contracts.

Policy may now be showing some renewed interest in the operational performance of non-domestic buildings (section 1.2.1). One way to regain the lost momentum of low carbon buildings policy would be for it to play a role in the standardisation of
operational energy targets. As discussed in Chapter 6, greater standardisation could help remove some of the confusion around exclusions and definitions that appear to trouble projects with bespoke energy targets. This would give construction teams greater comfort around guaranteeing future energy use, and more ability to transfer learning between projects. It would also deter them from getting themselves “off the hook” in fuzzy contractual areas (section 5.3.2), and remove some of the negotiability around what is acceptable performance. For clients, it would provide some more clarity around what level of performance might be expected from the buildings they procure. Lastly, a more consistent and committed policy to promote standards for operational energy use would provide the market demand needed to stimulate deeper changes in the industry to meet it.

However, as the literature in Chapter 2 emphasised, variation can occur in the situated implementation of low-carbon buildings policy. Gathering detailed intelligence that extends beyond the top-line results of building projects with energy targets is needed for policy appraisal, as other studies have highlighted (Palmer et al., 2016). In addition to more such work, a forum to share industry experience with operational energy targets could help all companies learn from others’ experiences, both good and bad. This would need to navigate the likely reticence between companies. This would require a sensitive positioning to avoid fear of blame for problems raised, which has been highlighted through this work as a key concern in the construction team, and a clear remit to benefit all commercial participants, in order to avoid friction between competitors. Government could have an important mediating role to play here that could dovetail effectively with the Construction Sector Deal (Department for Business, Energy & Industrial Strategy, 2018b).
However, if more standardised guidance is to be offered, its nature and boundaries need to be carefully considered by policymakers. As Chapter 6 concluded, how much standardisation is desirable is a delicate question. The findings across all chapters indicate that construction actors lack confidence in approaching energy targets, and have few developed systems and processes to support them (giving rise, for example, to the difficulties in translating targets into action as described in 6.2). Thus there is a practical need for standard tools. Yet, Chapters 4 and 5 both described how building performance as enacted and communicated by actors can be a moveable feast, subject to negotiation, and potentially manipulation. Whilst standardisation could decrease uncertainties arising from grey areas, it may also lead to inflexibility. Hence a standardised approach to energy targets could cut off alternative possibilities, and lock-in normative, or simplistic, expectations of what desirable energy performance should be. This embodies one of the central challenges of applied research in low carbon buildings policy, which is to balance the need for practical action with a considered awareness of the implications of taking it.

7.3.3. Further research

This thesis has applied STS ways of thinking to the empirical arena of building energy research. There is still much more that could be explored here, despite the body of interesting work that already sits in this intersection (section 2.3). As outlined in the conclusions to each of the empirical chapters, there are areas of the concepts that I have employed here that I have not had the chance to pursue. For instance, Star’s ideas of standardisation and “common coin” provide a very interesting angle to help frame more consistent conversations about building energy performance for construction teams (section 6.7.3), and to ease communications between specialists and non-specialists. As described in the Literature Review at the beginning of this thesis, there is already valuable work by STS scholars relating to energy. However,
there is much more to be mined from STS, of which the suggestions here only scratch the surface.

Thinking around the nature of prediction, the quantification of uncertainty and risk, and the importance of modellers’ choices, for example, could be usefully explored in the context of building energy modelling, as it has already been from an economic perspective for non-domestic retrofit projects (Fennell et al., 2016), and from a qualitative perspective for energy systems modelling (Li and Pye, 2018; Pye et al., 2018). The limited research on modellers’ practices discourse, and “folk ontologies” indicates that these are likely to impact on the results (Shipworth, 2013; Eidenskog, 2017; Ellenbeck and Lilliestam, 2019). Further qualitative study of how energy modellers approach their work would be highly instructive and would provide a counterpoint to the view that the performance gap can be reduced by “better” modelling (Menezes et al., 2012; Yan et al., 2015). It could also help companies like Construction Co. understand more about why energy performance in operation can be so hard for them to manage.

Thinking more conceptually, ways in which energy use is controlled and channelled engages with the relationship between technology and power that is core to STS. This thesis has highlighted ways in which this could be followed up further. For instance, Chapter 4 indicated how the energy targets may be expressed through various media such as modelling, building management software, drawings, or meters. The conclusions to Chapter 4 also considered the “transparency” of energy disclosure. Hence more research tracking how energy information is mediated through devices, and by whom, in non-domestic buildings, such as Lovell et al.’s work on domestic meters (2017), could be very instructive. Another example could be to consider how
designers use efficient technologies to ‘discipline’ users, as this would engage with some participants’ desire to control the risks of occupiers’ energy use (sections 5.3.2, 6.4.4).

The implications for policy and industry that have just been outlined indicate that producing more low carbon buildings will require structural changes in the construction industry. Further research into the best means to facilitate these changes in working processes and communications would therefore be extremely useful. A key area to consider is the digital transformation currently underway in the industry (Whyte and Hartmann, 2017), which also has the potential to disrupt the main contractor’s traditional role as an organisational pivot (Morgan, 2017). Research could usefully explore how energy concerns might be integrated into the deployment of virtual systems and tools using a more socio-technical approach, and consider how these changes might reimagine the role of the construction company in ways that benefit lower carbon buildings. However, there are also likely to be other areas that could also be considered.

In addition to working processes and technological tools, commercial incentives have repeatedly arisen in this research as an influence on actors’ energy-related decisions, whether through contracts as in Chapter 4, embedded ways of working and professional liabilities as in Chapter 5, or in the context of other imperatives such as in Chapter 6. This research has shown that incorporating operational energy targets can actually pose significant challenges to a construction company’s established ways of working and priorities. Integrated design would be one particularly relevant approach that could be considered further (Owen et al., 2010; Leoto and Lizarralde, 2019). Broader organisational literature that deals with relevant challenges, such as the
difficulties in changing embedded ways of working (Henderson and Clark, 1990), responses to innovation and habitual preoccupations (Zimmermann, 2011), and the consequences of incomplete cultural change (Colville et al., 2013) could be utilised to assess business responses to energy efficiency and low carbon buildings.

7.4. Learning from the research approach

In addition to suggestions for future research topics, there are also potential learnings for other researchers from the approach I have adopted here. These are both theoretical and methodological. In this section I will briefly explore what has been learnt from the deployment of the three theoretical and analytical concepts from STS, and revisit some of the main limitations of this PhD, so that these may be borne in mind when considering the final conclusions to this thesis that follow.

7.4.1. Using STS to think about energy targets

The energy performance gap can be considered a “wicked problem” (Janda et al., 2016), because it involves a vast and interacting Gordian knot of objects, stakeholders, infrastructures, incentives, and norms. High-level strategic thinking about the bundle of policy incentives needed to engage with it is therefore necessary (Mallaburn and Eyre, 2014; Committee on Climate Change, 2017). However, the intricacies of low carbon construction policies are played out in the local, situated theatres of individual building projects, as demonstrated by other case studies besides mine (Moncaster and Simmons, 2015; Boyd and Schweber, 2018). STS is, I believe, a discipline that is particularly suited to capturing these local interactions, whilst making a link to a more abstract, sometimes philosophical, way of thinking. The role of theory can be to enable the researcher “to see things differently than either their subjects or they would have without it” (Schweber, 2015:845). I believe that STS has provided just such a set of tools for this study.
STS’s method of choice is frequently the very small case study, as it is here. Although this does not allow us to ‘generalise’ from the findings in some statistical sense, it does not mean that the case study remains parochial. The engagement with what people do, say, or share has allowed me to ask simple questions that lead to complex answers, such as what an energy target, or an energy efficient building, is. Moreover, finding out, for example, who mediates energy information or the disclosure of operational data also begins to unearth some of the reasons why getting buildings to perform as promised is not a simple matter. Through facilitating these sorts of questions, STS can reveal the unintended consequences and perverse incentives that are the consequences of localised implementation of energy policy. Given the recent interest in energy targets as a solution to carbon emissions from non-domestic buildings, these are very important questions. They can thus help establish how we might judge whether policy incentives, like energy targets, are ‘working’.

However, if STS is good at raising questions, it may not always be so ready to develop answers. Challenging the basis of knowledge is useful, but to reduce carbon emissions from buildings, practical solutions are required. Using a pure STS lens therefore would present a hurdle to bridging the gap that sometimes exists between academic knowledge and the more pragmatic concerns of industry. Each of the three works chosen has brought out valuable findings, drawing on particular epistemological or ontological standpoints. In this final chapter, I have left these individual analyses behind, and tried to weave them together to indicate what they suggest collectively for industry and policy, as in the implications just presented. This task is important, if academics are to engage their research findings better with industry, policy, and society.
7.4.2. Considering the three approaches employed

I selected the three specific concepts for this PhD because they all shared a concern with multiplicity. This was my starting concern for two main reasons. Firstly, because energy targets aspire to unite actors around a common aim (UK Green Building Council, 2016). Secondly, because the literature presented in Chapter 2 indicated how this might be hampered by fragmentation in construction teams. Each of the three works offers a different perspective on multiplicity, and hence potentially different insights about “life in the gap”. So, Mol engages with multiple realities created through diverging practices, Gilbert and Mulkay show how varying discourses may provide us with several versions of “what really happened”, and Star and Griesemer explore the tension between diversity and cooperation. All three concepts allowed me to step back from the question of why and how operational energy targets could be deployed, as discussed in Chapter 2, and to place before it a primary question, as to what an energy target is for the actors involved in implementing them. This then offered a chance to explore how actors’ varied responses to the targets might contribute to issues in the building’s eventual energy performance.

However, using three different concepts also had its challenges and compromises. I used each of the three to gather data on what I originally anticipated were three different aspects of the ways in which the energy targets were implemented: doing, saying, sharing. However, in analysing my findings, I became aware that there were areas in which the different territories either overlapped, and I risked repeating myself, or in which they contradicted each other. I have tried to navigate a pragmatic course through these overlaps and contradictions, and pull out what was valuable from each. Furthermore, in choosing to use three different works, I obviously sacrificed the ability to pursue one in depth. As I have noted at the end of each empirical chapter, there
were sometimes other avenues that I would have liked to explore. I have captured some of these in the suggestions for further research. Clearly, had the PhD been based on one concept, I would have been able to explore other data and present more findings. However, overall I felt that the need to understand the different aspects of “life in the gap”, combined with the suggestions from my early work that energy targets were influenced by a combination of actors’ practices, discourse, and information sharing, meant that this was the best approach to take.

A further, rather specific, dilemma that I encountered was in applying the works derived from STS to a commercial case study. All three of the concepts have their empirical origins in scientific communities. Whilst there are well-known works in STS that have dealt explicitly with commercial concerns (for example: Cowan, 1985; Bijker, 1992; Vaughan, 1996), of my set of three, the boundary object is the only one that has often been applied to research in businesses. This is important, as all of the chapters emphasise the influence of commercial drivers on the practices and communications of construction actors. Commercial contracts and the distribution of risks and responsibilities, for instance, is a theme that arises frequently in my analysis, but not in the three works used to underpin it. However, part of the purpose of a case study can be to test out a theory in a new empirical arena (Vaughan, 1992). Whilst commercial concerns may not be part of the theories or concepts, they have nevertheless encouraged me to capture them by allowing me to reflect more on the motivations behind why actors might do and say what they do about energy targets. These motivations in turn provide insight around what drives “life in the gap”.

7.4.3. Limitations of the approach

As well as the benefits and challenges of the theories employed, it is also worth pausing to consider what could not be covered within the scope of this research.
However, as many of these issues have already been dealt with in some detail in the Methodology in Chapter 2, it is not proposed to provide more than a brief reminder. I will therefore outline what the thesis can and cannot offer in its approach and the case itself.

Data collection by a lone researcher is necessarily an exercise in selectivity when seeking to engage with, variously: a construction team of around five hundred contracted and sub-contracted staff; an international company whose direct employees number in the thousands; and a project where events happen every hour, over many years. I have had to make choices about which actors, events and documents to include in my research (section 3.6.2). However, this inevitably means that there are many actors with potentially very interesting viewpoints that I did not, or could not, gather information from. Most notably, these include the client, occupiers, non-contractually linked suppliers, and staff who had left Construction Co. The effect of these on the conclusions is unknown.

As the empirical chapters have shown, there are not always clear boundaries around what energy performance or energy efficiency is in the context of the hospital's targets. A key part of the research findings has been to explore these boundaries and actors’ different interpretations of them. However, it also forms a difficulty for me in determining how to locate the data, if, as the findings indicate, responsibility for and knowledge about energy is distributed, and the details of who is doing what about the targets is often vague. In order to fix the scope of the research and gather data, I have had actively to decide what is relevant and to draw the boundaries of the targets myself. Thus if energy targets are brought into being by actors, so it follows that my own enactments of them as a research topic must also be generative of the results.
The risk of my findings being influenced by my judgement and underlying interests was discussed more fully in section 3.9.

7.4.4. Limitations of the case

As raised in the methodology (3.4.1), this research has focussed in the majority on just one building project, the hospital, at a particular point in its development, during construction. The risk is not so much that the research is based on a case study. As already noted, if STS does anything, it demonstrates that insightful findings may be gathered from the smallest of cases. What I have been required to reflect on is whether this case might be exceptional or atypical amongst other projects with energy targets, or indeed amongst Construction Co.’s projects more generally. From my analysis, non-domestic buildings emerge as a product of familiar and embedded processes employed to produce a bespoke and unique building. This appears to be the nature of Construction Co.’s work, that each project is both general and particular. Moreover, for most of my participants, it is the energy targets that they comment on as exceptional, rather than the hospital itself. Those who have prior experience with energy targets tend to note differences the format of the targets, or specifics of the site, rather than suggesting that the hospital project itself is exceptional. This provides some comfort as to the reliance on a single project.

The case is also shaped by the commercial context in which it was conducted. The topic of energy targets had to dovetail with the sponsor’s own interests, and the case study itself could naturally only be selected from Construction Co.’s available projects. My research strategy as explained in sections 3.6 and 3.9 has tried to challenge Construction Co.’s preconceptions, as part of the value to them is in my independent point of view. Additionally, a hospital is a specialised, complex building, with resulting particular patterns of energy needs and design (section 3.5.1). Its experience of energy
targets could therefore be different to that of, say, an office, a school, or a shopping centre. However, the heterogeneous nature of non-domestic buildings is actually one of the key difficulties in controlling carbon emissions from this sector (Tian and Choudhary, 2012), and so is part of the challenge for the construction team that this research is trying to explore. As a result, I have tried to set aside particular sectoral concerns as much as possible, in favour of more commonly applicable issues relating to how actors in construction teams work together on energy targets, rather than on a hospital’s energy demand specifically. With these caveats in mind, this thesis will now conclude by reflecting on its original aims and the nature of the contribution it can offer to energy and buildings research.

7.5. Conclusions

7.5.1. Aims

This research set out to explore how actors in a construction team dealt with the challenge of operational energy targets. In doing so, it aimed to offer a situated understanding of the practices and communications of this group of actors who have such a critical role to play in enacting new low carbon building policies, but whose response to them is still under-researched. It has focused on a single case study of a PFI hospital project, but the research has wider relevance. There is a small, but growing, body of opinion that recommends making construction companies responsible for the operational performance of buildings, through incentives like energy targets, in order to curb carbon emissions from the non-domestic building stock. Yet research on energy targets in other projects suggests the implementation of such initiatives does not necessarily guarantee an energy efficient result. There is a need, therefore, to look under the bonnet of construction teams and reveal what is happening “inside the gap”.
It is in offering a detailed understanding of how energy targets play out in practice amongst a construction team charged with implementing them that this research offers its unique contribution to the body of research on the energy performance gap. To do so, it has leveraged three different concepts from STS to focus the research and interpret the findings. The insights generated were summarised at the beginning of this chapter. They strengthen the case for a greater use of STS in building energy research, given the usefulness of its central concern of the relationship between society and technology, which is at the heart of much of the debate on energy use. STS, as I argued in the Discussion, offers us a link between a detailed case and its conceptual implications, which in turn provides a rich, empirical basis from which to draw insights of more general interest.

7.5.2. Contribution

Firstly, the research has supported the value of engaging with industry. Low carbon non-domestic buildings are not uniquely a concern of academia, but, in common with all applied research, also of policy and industry. There are academic compromises in dealing with a sponsor, but the compromise runs both ways, as Construction Co. has also had to learn to work within academic constraints. Fostering a relationship between the two opens up vital avenues of research, and deepens the knowledge flows between them that are so important if the UK is to make genuine improvements to its building stock. Without the access provided by Construction Co., this research could not have uncovered as much detail of construction actors’ responses to the targets.

This research has also offered a situated understanding of the difficulties experienced by actors of doing something that sounds like a sensible policy idea, such as providing a common aim to unite actors around energy performance, but is actually quite hard to implement in practice. Operational energy targets certainly provide motivation and
focus around energy efficiency, but this analysis suggests that they cannot simply be applied on top of existing construction practices and its associated processes that are not equipped to deal with operational responsibilities. It will require significant change in the way that construction companies like Construction Co. organise themselves, and their subcontractors, and indeed clients as well in setting expectations and understanding results. This in turn goes some way to explaining more about the origins of the performance gap, and how it manages to persist in some projects despite the presence of operational targets for energy and carbon. Buildings do not turn out in the way expected because of the many twists and turns of practices and communications “inside the gap”. Without appreciating this, policy runs the risk of continuing disappointment.

The analysis presented here has picked up on themes already present in the performance gap literature, especially those suggesting that problems of collaboration, communication, and knowledge management in construction could be to blame for energy efficiency falling short in operation. The findings here have unpacked in much more detail how these high-level problems break down in specific projects and day-to-day actions. This PhD has not undertaken to discredit energy targets as a potential solution to reduce carbon emissions from the non-domestic sector. On the contrary, they do appear to provide potential to drive improvements in the building stock. What this PhD has drawn attention to are some of the significant obstacles that stand in the way of their successful deployment in the UK. In particular, greater attention needs to be paid to the optimal functioning of incentives that underlie the targets, and their pressures on different actors in the construction team, so that they do not produce the opposite of the effects intended.
The findings therefore indicate that policy and researchers should not treat transparency in building energy use as an unproblematic goal. Whilst more operational information is certainly required to inform low carbon design and construction, and to drive market motivations, care must be taken to think about what data is being disclosed, by whom and how. Transparency of energy performance is not a state that simply occurs. It is made and mediated by actors, and hence it is imperfect, negotiable, and potentially manipulable. A combination of more experience, more guidance, and increasing standardisation around operational energy use may well help. However, those charged with setting and enforcing standards for energy and carbon in-use, whether through numerical targets or other means, must remain vigilant to the construction of energy performance, as well as to the construction of the building to which it relates.
8. References


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Morgenstern, P. 2016. *Understanding hospital electricity use: an end-use(r) perspective*. Thesis (PhD), University College London, University of London.


Wade, F. 2015. An ethnography of installation: exploring the role of heating engineers in shaping the energy consumed through domestic central heating systems. Thesis (PhD), University College London, University of London.


## 9. Appendices

### 9.1. Appendix A. Industry, government and other sources relevant to energy targets and the performance gap

<table>
<thead>
<tr>
<th>Year</th>
<th>Construction</th>
<th>Government</th>
<th>Other</th>
</tr>
</thead>
</table>
| 1990s | Constructing the Team (Latham Review), 1994  
Rethinking Construction (Egan Review), 1998 | BREEAM launched, 1990 |                                                                                  |
Building Regulations Part L revision, 2006 | Flying Blind (UKACE/Bordass)  
Building the Future Today (Carbon Trust)  
Soft Landings Framework (UBT, BSRIA), 2009  
BREEAM revision, 2008 |
| 2010 | | Building Regulations Part L revision  
Low Carbon Construction, Innovation & Growth Team: Final Report (BIS/Morrell) |                                                                                  |
| 2011 | | The Carbon Plan (DECC) | Closing the Gap (Carbon Trust) |
| 2012 | What are the factors influencing energy behaviours and decision-making in the non-domestic sector?  
<table>
<thead>
<tr>
<th>Year</th>
<th>Construction</th>
<th>Government</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>2016</td>
<td>Hackitt Review (interim)</td>
<td>Clean Growth Strategy (BEIS)</td>
<td>London Environment Strategy consultation (Greater London Authority)</td>
</tr>
<tr>
<td>2017</td>
<td>Building A Safer Future (Hackitt Review - final)</td>
<td>Construction Grand Challenge (BEIS) Helping businesses to improve the way they use energy; call for evidence (BEIS)</td>
<td>BREEAM New Construction revision</td>
</tr>
</tbody>
</table>
9.2. Appendix B. Details of the hospital’s energy-related targets

<table>
<thead>
<tr>
<th>Units</th>
<th>How set</th>
<th>How assessed</th>
<th>Penalty</th>
</tr>
</thead>
<tbody>
<tr>
<td>GJ/100m³/annum (to 0 d.p.)</td>
<td>Specified by NHS Trust in their construction requirements at bid. Contractors make an offer against the number as part of bid assessment, using information from their design and energy modelling work. A final number is signed off as part of the contracts at Financial Close. This reduced the Trust’s proposed target to Project Co.’s offer of 5% below.</td>
<td>After a bedding-in period of 3 months, energy use is monitored over Initial Period of first 2 years of operation.</td>
<td>If variance found to be due to failure in design or construction, then construction contractor is liable for either: Additional cost of energy over remaining period of operation (up to 20 years); or cost of remedial work. The Trust decides which. There is no tolerance band for failure, except an allowance for Heating Degree Days, and no incentive for better than expected performance.</td>
</tr>
<tr>
<td>Units</td>
<td>How set</td>
<td>How assessed</td>
<td>Penalty</td>
</tr>
<tr>
<td>------------------------</td>
<td>-------------------------------------------------------------------------</td>
<td>------------------------------------------------------------------------------</td>
<td>-------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Carbon target</td>
<td>Specified by NHS Trust in their construction requirements at bid.</td>
<td>After a bedding-in period of 3 months, energy use is monitored.</td>
<td>If variance found to be due to failure in design or construction, then construction contractor is liable for either: Additional cost of CRC allowances over remaining period of operation (up to 20 years); or cost of remedial work. The Trust decides which. There is no tolerance band for failure, except an allowance for Heating Degree Days, and no incentive for better than expected performance. However, the compensation should not double-count any penalty already paid for exceeding the energy target.</td>
</tr>
<tr>
<td>tCO₂e/100m³/annum (to 2 d.p.)</td>
<td>Contractors make an offer against the number as part of bid assessment, using information from their design and energy modelling work. A final number is signed off as part of the contracts at Financial Close. In the case of the carbon target, Project Co. did not choose to make a lower offer.</td>
<td>equivalent carbon emissions calculated using pre-determined emission factors.</td>
<td></td>
</tr>
<tr>
<td>Units</td>
<td>How set</td>
<td>How assessed</td>
<td>Penalty</td>
</tr>
<tr>
<td>-------------------------------------------</td>
<td>-------------------------------------------------------------------------</td>
<td>--------------</td>
<td>------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Energy and carbon proportions</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>% of conventional energy and renewables</td>
<td>Based on signed off energy model at Financial Close.</td>
<td>Not noted.</td>
<td>If Project Co. does not deliver these energy proportions,</td>
</tr>
<tr>
<td>(to 1 d.p.) and associated carbon emissions</td>
<td>Carbon is calculated using determined emission factors.</td>
<td></td>
<td>Project Co. shall be liable to the Trust for any resultant increase in the cost to the Trust of purchasing energy.</td>
</tr>
<tr>
<td>Renewable energy proportion</td>
<td>Requires minimum percentage of energy requirement to be met by renewable sources, or to abide by Local Authority requirement if more onerous.</td>
<td>Not noted.</td>
<td>If not achieved, would be in breach of contract.</td>
</tr>
<tr>
<td>BREEAM</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BREEAM Excellent rating</td>
<td>According to BREEAM Healthcare Standard current at time of procurement.</td>
<td>Certification from BRE.</td>
<td>If not achieved, would be in breach of contract.</td>
</tr>
<tr>
<td>Units</td>
<td>How set</td>
<td>How assessed</td>
<td>Penalty</td>
</tr>
<tr>
<td>--------------</td>
<td>------------------------------------------------------------------------</td>
<td>-----------------------------------------------------------------------------</td>
<td>--------------------</td>
</tr>
<tr>
<td>Annual energy target (operation)</td>
<td>An annual target is set after 2 years 3 months of operation, and thereafter revised annually. Using measurements gathered by facilities team, an annual target is calculated and split between fixed (baseload) and variable (weather-related, based on heating degree days) energy consumption.</td>
<td>Compare annual consumption to target, adjust for qualifying variations and heating degree days.</td>
<td>Variance:</td>
</tr>
<tr>
<td>GJ/annum</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>&lt;3% no action</td>
<td>&gt;3% and &lt;13% pain/gain share at 50% of variance in kWh x unit cost</td>
<td>&gt;13% extraordinary investigation</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Units</td>
<td>How set</td>
<td>How assessed</td>
<td>Penalty</td>
</tr>
<tr>
<td>------------------------------------</td>
<td>-------------------------------------------------------------------------</td>
<td>------------------------------------------------------------------------------</td>
<td>-------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Annual emissions threshold (operation)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Annual CRC allowances</strong></td>
<td>An annual target for emissions based on the amount and type of energy used as projected by the Annual Energy Target.</td>
<td>Comparison of CRC allowances required based on actual consumption compared to target, and assessment of resulting change in allowance purchases required.</td>
<td>If excess allowances are sold then the revenue is shared between Project Co. and the Trust. Any additional CRC cost in operation is borne by the Trust, unless arising from excess energy as above, in which case 50% of allowance cost is payable. Specified that only applicable as long as CRC scheme applies.</td>
</tr>
<tr>
<td>Planning conditions</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BREEAM Excellent and 10% of onsite demand to come from renewable energy</td>
<td>Planning conditions from Local Authority</td>
<td>Presentation of BREEAM Certificate. Statement of predicted renewable energy provision in Energy Statement. Renewable technologies must be installed prior to occupation and maintained in-use unless agreed in writing.</td>
<td>Planning will not be given unless design demonstrates these requirements.</td>
</tr>
</tbody>
</table>
### 9.3. Appendix C. Schedule of data gathered

<table>
<thead>
<tr>
<th></th>
<th>Hospital case study</th>
<th>Other (school and office projects, early work in Construction Co.)</th>
<th>Total for whole PhD</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Interviews</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Project</td>
<td>25</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>Company</td>
<td>6</td>
<td></td>
<td>38</td>
</tr>
<tr>
<td><strong>Documents</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Project</td>
<td>136</td>
<td>41</td>
<td>8</td>
</tr>
<tr>
<td>Company</td>
<td>6</td>
<td></td>
<td>185</td>
</tr>
<tr>
<td><strong>Observation</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Project</td>
<td>35</td>
<td>38</td>
<td>51</td>
</tr>
<tr>
<td>Company</td>
<td>38</td>
<td></td>
<td>124</td>
</tr>
</tbody>
</table>

1 As some actors were interviewed more than once, and others interviewed together, this is the number of interviewees.

2 Of the interviewees, 8 from the hospital project and 3 from other work were contractors, the balance being staff employed by Construction Co..

3 Includes only documents analysed (450 were collected in total).

4 “Project” refers to contact with staff and contractors working full-time on the hospital project; “Company” refers to contact with staff of Construction Co. providing periodic support to the hospital project, and events observed off site.
## 9.4. Appendix D. Mapping interview questions to the three STS works

<table>
<thead>
<tr>
<th>Basis</th>
<th>Areas to test</th>
<th>Questions to ask (priorities in bold)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mol-practices</td>
<td>How do different groups or individuals enact the targets?</td>
<td>Could you explain how you have been involved in the energy targets on the Hospital?</td>
</tr>
<tr>
<td></td>
<td>Is there any evidence for different enactments of energy targets?</td>
<td>So what does this mean you have to do on a day-to-day basis because of the energy targets?</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Who else in your team or elsewhere do you work with on the targets?</td>
</tr>
<tr>
<td></td>
<td></td>
<td>What are their responsibilities in relation to the targets compared to yours?</td>
</tr>
<tr>
<td></td>
<td>Can I see any ‘clashes’ between different enactments that make them incompatible?</td>
<td>Does the target make understanding energy issues between different teams harder or easier?</td>
</tr>
<tr>
<td></td>
<td></td>
<td>What do you find is the best way of resolving any difficulties?</td>
</tr>
<tr>
<td>Are practices distributed – can we see different practices in different places – and how? (e.g. place, time, role)</td>
<td>When did you get involved with the Hospital project? Are you still working on it now? How much longer have you got to go? Whereabouts are you based usually? (e.g. office, site, home)</td>
<td></td>
</tr>
<tr>
<td>Are practices coordinated? What happens if different practices meet each other and how often does this happen?</td>
<td>How does your team work together on the energy targets?</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>How do you communicate? (e.g. meetings, emails, calls, IT systems)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>How often?</td>
</tr>
<tr>
<td></td>
<td></td>
<td>How do you work with others outside your own company?</td>
</tr>
<tr>
<td></td>
<td></td>
<td>What sort of things do you talk to them about when discussing the target?</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Do you think other people talk about energy in different ways to you?</td>
</tr>
<tr>
<td>Basis</td>
<td>Areas to test</td>
<td>Questions to ask (priorities in bold)</td>
</tr>
<tr>
<td>-------</td>
<td>--------------</td>
<td>--------------------------------------</td>
</tr>
<tr>
<td>Basis</td>
<td>Areas to test</td>
<td>Questions to ask (priorities in bold)</td>
</tr>
<tr>
<td>Can ‘reality move’? (i.e. if practices shift what is the impact on the reality of the target?)</td>
<td>How have you found working on the Hospital energy targets different to your normal work? What sort of things did you have to adapt? How did you decide how to best approach the targets?</td>
<td></td>
</tr>
<tr>
<td>Gilbert and Mulkay - repertoires</td>
<td>What discourse around energy targets is produced in different social contexts (gather written informal/formal and verbal examples)? Can we see individuals explaining what is apparently ‘the same thing’ in different ways?</td>
<td>How do you communicate? (e.g. meetings, emails, calls, IT systems) How often? [shared with Mol] How do you work with others outside your own company? [shared with Mol] What are your main outputs or deliverables for the energy targets?</td>
</tr>
<tr>
<td>Are there distinct repertoires that can be discerned? What is the social context that is causing the shift in repertoire?</td>
<td>Why are the outputs produced? (e.g. for planning, procurement, consultation etc.?) Who are they produced for? Do you use different information for different outputs?</td>
<td></td>
</tr>
<tr>
<td>How do they deal with contradictions in the repertoires?</td>
<td>Does the target make understanding energy issues between different teams harder or easier? What do you find is the best way of resolving any difficulties? [shared with Mol]</td>
<td></td>
</tr>
<tr>
<td>Do they experience any difficulties or misunderstandings in the way that their repertoires are interpreted?</td>
<td>Is it always easy to explain to others what you are doing/have done on the energy targets? Do you think they understand the details of your work? [shared with boundary objects] Does it depend on whom you are talking or writing to? How do you include risks to meeting the energy targets in the outputs? What can you do to help others understand what you have done? What might stop you doing this?</td>
<td></td>
</tr>
<tr>
<td>Basis</td>
<td>Areas to test</td>
<td>Questions to ask (priorities in bold)</td>
</tr>
<tr>
<td>---------------------</td>
<td>------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td>-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td><strong>Boundary objects</strong></td>
<td>Is there interpretative flexibility in the energy target – does it mean different things to different groups?</td>
<td>Who else in your team or elsewhere do you work with? [shared with Mol]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>What are their responsibilities in relation to the target(s)? [shared with Mol]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>How are these different to yours? [shared with Mol]</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>How do you communicate? (e.g. meetings, emails, calls, IT systems)</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>How often?</strong> [shared with Mol and G&amp;M]</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>How do you work with others outside your own company?</strong> [shared with Mol and G&amp;M]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>What do you think the energy target is there for?</td>
</tr>
<tr>
<td></td>
<td></td>
<td>What do you think it will achieve?</td>
</tr>
<tr>
<td></td>
<td></td>
<td>How will you know if it has worked?</td>
</tr>
<tr>
<td><strong>To what extent is there “invisible” work – i.e. do groups assume knowledge of their work and assumptions underlying it - that others haven’t actually got?</strong></td>
<td>What parts of your work don’t you need to share?</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>How do you include risks to meeting the energy targets in the outputs? [shared with Mol]</td>
</tr>
<tr>
<td></td>
<td>Can the target be used simultaneously to meet specific needs of specific groups whilst maintaining the big picture – or not? (Is it plastic yet robust?) Can we see evidence of groups successfully ‘tacking back-and-forth’ between the two? How is heterogeneity dealt with? e.g. deliberate vagueness, or using repositories can allow ‘cooperation without consensus’ between different groups.</td>
<td>How do you identify issues that might affect the energy target for another member of the team? (e.g. a technology change)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>How do you use what other people have contributed?</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Do you check it?</td>
</tr>
<tr>
<td></td>
<td></td>
<td>How do you select what you need?</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Do you need to adapt it?</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>What sources of knowledge do you use to complete your work?</strong> (colleagues, prior experience, organisational resources, professional or government bodies, training)</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>How do you feedback any learnings from the project?</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td>What sort of information do you include?</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Who do you think will find it useful?</td>
</tr>
<tr>
<td>Basis</td>
<td>Areas to test</td>
<td>Questions to ask (priorities in bold)</td>
</tr>
<tr>
<td>-------</td>
<td>---------------</td>
<td>--------------------------------------</td>
</tr>
<tr>
<td></td>
<td>Are there standardised inputs or forms of energy information for the target? To what extent are there outliers or residuals that don’t fit the standardised data?</td>
<td>What processes are there for reporting, tracking and sharing information about the energy target/performance? How do you deal with information that doesn’t fit the standardised processes? (e.g. approximations, omissions)</td>
</tr>
</tbody>
</table>
9.5. Appendix E. Interview guides (examples)

INTERVIEW GUIDE – GENERAL TEMPLATE FOR HOSPITAL PROJECT

General introduction to research, researcher, data recording and confidentiality.

Introduction

- When did you get involved with the Hospital project?
- Are you still working on it now? How much longer have you got to go?
- Could you explain how you have been involved with the energy targets?

Responsibilities and tasks

- So what do you have to do on a day-to-day basis because of the energy targets?
  - Who else in your team or elsewhere do you work with on the targets?
  - What are their responsibilities in relation to the targets compared to yours?
- How have you found working with the Hospital energy targets different to your normal work?
  - What sort of things did you have to adapt?
  - How did you decide how to best approach the target?

Communications and outputs

Communications

- How does your team work together on the energy targets?
  - How do you communicate? E.g. meetings, emails, IT systems, calls and how often?
  - How do you work with people outside your own company?
  - Whereabouts are you based usually? (e.g. office, site, home)
- What sort of things do you talk to them about when discussing the target?
  - Do you think other people talk about energy in different ways to you?
  - Does the target make understanding energy issues between different teams harder or easier?
  - What do you find is the best way of resolving any difficulties?

Outputs relating to energy targets

- What are your main outputs or deliverables for the energy target?
- Why are they produced? (e.g. planning, procurement, consultation etc.)
- Who are they produced for?
- Do you use different information for different outputs?
Explaining the outputs

- Is it always easy to explain to others what you are doing/have done on the energy target?
  - Does it depend on whom you are talking or writing to?
  - Do you think they understand the details of your work?
- What can you do to help others understand what you have done?
  - What might stop you doing this?
- How do you include risks to meeting the energy target in the outputs?

Working with information

Uncertainties and standardisations

- What processes are there for reporting, tracking and sharing information about the energy targets/performance?
- How do you deal with any information that doesn’t fit the standardised processes? (e.g. approximations, omissions)
- What parts of your work don’t you need to share?
- How do you use what other people have contributed?
  - Do you check it?
  - How do you select what you need?
  - Do you need to adapt it?

Feedback and knowledge

- How do you identify issues that might affect the energy target for someone else on the team? (e.g. a technology change)
- What sources of knowledge do you use to complete your work? (e.g. colleagues, prior experience, organisational resources, professional or government bodies, training)
- How do you feedback any learnings from the project?
  - What sort of information do you include?
  - Who do you think will find it useful?

Reflecting and summing up

- What do you think the energy target is there for?
- What do you think it will achieve?
- How will you know if it has worked?
- [ask for copies of any useful documents mentioned, ask if anyone else useful to talk to]

Thank them for their help and time. Explain will keep in touch if ok and how feedback will be given.
INTERVIEW GUIDE – GENERAL TEMPLATE FOR NON-PROJECT

General introduction to research, researcher, data recording and confidentiality.

Role and relationship to energy performance

- Could you just explain a bit more about your role? For example:
  - Which team do you work in?
  - What does your team do? And what is your role in it?
  - Where are you based?
  - Who else do you work with in the company?
- Could you explain what part energy efficiency, carbon emissions or sustainability play in your work?
- How important do you think these issues are to your work?
- How does the energy performance of the buildings Construction Co. builds affect you?
- How have you been involved with the Hospital project/energy targets in general?
- How have you found working with the Hospital energy target (or targets in general) different to your normal work?
  - How did you decide how to best approach it?
  - What else might you have done?

Communications and outputs

Communications

- In what forms
  - How do you communicate with others within your team and how often? (e.g. meetings, emails, calls)
  - How do you communicate with others outside your team and how often?
  - What IT or other systems do you use to communicate?
- How
  - What do you talk about with them?
  - Do you think other people talk about energy performance in different ways to you?
  - Do you ever have any sort of problems or difficulties between different teams?
  - What do you find is the best way of resolving these?
  - Do any of them relate to energy targets or performance?

Outputs relating to energy targets

- What are your main outputs or deliverables?
  - How much are other people involved with these?
  - What differences are there between your various outputs?
- Why are they produced? (e.g. planning, procurement, consultation etc.)
  - Who do you expect reads or uses them?
  - In what form are they shared and when?
- Can I have a copy? (example)
Explaining the outputs

- Is it always easy to explain to [relevant audience] what you are doing? Or about energy issues?
- Do you have to use different information for different outputs? [compare examples if possible]
  - Do you think other people in the team/organisation understand the details underlying your work?
  - Does it depend on whom you are talking or writing to?
  - Are there any risks to meeting the energy target that are explained or not in the outputs?
  - What can you do to help [relevant audience] understand them?
  - What might stop you doing this?

Working with information

Uncertainties and standardisations

- Are there standardised processes for information about the energy target/performance?
- How do you deal with information that doesn’t fit the standardised process? Is there any?
  - Do you have to make approximations or put aside detail?
- Are there parts of your work that don’t get represented in the outputs?
- Do you have to understand what other people have contributed from other teams?
  - At what level?
  - Do you check it?
  - How do you select what you need from the systems or available information?
  - Do you find that you have to tailor general project information to your needs? Or do you find that you have to select the most relevant bits, and if so, how?

Feedback and knowledge

- How do you identify issues that might affect the energy target for another member of the team? (e.g. a technology change)
- In general, what sources of knowledge do you use to complete your work? (colleagues, prior experience, organisational resources, professional or government bodies, training)
- How do you feedback any learnings from the project?
  - What information do you put back into the system(s) (which ones?) and how do you ensure it is clear to others?
Reflecting and summing up

- What do you think the energy target is for?
- How will you know if it has worked?
- [ask for copies of any useful documents if relevant]

Thank them for their help and time. Explain will keep in touch if ok and how feedback will be given.
9.6. Appendix F. Document selection criteria

Criteria for the selection of documents

Firstly on the principle of “following the energy target”. Hence:

- They may be factual – providing information on what the target is – e.g. contracts, policy documents etc.
- Describes energy and carbon performance of the building
- Describe practices relating to energy targets (e.g. a protocol)– or represent these (e.g. a form that is filled in)
- Relate to information sharing between groups – especially on energy and carbon issues
- Note that this may also involve following places where the target does not go – where energy and carbon is not expressly mentioned (missing). Such as a variation procedure that fails to mention energy performance.

In relation to the three STS concepts, selection should also consider:

- For discourse analysis: Different discursive representations of the target by different people, or the same people describing things in different ways in different contexts. So for example, try to get a written document from an interviewee, or try to get a formal and informal account of a particular aspect, and an aspect described by different professions.
- For practices: documents should reveal a bringing into being of the energy target – e.g. by making it into a number, or by the setting of boundaries and specialisms.
- For boundary objects: look for both successful and unsuccessful sharing between groups – do not consider just the top down. Consider what is not recorded - residuals (people and data).

Finally, methodological practice should be considered:

- As discourse analysis is more intensive, a smaller sample of documents is practical (although this excludes forms and drawings).
- Considerations of ‘representativeness” (Scott, 1990) around what might be over- or under-represented – e.g. what types of document are more likely to be produced, what sort of documents I have access to (private email, commercially sensitive...), and what might not be recorded (in a non-writing culture).
- Try to balance characteristics (Hammersley and Atkinson, 2007) e.g. time, “member identified” vs. “observer identified”.
9.7. Appendix G. Ethics approach to participant data, information and consent

Catherine Willan, UCL Energy Institute, PhD project
Supplement to BSEER Low Risk Ethics Questionnaire
Participant data, information and consent

This document sets out the process for informed participants about the research and gaining their informed consent. A separate document specifically dealing with data protection issues has also been prepared.

There are two sections to this document: the first describing some of the particular characteristics of this PhD which impact on the design of the information and informed consent process; and the second which sets out the information provided to participants.

1. Relevant characteristics of this research

Firstly, there are a few particular characteristics of this PhD research that are important to recognise as they affect the way in which the information and consent process has been designed.

Contract

The research is governed by a contractual sponsorship agreement between UCL, the sponsor and the student, which protects the sponsor’s commercial confidentiality. There is also an understanding with the sponsor that research findings will only be shared outside the immediate UCL research team if the company name and identifying features are removed. This aims to protect the company as a whole from harm through its employees’ participation, but requires balancing with the research imperative to produce unbiased results.

Nature of relationship with research subject(s)

This research takes place as part of a four-year continuous relationship with the sponsoring company. The process of information and consent is not therefore designed around a one-off interaction between a participant and an unknown or remote researcher. Instead the researcher may often meet participants several times – sometimes as part of generating research data and sometimes not (e.g. bumping into them at the office). Participants may sometimes know quite a lot about the researcher and the research before they are interviewed, for example. The long-term relationship also creates the opportunity to offer feedback to participants on the research findings on a more regular basis rather than just at the end of the PhD.

Additionally, the on-going relationship affects participants’ anonymity, in that it is very difficult to conceal whom I have spoken to from others in the company. There is a small risk of harm to participants arising from, for example, offering their opinions, or in
offering what may be sensitive information. Consequently, it is very important that I do not repeat information between participants, nor attribute information obtained to a named individual (e.g. “I heard from so-and-so that you have a problem with…” must absolutely be avoided).

**Power relationships**

Unlike research projects dealing with vulnerable individuals, some of the research participants in this PhD are senior members of the sponsor or its contractors, such as directors and partners. This impacts on the power relationship between the researcher and these participants, as power does not lie disproportionately with the former. Indeed participants may be able to use their status to control the researcher’s access to information (Bell and Bryman, 2007). However, this does not necessarily mean that senior participants are not vulnerable to the impacts of research findings that uncover “errors” or “problems” in their work, and therefore they still need to be clearly informed about how the research findings will be disseminated.

Participants are frequently well-informed professionals. For example, they are may be aware of how the research can feed into the debate on the performance gap through their own knowledge of this concept, or they may know a great deal more about construction and energy technology design than the researcher. This again means that it is important to be flexible and responsive in explaining the research and participation in it to reflect the participants’ experience. Practically speaking, it is important to tailor the language used so that it is appropriate in level to the participants’ background. So whilst an attempt is always made to avoid jargon and explain things clearly, it may not always be appropriate to explain the research in the most basic terms.

2. Information given to participants

This section sets out the approach to informing participants about the research and gaining their informed consent. Note that due to the nature of the project, participation may involve (or combine) an interview, observation (such as the researcher sitting in on a meeting), or contact via email or telephone. Whilst a written information sheet exists, it is not invariably used due to the nature of the research as already outlined, which makes a verbal, iterative consent process more suitable in some instances.

Please see the separate information sheet. The paragraphs below explain what information is conveyed for verbal transmission of this information and gaining informed consent.

*Introducing myself*

I begin by introducing myself and my role as a PhD student researching energy efficiency in buildings. (Although as previously noted, often the participants that I am meeting already know my name and that I am a student researcher at their company as I have met them on another occasion or been introduced via another contact).

I explain that the project is a joint one between UCL and the company who are funding this. UCL Energy Institute is a specific part of UCL that deals with how we can improve
energy efficiency in buildings – we have expertise in all sorts of areas from physics, to engineering, to policy and social science – the last being the one where I fit in. So I am here to look at people and processes not the engineering. (It is worth pointing out that I am not an engineer so that they know what sort of issues I might be interested in – and so that they are not disappointed that I am not a building services engineering expert).

I have signed a confidentiality agreement so that you do not need to be concerned about me talking about commercially sensitive information for the business (this is a concern sometimes raised by participants – e.g. if they want to talk about projects they are currently bidding on, business plan/corporate strategy or their clients).

I also have to comply with the Data Protection Act. In practice this means I don’t leave their personal information lying around, it is stored securely and it is only used for this project – not anything else.

**Explaining the research**

The idea of the research project is to share information on energy performance in buildings between UCL and Construction Co. – as we both have expertise in this and knowledge to share. By doing this, we should generate insights as to how we could improve energy performance. I am particularly interested in projects with energy targets. (Note that many of my interviewees are well informed and often ask about whether I am looking at the “performance gap” – to which I answer yes. As this a current industry debate, it helps them see the value of the PhD for their business).

The research is for academic purposes, so for example, as well as my PhD, we would hope to publish something on this in an academic journal. In addition to this, I will feed back my findings to the business as well (this is usually more interesting to them). You will get a chance to comment on anything I produce.

I will need around an hour of your time. I am trying to gather as many perspectives as I can from different roles in the business and its subcontractors, so your input is very valuable and part of a larger programme of interviewees.

You can contact me at any time if you have any questions – I am on the internal company directory. If external to the sponsor, I would provide my UCL business card. Contact in this project is made easier as many of my interviewees I will meet several times over the course of the PhD – so the interaction is not a one-off. Also they know the name of my primary contact at the organisation so through him they can either contact me or get some more information about the project.

If you change your mind at any time about taking part – let me know and I will take your information out of the project. When recruiting participants they sometimes like to speak or email first, receive some information on the research, and then think about participation before definitely confirming.

**If interview:**

Are you happy to be interviewed as part of this project? Is it ok if I record the interview?
I usually also explain that recording what you say is normal for academic research. The point for me is that it stops me making mistakes if I need to write up your opinion on this – so it stops me misrepresenting you. It also helps me listen to you better because I don’t have to concentrate on making large amounts of notes, and I can go back and check if there’s something I missed.

As I have a recording pen, which many people haven’t seen before, I usually have to show them how this works, and answer questions about where I got it, and whether it works well etc.

I then need to explain that if I do write up what they say, it does not have their name against it. So I would report it in the format of “a design manager said” for example. The company and projects would not be named. For an external reader it would therefore be very hard indeed to identify. However, for internal staff it would be easier so this is worth bearing in mind for them.

**If observing:**

As for interviewing with following differences:

I have to address the whole group – or if a really large meeting then be introduced by whoever is in charge of the meeting.

As this does not involve digital recording, I need to ask if it is ok if I take notes.

**Feedback and further anonymisation**

Feedback provided to the company is also likely to be presented back to the participants themselves as part of the team involved.

In addition to asking questions at the time of interview/observation, some participants have also had the opportunity to review particular quotations from them, where I have felt that this was important. For instance, if they have said something that might be considered controversial, and that therefore might expose them to blame or harm. In response, these particular quotations have either been agreed directly with the participant, anonymised completely (e.g. attributed to “Int – anon”), or phrased indirectly instead.
Appendix H. Information sheet

PhD Research Project
Catherine Willan, Doctoral Researcher, UCL Energy Institute
Energy Performance in Buildings
2015-18

Information sheet

Who is conducting the research?
I am studying for a PhD at UCL, jointly funded by XXXX and the Engineering and Physical Sciences Research Council. I am based in the UCL Energy Institute, which is a centre of inter-disciplinary expertise in energy efficiency in the built environment. In collaborating with XXXX, we hope to share the knowledge and experience that we both have in sustainable construction.

This information sheet will try and answer any questions you might have about the project, but please don’t hesitate to contact me using the details given below if you have any questions about this research.

Why are we doing this research?
My research focuses on the management of contractual energy efficiency targets in non-domestic construction projects. It deals with the people and processes that can help influence energy performance, rather than focusing only on engineering or technical factors. The project is intended to be collaborative and I hope that the insights gained should contribute to a better understanding of energy efficiency in buildings.

Why am I being invited to take part?
I am trying to gather as many perspectives as I can from different roles in XXXX’s business and its sub-contractors, so your input is very valuable and part of a larger programme of interviews and information gathering.

What will happen if I choose to take part?
I will need around an hour of your time to meet in person. I would like to find out more about your day-to-day role, and how energy efficiency targets fit into your work.

Is my participation confidential?
I have signed a confidentiality agreement with XXXX so that you do not need to be concerned about accidental disclosure of commercially-sensitive information. Your comments may be included in the research findings, but if so, will be anonymous. Neither you, your company nor the projects will be named in my findings if published.
What will happen to the results of the research?
The research is for academic purposes, so for example, as well as my PhD thesis, UCL would hope to publish an article in an academic journal. However, I will also be updating those who have participated in this project on my findings as I go along. As a contributor to the project, you will get a chance to comment on anything I produce.

Any of your data that I gather will be stored in accordance with the Data Protection Act and used only for the purposes of this project.

Do I have to take part?
It is entirely up to you whether or not you choose to take part. I hope that if you do choose to be involved then you will find it a valuable experience.

Thank you very much for taking the time to read this information sheet.

If you have any further questions before you decide whether to take part, or would like to keep in touch with findings after you have taken part, please contact me on:

Email:  xxxxxxxxxx or  xxxxxxxxxx
Tel:  xxxxxxxxxx
9.9. Appendix I. Sponsor outputs

Appendix I Sponsor outputs:

i. Top 10
ii. Webinar slides
iii. Powerpoint summary of findings
ENERGY TARGETS:
KEY LEARNING POINTS

EXPECTATIONS
Get a clear understanding of what the contract requires

WHAT'S INCLUDED
Know what's included and check how it's been accounted for

KEEP TRACK
Keep track of energy impacts through construction

UNCERTAINTY
Be aware of the main sources of uncertainty

RESPONSIBILITIES
Is it clear who has responsibility for the target, and what they need to do?

COMMUNICATIONS
Identify who needs to know about the targets, and what they should know

USERS
What assumptions have been made, and what if they change?
<table>
<thead>
<tr>
<th><strong>Expectations</strong></th>
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<tbody>
<tr>
<td>• How does the target compare:</td>
<td></td>
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<tr>
<td>o How stretching is compared to other projects (but remember each building is different)</td>
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<tr>
<td>o What does the contract permit as sources of variation in energy use from target:</td>
<td></td>
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<tr>
<td>o E.g. change of use, degree days?</td>
<td></td>
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<tr>
<td>• Is there time allowed for learning and optimising energy use in the first couple of years?</td>
<td></td>
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<tr>
<td>• Be clear on contract terms in plain English:</td>
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<tr>
<td>o E.g. what does a “baseload” or “good energy housekeeping” mean in practice?</td>
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<table>
<thead>
<tr>
<th><strong>Understand what’s included</strong></th>
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<tbody>
<tr>
<td>• Know what’s included in the target and what’s not:</td>
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<tr>
<td>o Hours of use, types of activity, which equipment</td>
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<tr>
<td>o How these are going to be tracked once the building’s in-use</td>
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<tr>
<td>o Electricity use not covered by Building Regulations:</td>
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<tr>
<td>o How has it been considered in the energy model?</td>
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<tr>
<td>o What assumptions made and where did the data come from?</td>
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<tr>
<td>• Has everything been included in the energy model:</td>
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<tr>
<td>o e.g. distribution losses, late design changes, energy use from sources outside main contractor’s control (e.g. catering, cleaning)</td>
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<tr>
<td>• If there’s a carbon target has everyone used the same emission factors to convert between energy and carbon?</td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Uncertainty</strong></th>
<th></th>
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</thead>
<tbody>
<tr>
<td>• Do you know what the main sources of uncertainty or sensitivity in energy use are?</td>
<td></td>
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<tr>
<td>o At contract signing, how far has the technical design progressed?</td>
<td></td>
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<tr>
<td>o What uncertainties remain that might affect the level of energy performance committed?</td>
<td></td>
</tr>
<tr>
<td>• Are assumptions around performance realistic:</td>
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<tr>
<td>o E.g. in specification and manufacturers’ claims</td>
<td></td>
</tr>
<tr>
<td>o Do you have any previous examples to go on?</td>
<td></td>
</tr>
<tr>
<td>• How near is the simulation estimate of energy or carbon to the target?</td>
<td></td>
</tr>
<tr>
<td>o How much headroom is there?</td>
<td></td>
</tr>
<tr>
<td>o Understand that energy simulations aren’t predictions: they won’t be exactly “right”</td>
<td></td>
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</table>
### Keep track

- Keep track of the energy impact of variations during construction
  - Do procurement understand the impact of energy performance when looking for better VFM?
  - Ensure adequate sub-metering to monitor energy in-use is specified, installed and functioning
  - This has got to be able to pinpoint problems – e.g. variations between similar departments, energy use out of expected hours
  - For targets that include carbon, consider what happens if the fuel mix changes in-use

### Responsibilities

- Who has overall responsibility for the energy target?
  - And who is responsible for a) monitoring the target from bid to operation and b) reviewing it?
  - If this changes by stage and by area of responsibility how are they going to coordinate?
  - To what extent does responsibility depend on experience vs. process?
  - Are you relying on someone with experience to notice – e.g. if a change is made which impacts energy – what if they don’t notice, no one tells them, or they leave?
- To what extent have you changed what you do normally to account for energy?
  - E.g. time in programme for commissioning, standards of installation
- If something hasn’t got a defined process to follow, how will you make sure it gets done?
  - E.g. Soft Landings
- How does energy review incorporated into stage gates/check points?
- How do you get an overall picture of energy use?
- Do all different teams understand how they need to work together? (energy performance is made of many different parts and particular responsibilities such as lighting, or insulation, or renewable technologies) – how do they interact?
<table>
<thead>
<tr>
<th>Communications</th>
<th>Users</th>
</tr>
</thead>
</table>
| • Who needs to know about energy performance and how do you get them to listen?  
  o Is a big meeting the best solution?  
  o What about visual means of communication (esp. onsite)?  
  o How do you get people’s attention when there are too many other things to attend to?  
  o Do subcontractors understand what they need to do?  
• Is energy efficiency and/or carbon emissions a clear priority?  
• How will Facilities Management understand energy decisions made in design and construction?  
  o What are the plans for handover and ongoing energy management?  
  o How will Facilities staff deal with any unfamiliar systems?  
• Producing feedback at the end of the project:  
  o Can you include feedback from staff involved in bid, design, construction and FM?  
  o Include key subcontractors  
  o Include learning points for improvements as well as what went well |
| • What assumptions have been made about user behaviour:  
  o What are the default values being used in energy models, and where have they come from? What confidence can you have in them?  
  o What will happen if they turn out to be different in practice? (e.g. window/door opening, use of blinds, overriding heating controls)  
  o Does the client understand the impact of variations, or their changing behaviours, on the energy use?  
  o If senior client personnel change since the original target was set, do they understand too?  
  o Have they considered all their occupiers' activities, such as cleaners, visitors, and not just staff needs? |
### Energy targets: Top 10 items to consider

<table>
<thead>
<tr>
<th></th>
<th>Question</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>What do contract definitions mean in practice? (e.g. what is a &quot;baseload&quot;?), and what's included and what is not (hours, activities, or equipment)?</td>
</tr>
<tr>
<td>2</td>
<td>Does the client understand the impact of the variations they make during construction and changes of behaviour in use?</td>
</tr>
<tr>
<td>3</td>
<td>How are you tracking energy or carbon impact of construction variations?</td>
</tr>
<tr>
<td>4</td>
<td>How has electricity for IT equipment, server rooms and other small power equipment been accounted for in the energy model? How will you know if these are different when the occupiers move in?</td>
</tr>
<tr>
<td>5</td>
<td>Is everything in the energy model, including areas that might not be under the main contractor's control (e.g. distribution losses, communal areas, catering)?</td>
</tr>
<tr>
<td>6</td>
<td>What assumptions have been made about occupier behaviour in the energy model are these broad brush defaults, and how sensitive are they to change?</td>
</tr>
<tr>
<td>7</td>
<td>If you've got a carbon target, what happens if electricity use is more than expected, or the carbon content of electricity is higher than planned? Who is liable?</td>
</tr>
<tr>
<td>8</td>
<td>Sub-metering needs to be procured, commissioned, installed and checked operational. Does it match up to what the contract requires you to track?</td>
</tr>
<tr>
<td>9</td>
<td>Have the implications been explained to sub-contractors so that they can contribute effectively to energy efficient design and installation? Is the quality of installation and commissioning for energy efficiency being monitored effectively?</td>
</tr>
<tr>
<td>10</td>
<td>Who has responsibility for the energy target at various stages and how do these people communicate with each other and keep sight of the overall picture?</td>
</tr>
</tbody>
</table>
Two case study projects

**School**
- X.000m², completed 20XX
- Design targets: kgCO₂/m², CO₂ lower than regulations
- Operational target: kWh/year

**Hospital**
- X.000m², in construction
- Design targets: GJ/100m³/year, tCO₂e/100m³/year, % renewable energy
- Operational target: GJ/year
How are the energy guarantees calculated?

- What is included or excluded?
- What assumptions are made?
- Are Construction Co. or the client responsible?

For example:
The school building was used by many different users at different times – for which was Construction Co. responsible?

What uncertainties are in the energy simulation?

- How will users operate the building?
- How is unregulated energy use considered?
- Effect of construction variations?

For example:
The hospital simulation is based on a certain level of electrical equipment in each area of the building.
Communications

- Operating Units may have different targets and incentives
- Team members can be in different offices and work at different times
- Are responsibilities clear?

For example:
The hospital facilities management target depends on decisions taken in design and build

Preparing for occupation

- Is adequate sub-metering planned?
- Do occupiers understand how to use the building efficiently?
- Does the client understand the impact of changing use or equipment?

For example:
In the school, teachers did not operate lighting as designed
What did we learn?

- Understand how the guarantee is calculated
- Recognise uncertainties of simulation
- Plan for sub-metering
- Manage client expectations
- Communicate between departments

Energy Performance Guarantees deliver on Construction Co. values
Summary PhD findings

Catherine Willan
Paul Ruyssevelt, Michelle Shipworth, Russell Hitchings
October 2018

Scope
Aims
Low carbon buildings are not just a technical challenge

Question:
• How does a construction team deal with the challenge of operational energy targets?

Scope:
• Hospital case study, plus other projects and company
• Explore what people do, say and share about the energy targets

Outcomes:
• What can we learn about the origins of the energy performance gap?
• Therefore, what insights could help Construction Co. build better performing buildings?

Process

Data gathered:
• 40+ interviewees
• 220+ documents (from sample of 450)
• 120+ hours observation

Literature review:
• Over 600 academic and industry sources

Outputs:
• Thesis
• Feedback
  • MRes report and presentation, webinar, informal updates, team meetings, academic conferences, UCL Colloquium
• More planned (for discussion)
## Findings

## Summary findings 1

Energy targets are simple in concept but difficult in practice.

<table>
<thead>
<tr>
<th>Controlling energy targets</th>
<th>Being a systems integrator</th>
</tr>
</thead>
<tbody>
<tr>
<td>Difficulty in translating into actions</td>
<td>What information is transferred between Construction Co. and its contractors? (liability, IP, process)</td>
</tr>
<tr>
<td>Lack of experience, confidence</td>
<td>What needs to be? (sensitivities, changes, dependencies)</td>
</tr>
<tr>
<td>Lack of process to follow</td>
<td>Managed through mitigations (assumptions, margins, legal)</td>
</tr>
<tr>
<td>Single solutions vs holistic strategy?</td>
<td>Belief in market pull or low carbon offer?</td>
</tr>
<tr>
<td>Who is responsible throughout?</td>
<td>Mediators and managers</td>
</tr>
</tbody>
</table>
What is an energy target?

Energy in design

Fragmentation of energy targets occurs during construction

Energy in operation

Energy Model

Specifications and variations

Specialist designers, suppliers, initiators

Translation into action is problematic and there is no overall monitoring

Energy bills

Difficulty in reconciling design and actual arises due to lack of coordination

Overall responsibility for energy targets?

Perceived time limits of responsibility by construction stage, as defined by participants

<table>
<thead>
<tr>
<th>Bid</th>
<th>Design</th>
<th>Construction</th>
<th>Initial monitoring</th>
<th>Long-term occupation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Legal</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Environment</td>
<td>Project co.</td>
</tr>
<tr>
<td>Design management</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M&amp;E contractors</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Architect</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Engineering advice</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Commercial</td>
<td></td>
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</tbody>
</table>

Collective responsibility?
Summary findings 2

Energy targets are simple in concept but difficult in practice.

How does energy knowledge circulate?
- Energy gurus and technical groups
- Success stories/internal investigations/lessons learned
- Gossip
- Commercial barriers to sub-contractors
- Specific vs general knowledge
- Getting over the line (no need to gather more...)

Dealing with a different risk
- Energy as a risk
- Uncertain odds & unknown quantities
- Contingent behaviours
- Reliant on external expertise
- Incentive for innovation?

Energy knowledge

- Company
  - Limited extent
  - BIM
  - Legal
  - Engineering team
  - Energy experts
  - Project Co.
- Support staff
  - Limited knowledge in project
- Environment
- Project staff
  - Energy target knowledge
  - Construction
  - Design management
  - Facilities
- Sub-contractors
  - Engineering design contractors
  - BREEAM
  - Architects
  - Technology suppliers
  - Peripheral knowledge appreciated?
  - Feedback loop to constrained knowledge?
What is “thrown over the wall”? Does each party receive the energy information they need?

Changes, procurement, operational data?

Sensitivities, assumptions, dependencies?

Construction Co.
- Management & mediation
- Overview

Contractors
- Specialised knowledge
- Detail

Strategies for dealing with uncertainty:
- Assumptions
- Safety margins
- Legal mitigations

Questions
Do targets make the construction team more responsible for energy in use?

Yes
- Contract & reputation both drivers
- Strong focus in design
- Investment in monitoring
- Links to Facilities
- Sense of pride

No
- Conflicting internal incentives
- What is not covered? (costs, occupiers, equipment, IT, Soft FM)
- Managing targets not energy
- Building is dynamic

Do targets make more efficient buildings?

- Participants often talk about difficulties of getting theory and reality to match
- What is being measured?
- How negotiable is efficiency?
- Comparison in total
- How do you compare (and learn?)
- Little incentive for collective responsibility
### Summary implications

<table>
<thead>
<tr>
<th>Area</th>
<th>Suggestion</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Inconsistencies &amp; uncertainties</strong></td>
<td>• Standard guidance (e.g. CIBSE, Soft Landings)&lt;br&gt;• Internal tools (e.g. specific checklist, gateway)&lt;br&gt;• Communications (e.g. workshop, KPI)&lt;br&gt;• Energy strategy vs single solutions</td>
</tr>
<tr>
<td><strong>Knowledge diffusion</strong></td>
<td>• Empowering on-the-spot decisions&lt;br&gt;• Use employees with experience throughout&lt;br&gt;• Involve Facilities&lt;br&gt;• Escape technical pigeonhole</td>
</tr>
<tr>
<td><strong>Dialogue with client</strong></td>
<td>• What are their priorities and trade offs?&lt;br&gt;• Cooperative discussion of variances&lt;br&gt;• Potential for value-added service</td>
</tr>
</tbody>
</table>
Summary implications

<table>
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<th>Area</th>
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</tr>
</thead>
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<tr>
<td>Coordination</td>
<td>• What are priority areas? (e.g. variations, VE, modelling?)</td>
</tr>
<tr>
<td></td>
<td>• Fit with new digital systems, and other process innovations</td>
</tr>
<tr>
<td></td>
<td>• Overall responsibilities made clear</td>
</tr>
<tr>
<td>Mainstreaming low carbon in-use</td>
<td>• Commitment to change processes</td>
</tr>
<tr>
<td></td>
<td>• An integrator or with own expertise?</td>
</tr>
<tr>
<td></td>
<td>• Beyond immediate goal of target, what is the offering?</td>
</tr>
</tbody>
</table>

Policy has a role to play in procurement, standardisation, compliance/regulation, performance norms, industry mediation...