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An investigation of the required skills for the delivery of low and zero carbon buildings within a region

By

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Dedication

To my grandmother for her continuous support and words of encouragement.

‘You will get there because you are determined.’

Abstract

The UK is committed to a raft of requirements to create a low carbon economy. As buildings consume approximately 40% of UK energy demand, any improvement on the energy performance of buildings can contribute to the delivery of a low carbon economy. The challenge for the construction sector and its clients is how to meet the policy requirements to deliver low and zero carbon (LZC) buildings, which span broader than the individual building level to requirements at local and regional levels, and wider sustainability pressures. Further, the construction sector is reporting of skills shortages surrounding the need for 'project management skills' and 'communication skills' within construction projects, and further requirement of 'new skills,' 'green skills' and 'low carbon skills' for the delivery of LZC buildings.

The aim of this research was to identify, and better understand, the skills required for the delivery of LZC buildings within a region. The theoretical framing for this investigation was regional innovation systems (RIS) using a socio-technical network analysis (STNA) methodology. Both deductive and inductive approaches were adopted, which framed the investigation. A single case study approach of a local authority region was chosen. Data collection consisted of a review of relevant documentation, observations and semi-structured interviews with five school retrofit projects within the region.

The research results revealed the complexity surrounding the form and operation of the LZC networks for the school retrofit projects. Key findings identified principal actor groups and their required skills for the delivery of LZC buildings: communication skills, energy management skills and project management skills required by the local authority; communication skills and technical skills required by the energy efficient measure (EEM) contractors; and communication skills and project management skills required by the school end-users. Technical skills and energy management skills captured the need for 'new skills' surrounding the adopted EEM technology, however, there was little evidence of the required skills being associated with 'green skills.'

The primary contribution to the RIS theory is empirical evidence that captures the significance of specific RIS 'elements' and 'mechanisms,' and highlights challenges within the RIS system. Adaptations to the RIS framework recognises the need for interactions between RIS components and their involvement to describe, explain and predict the innovativeness of a region. In consideration to skills theory, the investigation provided insights and captured meanings surrounding the type of required skills for the delivery of LZC buildings. Implications for policy practice may surround the management of the RIS framework, and further tensions between skill development within the region and policy pressures.

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Declaration

I confirm that this is my own work and the use of all material from other sources has been properly and fully acknowledged.

Whitney Bevan

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List of abbreviations

ASHP	**Air Source Heat Pump**
CIOB	**Chartered Institute of Building**
CITB	**Construction Industry Training Board**
DCLG	**Department for Communities and Local Government**
DEC	**Display Energy Certificate**
DECC	**Department of Energy and Climate Change**
EEM	**Energy Efficient Measure(s)**
IPMA	**International Project Management Association**
LA	**Local Authority**
LZC buildings	**Low and Zero Carbon Buildings**
NHBC	**National House Building Council**
PV	**Solar Photovoltaic**
RIBA	**Royal Institute of British Architects**
RICS	**Royal Institution of Chartered Surveyors**
RIS	**Regional Innovation Systems**
SDC	**Sustainable Development Commission**
STNA	**Socio-Technical Network Analysis**
UKCES	**UK Commission for Employment and Skills**

Chapter 1 Introduction

This chapter will present the background to the investigation in the context of the research problem. The aim of the research and objectives will also be outlined in this section. Furthermore, a brief summary of the methods adopted for the study will be given, and an outline for each chapter will be set out by describing the thesis structure.

1.1 Research background

The United Kingdom is committed to a raft of requirements to create a low carbon economy, which include changes to the transport systems, buildings, and energy generation (DTI 2003, DECC 2011a). Buildings produce approximately 50% of UK carbon dioxide emissions (HM Government 2010) and consume approximately 40% of UK energy demand (DECC 2011b, The Carbon Trust 2012, DCLG 2014). As a consequence, any improvement on the energy performance of buildings can significantly contribute to the delivery of a low carbon economy. Within the context of building emission reduction, there are a significant number of policy pressures on the construction sector and its clients to deliver low and zero carbon (LZC) buildings. As the definition of 'zero carbon' continues to be revised (DCLG 2013, DCLG 2015) this research defines a LZC building as a building that has improved its energy performance to reduce a proportion of its energy use and carbon emissions, or its carbon emissions from energy use are zero. The justification for this definition of a LZC building is made in section 2.4.

At the individual building level, for example, Building Regulations are becoming a key policy driver for LZC buildings. More specifically, Part L (2013) requirements are being revised to include tighter guidelines of carbon dioxide (CO_2) emission rates (NHBC 2014). Closely connected to the CO_2 levels of buildings, Part L is introducing strict pressures that relate to the development and use of properties, which can affect both the construction sector and its clients (e.g. local authorities and landlords). Changes to building fabric, heating systems and lighting are being carefully monitored in connection to emission rates (NHBC 2014). In order to meet the Part L guidelines, it is likely the construction sector may need to gain further information and understanding of the building fabric and low and zero carbon (LZC) technology (i.e. the need for training and skills). Similarly, the use of Energy Performance Certificates (EPC) to provide information on the energy efficiency of buildings is required for the construction, sale or rent of domestic and non-domestic buildings (DECC 2011a, EST 2014a). The focus on EPCs highlights the pressure to implement changes at the individual building level, which can potentially improve the energy rating and energy use of the building. Similar to the Part L pressures, the regulations for EPCs will require project stakeholders to communicate, share information and learn from each other. There will be a need for landlords to understand energy requirements and heating systems within the property, for instance. Furthermore, there have been a number of UK Government schemes, also referred to as 'pay as you save' schemes (The Carbon Trust 2013), associated with the finance of energy efficient measures (EEM) within buildings. This research defines an EEM as a measure or device consisting of either a fabric or technology solution, which can be adopted and integrated within a building to reduce the building energy consumption. Justification for this definition of an EEM is given in section 2.4. A Government scheme known as the Green Deal, for instance, was launched by the UK Government to provide a loan to domestic and non-domestic owners (DECC 2011b, DECC 2013). Even though the Green Deal experienced a relatively slow uptake (DECC 2014a), due to insufficient budget funds (DECC 2014b), applications for the scheme are no longer being accepted, i.e. the scheme is currently closed.

The policy pressures, however, are broader than the individual building level and demand the construction sector and its clients to consider requirements at local and regional levels. As a consequence, policies are placing greater focus on the importance of local and regional level actions and increasing the priority of policy requirements at this level. Cooke et al. (1997: 480) argues a region is defined as "…territories smaller than their state possessing significant supralocal governance capacity and cohesiveness differentiating them from their state and other regions." The definition acknowledges, and places emphasis, on how a region is distinguished by its unique regional characteristics, and contrasting to its surrounding regions. Both the physical and non-physical boundaries of a region, however, are unclear and there is the possibility that regions may connect or overlap (Cooke et al. 1997). There is also a contrast between the regional level and local level, in which the regional level is described as a larger area and can operate at a greater scale (DCLG 2007). The separation and boundaries of regions, and indications of authority or power discussed in terms of regional attributes, supports the argument of specific regional pressures, and further implies potential problems that need to be understood at a regional level. Moreover, in attempts to mitigate the regional challenges, a regional area is suggested to implement broader strategies (e.g. regional development strategies), as opposed to local level plans more specific to the area (DCLG 2007) and closely connected to communities (DCLG 2007, DCLG 2010).

Local and regional pressures, however, such as Localism (discussed below), highlight the connection, and possible overlap, between the local, regional and community levels. The Localism Act, for instance, aims to promote power to local government and communities (DCLG 2011, Hopkin and Atkinson 2011), but, there is also the need for Localism to address and replace a number of regional strategies (DCLG 2011). In simple terms Localism is an increase or shift in responsibility (DCLG 2011) and authority (Hopkin and Atkinson 2011) to local government (i.e. a local authority) in order to act within the interests of the local community (i.e. what local people want) (DCLG 2011). As a consequence, decision makers within local areas are required to involve and support local level actors (e.g. local authorities, individuals and communities) (DCLG 2011). The empowerment of local actors can provide benefits, such as freedom in the context of laws and rights made by the local authority for the local area (e.g. changes to businesses rates) (DCLG 2011). On the other hand, Localism can also impose restrictions such as a reduction to local budgets, and uncertainties regarding the influence of local governance (Hopkin and Atkinson 2011). Localism challenges the construction sector and its clients by the demand to recognise and incorporate local requirements. Pressures of Localism can be associated with the planning of buildings, support to local businesses, jobs and investment (DCLG 2011, LGA 2013a), demand for the use of local resources (e.g. local labour and materials) and further enhance the required local skills where possible (SDC 2010). In addition to demands at the individual building level, when delivering LZC buildings, the construction sector and its clients must further engage with the local and regional level pressures. The literature provides valuable detail on the demands that need to be met to achieve Localism, but further insight on how to meet these pressures, and any possible challenges associated with the requirements, would be of benefit. How to develop of ‘local skills’ for actors within the region, for instance.

Furthermore, the construction sector and its clients are required to recognise not only individual building and local pressures, but broader policy pressures that are associated with more social demands (Dixon 2011). There are pressures to create sustainable communities (Egan 2004, SDC 2010) and cities. Sustainable communities within this research adopts the views by the Sustainable Development Commission (2007, 2010) and Dixon (2011), whereby a sustainable community comprises of a number of elements such as housing, schools, open space, opportunities for skill development and enhancement, community integration and well-being. A community (or communities) can be referred to as located within a local area (DCLG 2011). As a region can also have its own communities, there are indications a community level can refer to large or small scale depending on the context. There is further emphasis on the need for sustainable communities for the link towards regional, national and international communities (ODPM 2003).

The broader sustainability demands aim to encourage strong communities and integration, which support social sustainability, “people based” outcomes and liveability (ODPM 2003), e.g. job creation, quality of life and resource efficiency (Dixon 2011: 7). There are further pressures associated with sustainable communities, in which community stakeholders (e.g. local authority, local residents, developers) are encouraged to adopt a ‘common goal’ and possess the same ‘vision’ of sustainability and community requirements (Egan 2004). Many reports suggest a wide range of pressures for sustainable communities, which are connected to a number of key requirements including good quality local services and employment, a healthy and safe environment, and sense of place (ODPM 2003, Egan 2004). In line with the demands of delivering the principal elements for sustainable communities, there is an emphasis towards relevant sustainable community stakeholders possessing certain ‘generic’ skills (Egan 2004), such as leadership skills, decision making ability, project management skills and communication skills, to name a few recurring within the report. Furthermore, there is the idea that sustainable community requirements can help strengthen the support and development of housing within the community (ODPM 2003). Policy pressures, such as Building Regulations, Localism demands and sustainable communities’ requirements, emphasise the need for the construction sector and its clients to comply with a number of demands to deliver LZC buildings. To meet the demands, the dominant role of local authorities to drive integrated strategies (Dixon and Wilson 2013) and partnerships between actors to deliver LZC buildings is emphasised (SDC 2010, RICS 2012).

In addition to the challenge of policy pressures for the construction sector and its clients, skills challenges for the UK construction industry are mentioned within current skills literature (Chan and Dainty 2007, CIOB 2013), which suggests a need to attract skilled construction sector workers to the sector. The issues surrounding skills within the construction sector are associated with ‘skills shortages,’ where there appears to be a lack of labour for projects within the industry (Dainty et al. 2007, CIOB 2013). There are also discussions surrounding the challenge of ‘skills gaps’ within the sector (Construction Skills 2010). Even though both terms are used interchangeably in discussions, skills gaps appear to be more of a concern as the term primarily relates to the need for the development of ‘new skills’ or the enhancement of ‘existing skills,’ which often requires training for the construction workforce. A number of concerns surrounding the need for training and development for the construction sector are linked to the knowledge and understanding for the adoption of low carbon technology, low and zero carbon technology (LZC) or advanced technology within buildings (Killip 2008, Construction Skills 2010, Home Building Skills 2013a).

In terms of the type of skills required, investigations focus on a selection of specific skills for the construction sector, primarily the need for ‘project management skills’ (Zhang et al. 2013) and ‘communication skills’ (Fisher 2011) surrounding a construction project. Construction innovation literature also highlights to the need for knowledge, such as knowledge surrounding techniques, construction methods (Home Building Skills 2013a) and use of technology during its adoption within buildings (Thamhain 2016). Although the focus is predominantly on gaining knowledge and information, and links to how new knowledge can lead to skill development, literature highlights challenges associated with the management of knowledge following its production or transfer (Ernst and Kim 2002, Howells 2002). More specific to LZC buildings, the skills issue is coupled with the requirement of ‘new skills’ (DCLG 2006, Construction Skills 2010) and there is further association with the use of ‘green skills’ and ‘low carbon skills’ for both the construction sector and its clients. A number of different ideas relating to new skills, green skills and low carbon skills are provided within the construction innovation and skills literature. The numerous types of technology associated (e.g. renewable technology, low carbon technology and advanced technology), the variety of project stakeholders involved (e.g. the construction sector, local authorities, end-users) or diverse training required add to the complexity of required skills ideas. The lack of definition and broad meanings surrounding the required skills present vague accounts of what new skills, green skills and low carbon skills actually consist of.

To investigate how the construction sector and its clients meet these policy pressures and demands for the development and the implementation of LZC buildings and explore the type of skills required, the study will focus on the research problem (see below), and the research aim and objectives (see section 1.3). The skills issue will also be explored as the investigation will aim to gain insight into the ideas associated with the dominant focus on ‘project management skills’ and ‘communication skills.’ Furthermore, the connection to the demand for ‘new skills,’ ‘green skills’ and ‘low carbon skills’ during the delivery of LZC buildings will be explored, and understandings and meanings of the terms will be investigated.

1.2 Research problem

The challenge for the construction sector and its clients is how to meet the policy pressures to deliver LZC buildings. The key problem relates to the current research into the delivery of LZC buildings. The prevailing construction innovation literature tend to focus investigations at the firm, technological and community level, rather than the local and regional levels. This research requires a focus on a level of analysis that recognises the need to incorporate the number of pressures explained above, i.e. requirements at the individual building level, local and regional levels, and pressures to achieve sustainable communities.

Furthermore, as mentioned briefly in section 1.1, the prevailing construction skills literature suggests the UK construction industry is experiencing a number of skills shortages (Chan and Dainty 2007, Construction Skills 2010, CIOB 2013, CIOB 2014) and skills gaps (Construction Skills 2010). There is no clearly defined boundary between skills shortages and skills gaps, and confusion towards both terms within the literature. It is clear, however, that training is required to achieve an ‘up-skilling’ of the construction workforce (Construction Skills 2010). To worsen the issue surrounding a lack of skills within the industry, reports state the need for the construction sector (DCLG 2006, Construction Skills 2010, Home Building Skills 2010) and its clients (SDC 2010) to develop 'new skills' for the delivery of LZC buildings. The idea of what a new skill consists of is unclear within the literature. There are accounts of a new skill relating to the need to integrate or implement a piece of technology within a building or building energy system, or further use of advanced techniques and construction methods by the construction workforce. There are also discussions that indicate new skills can be combined with 'existing skills' during the delivery of LZC buildings, for which a multi-skilled workforce is required (Killip 2008). In addition to new skills, literature relates specifically to the need for 'green skills' (Bird and Lawton 2009, Energy UK 2014) or 'low carbon skills' (RIBA 2008, HM Government 2010), in order to deliver LZC buildings. Similar to the demand for new skills, however, definitions and the understanding of what green skills and low carbon skills consist of are vague. The complexity surrounding the terms is associated with the lack of clarity in regards to what green skills and low carbon skills actually consist of, where the skills can be described as 'generic skills' or 'specialist skills,' or no specific classification at all. There are discussions surrounding the connection of these skills to the reduction of energy or carbon emissions, but further confusion is presented in terms of how this goal is achieved, e.g. opposing ideas for the use of green skills and low carbon skills to implement low carbon technology, and the adoption of skills to adhere to policy demands.

To complicate the problem further, the current research and knowledge on the skills challenges for the construction sector and its clients is primarily focussed on the industry-sector level as opposed to local and regional challenges. There is literature that offer insights into the skills challenges on local and region levels (Ball 2005, Killip 2008), however, the majority of investigations and reports tend to have a dominant viewpoint at an industry level. The prevailing skills literature at this industry level tends to focus on the importance of 'project management skills' (Hwang and Ng 2013, Zhang et al. 2013), and in many cases closely connected 'communication skills' (Egbu 1999, Chen et al. 2008, Fisher 2011). Even though the classification boundaries are unclear, project management skills can be further classified as 'technical skills,' i.e. the use of a form of technology or information technology systems, and 'behavioural skills,' i.e. more personal attributes such as 'leadership skills' (Dainty et al. 2005b). The literature also gives insight into the possibility of classifying project management skills by 'hard skills' and 'soft skills' (Ingason and Jónasson 2009). Again, the classification boundaries for hard and soft skills are blurry, due to the possibility of a skill being classified as both technical skills and hard skills. To add to the complex task of defining project management skills, there is reference to 'specialist skills' (Edum-Fotwe and McCaffer 2000), which may be a result of the changing roles of a project manager or the variation of construction projects, leading to a variation in project management tasks.

In contrast to project management skills, there appears to be no methods of classifying communication skills, but dominant ideas of essential characteristics, actions and outcomes required from these skills. The literature states the need for ‘effective communication’ (Janthon et al. 2015) and ‘appropriate communication’ (Siriwardane et al. 2015), which emphasise the need for communication skills to go beyond the exchange of information. It is also fundamental for a relationship to be built between the communicator and receiver of information, which may enhance the communication and provide an understanding for the ‘active listener’ (Fisher 2011). Furthermore, as indicated by the description above, communication skills can be linked to the broader concepts of ‘social skills’ and ‘interpersonal skills’ (Benson 2014).

The construction skills literature appears to focus on the detail of project management skills and, in many cases, the connected communication skills, i.e. the requirement of communication skills for a project manager. The details of what these skills consist of, however, are vague. Due to the range of contrasting ideas provided within the literature, both project management skills and communication skills are also presented as complex. The problem is associated with little sensitivity to any other skills required for the construction sector. Whilst it is valuable to gain knowledge of the issues experienced at an industry level, the use of project management skills and communication skills, it would be beneficial to explore the prospect of other skills required by the construction sector and possibly its clients. Furthermore, it is essential to recognise the multitude of policy pressures and identify skills challenges for the delivery of LZC buildings, and gain insight for the demand of new skills, green skills or low carbon skills. In consideration of these problems the research will look to focus on local and regional levels, and address the following aim and objectives.

1.3 Research aim and objectives

The aim of the research is to identify and better understand the skills required for the development and the implementation of LZC buildings within a region. The research will adopt the regional innovation system (RIS) as the theoretical framework and socio-technical network analysis (STNA) methodology. The RIS framework directs the research in terms of the identification of the RIS surrounding the LZC buildings, and specifying characteristics of the RIS to be investigated. The STNA mobilises the investigation, providing research direction by identifying actors, and further recognition of the interactions and negotiations between actors that surround the delivery of LZC buildings. The following objectives will be addressed:

1. Identify key actors involved in the delivery of LZC buildings within the region, and their roles that contribute to this process.
2. Identify and explore the EEM adoption process for the LZC buildings and the level of involvement from the key actors in this process within the region.
3. Explore key actors' interests and negotiations surrounding the EEM adoption process to identify and further understand the type, significance and meanings of required skills for the delivery of LZC buildings within the region.
4. Identify activities and exchanges between key actors in support and development for the skills required for the delivery of LZC buildings within the region.
5. Explore primary challenges experienced by key actors during the delivery of LZC buildings within the region.
6. Critically reflect and contribute to the current understanding of the RIS theoretical framework and prevailing skills theory.

1.4 Research methodology

An interpretive approach philosophy was adopted for the research, which allows the capturing of the social setting and social elements of the investigation. Both deductive and inductive concepts were also applied within the research. Deductive methods, for example, were adopted as the research was guided by themes within the prevailing construction innovation and construction skills literature, and further guidance of the RIS theoretical framework and guidance by STNA methodology. Inductive concepts were used as the research explored the delivery of LZC buildings within the empirical setting, and further meaning and types of skills required by both the construction sector and its clients. The application of both deductive and inductive concepts for data collection and data analysis can also be referred to as hypo-deductive (see section 3.3 table 3.1). Within this context, a case study approach was employed, adopting a single case study of a local authority. The research object was to explore the skills required for the development and the implementation of LZC buildings, where the unit of analysis consisted of the LZC building projects, i.e. how the retrofit of LZC buildings were being delivered within the region. The level of analysis for the research was at the decision making level, where the aim was to identify the required skills for both the construction sector and its clients to deliver the LZC buildings, i.e. fulfil the design and construction brief. The data collection methods included a literature review, twenty-four semi-structured interviews (either through face-to-face or telephone), observations and a review of relevant organisational documentation. The data analysis method included content analysis by using Nvivo software, and the production of network diagrams (see section 3.4.1, table 3.2 and figure 3.1), in order to highlight the socio–technical network (STN) and regional innovation system (RIS) for each project.

1.5 Structure of the thesis

This thesis is structured into the following chapters:

Chapter 1: Introduction

Chapter 1 introduces the investigation and describes the background to research in the context of the research problem. The aim and objectives are also explained within this chapter, and a brief description is provided of the research methodology employed within the investigation.

Chapter 2: Literature review

Chapter 2 reviews relevant construction innovation literature with a particular focus on how the construction sector and its clients deliver LZC buildings. Skills literature, both general and construction skills, is also discussed to provide an insight into the current understanding, meanings and challenges surrounding skills. Furthermore, chapter 2 describes a number of EEM options to deliver LZC buildings, and introduces the RIS framework that has been adopted for the investigation.

Chapter 3: Methodology

Chapter 3 details the research methodology that is used to address the research aim and objectives outlined above. The interpretive philosophy, and both deductive and inductive approaches adopted for the research are justified and explained, along with an introduction and further details of the STNA methodology and STN that was employed for the research. This chapter also presents the case study approach adopted within the research, and further specifies the research design, data collection, data analysis, the process for the production of project network (STN / RIS) diagrams and validation methods used within the investigation.

Chapter 4: Case study and school retrofit project 1

Chapters 4 introduces the case study within the investigation, the local authority of the region where the research was carried out. Furthermore, school retrofit project 1 is introduced. A description of the school under investigation is given, the school retrofit project process explained (the EEM adopted), and the identification of the skills required for the delivery of the project and RIS mechanisms evident are detailed.

Chapters 5 – 8: School retrofit projects 2-5

Chapters 5 to 8 present the school retrofit projects 2 to 5 in detail, providing a description of the projects under investigation, the retrofit and EEM adoption process and the identification of the skills required for the delivery of each project. The RIS mechanisms captured within projects 2 to 5 are also described and explained.

Chapter 9: Discussion

Chapter 9 provides a discussion surrounding the key findings of the investigation. This chapter summarises the research results that have emerged in connection to the RIS framework, and the skills required by the construction sector and its clients for the delivery of LZC buildings.

Chapter 10: Conclusion

The final chapter discusses the key findings of the investigation, and further connects the results to the research aim and objectives (see section 1.3) and broader research problem (see section 1.2). This section also explains the investigation in terms of how it contributes to the RIS and skills theory, the implications for policy practice and issues surrounding methods adopted within the research. Furthermore, chapter 10 states the limitations of the research and areas of investigation that will be of benefit to future research are set out.

Chapter 2 Literature review

2.1. Introduction

The chapter will introduce the literature reviewed for the investigation. The construction innovation literature will be reviewed, with a particular focus on how the construction sector and its clients respond to the delivery of low and zero carbon (LZC) buildings. The research will also comment on both the general and construction skills literature to gain an insight into the meaning of skills and the types of skills associated with LZC buildings. Furthermore, construction innovation literature will be explored to seek detail on the possible types and adoption of energy efficient measures (EEM). Finally, an introduction and review of the theoretical framework adopted, regional innovation systems (RIS), will be detailed.

2.2 The challenges towards the delivery of low and zero carbon buildings

The construction innovation literature recognises the challenge for the construction sector and its clients to deliver LZC buildings, i.e. the need to develop and implement EEM. An issue lies with the focus of the prevailing literature, which tends to surround a firm, technological and community level, but not local and regional levels.

2.2.1 Firm level

There are investigations, for instance, which explore the barriers associated with the delivery of LZC buildings by concentrating on a firm level as the unit of analysis (Osmani and O'Reilly 2009, Davies and Osmani 2011). The authors acknowledge challenges experienced from both the housing developers' perspective (Osmani and O'Reilly 2009) and the architects' perspective (Davies and Osmani 2011). The difficulty of understanding regulations, along with financial issues when delivering LZC buildings are examples highlighted within the investigations. The dominant focus at the firm level, however, is silent to wider demands surrounding the firm and possible challenges to deliver LZC buildings. Capital costs and specific requirements, such as local level pressures, are principal examples that may pose further challenges for actors external to the firm. In addition, there are indications that skills may hinder the delivery of LZC buildings, in connection to the design and technical challenges associated with the building and adopted technology (Davies and Osmani 2011). Similarly, the work by Lees and Sexton (2013) focuses on a firm level to investigate the delivery of LZC buildings. The developers' rational and further drivers surrounding the adoption of technology to deliver LZC buildings are identified. However, the work is silent to the broader requirements and pressures for clients of the construction sector surrounding the delivery of LZC buildings. The investigations provide significant insights to key issues associated with the delivery of LZC buildings, but the firm level unit of analysis has a narrow scope with regards to studying the key challenges for the construction sector and its clients.

2.2.2 Technological level

Furthermore, there is literature that predominantly focuses on the technology itself in response to the pressures to develop and implement LZC buildings. The investigations identify a broad range of technologies, from building insulation to microgeneration technology, and place emphasis on their adoption in order to create LZC buildings (Hinnells 2008, Kneifel 2010, Xing et al. 2011). The research provides valuable insights with regards to the issues and complexities surrounding a variation of technologies (Hinnells 2008, Xing et al. 2011), which can be experienced by the construction sector and its clients when delivering LZC buildings. Similar is the research by Berry et al. (2014) that focuses on the implementation of energy efficient appliances and renewable technologies to reduce energy use in houses. There is reference within the research to the impact of government policy intervention to aid the challenges for the delivery of LZC buildings (Xing et al. 2011, Berry et al. 2014), and the issues concerning infrastructure during technology implementation (Hinnells 2008).These investigations, however, centre on the need to select the appropriate technology in order to achieve energy reduction within buildings.. Ridley et al. (2014), employs a similar approach to an investigation that focuses on challenges associated with building design strategies for the development of low and near zero carbon buildings. The research does touch upon the concerns and influences of occupant behaviour, but this consideration of building users is mainly interested in the occupants' choice of energy efficient appliances and practices (Ridley et al. 2014). The technological level of analysis adopted within the investigations appears silent to broader challenges for the construction sector and its clients, such as recognition of various actors surrounding the technology (e.g. installers and suppliers). The dominant focus of the technological issues associated with the delivery of LZC buildings offers partial insights for the construction sector and its clients.

2.2.3 Community level

In comparison to the previous literatures, there is construction innovation literature that engages with the broader requirements for the delivery of LZC buildings by focussing on community (Curwell and Cooper 1998, The Berkeley Group 2012) and city levels (RICS 2012, Eames et al. 2013) as the unit of analysis. The community and city focus on investigations emphasise the need to consider pressures beyond the individual building level, and recognises requirements to enhance residential quality of life, understand the interests of the community, and encourage appropriate actions to transition to a sustainable community or city (Eames et al. 2013). A community level of analysis further highlights the elements that can lead to the delivery of an 'unsustainable community' (Curwell and Cooper 1998). Research by Marique and Reiter (2014), for example, assess the complications for the delivery of zero-energy buildings looking at larger scale neighbourhood development, and further considers challenges and effects to residents and the wider community. The community level focus offers insight to the more widespread demands (e.g. employment opportunities, skill pressures) (RICS 2012) and requirements (e.g. developing community infrastructure) (The Berkeley Group 2012) that have the potential to impact on the development and the implementation of LZC buildings. The unit of analysis, however, offers little reference of challenges to individual building level pressures. The strict building regulations, for example, which are becoming more stringent and challenging for the construction sector (see section 1.1). Furthermore, there is little detail of how the construction sector and its clients can actually meet the sustainable community pressures. Much the same as the focus of a firm and technological level of analysis, the literature offers partial accounts of the issues associated with the delivery of LZC buildings. It would be of value for the investigation to recognise the combination of requirements to deliver LZC buildings, in order to understand the challenges for the construction sector and its clients.

2.2.4 Local and regional level of analysis

The policy pressures highlighted in the research problem, such as pressures at the individual building level, local and regional level and further sustainable community demands, indicate the need for a holistic approach to investigate how the construction sector and its clients deliver LZC buildings. The units of analysis of investigations at a firm, technological and sustainable community level offer partial accounts of how to address the raft of challenges for the construction sector and its clients. A research investigation, which focuses on the local and regional level of analysis can offer insights to pressures in relation to / concerning Building Regulations, government schemes, localism and requirements of broader sustainability demands. Furthermore, a perspective that recognises the range policy pressures from a local and regional perspective, may offer insight into the challenges for the construction sector and its clients to deliver LZC buildings. The deliberation surrounding the skills required for the development and implementation of LZC buildings, for example, which has been referred to by a number of authors (Hinnells 2008, Davies and Osmani 2011).

This section has identified the theoretical problem that relates to the focus and lack of integration between the current construction innovation authors. A second problem presents an empirical question for the research that is connected to the discussions surrounding skills challenges for the construction sector and its clients, and is the focus of the next section.

2.3 The skills issues within the construction sector

One of the recurring themes within the construction skills literature relates to a decline in skills base and skills shortages within the workforce. Furthermore, the knowledge surrounding the challenges associated with skills appears to be focussed at an industry level, where dominant construction skills literature brings attention to the need for 'project management skills' and 'communication skills' for the construction sector. There are, however, broad definitions and vague accounts provided for both project management skills and communication skills, and the suggestion that they are very much related. To worsen the skills issues, there is a requirement for 'green skills,' 'low carbon skills,' 'new skills,' or possibly a combination of all three skills, by the construction sector and its clients to deliver LZC buildings. Similar to the ideas for project management skills and communication skills, ideas of the skills are provided, but clarity of what the skills actually consist of is neglected. This review will aim to distinguish the term 'skills,' identify the various types of skills and skill classifications, and further investigate the skills used by the construction sector for construction projects and those skills required specifically for the delivery LZC buildings. General literature and construction specific literature is reviewed.

2.3.1 The definition of a 'skill'

In the general literature, a 'skill' can be described as (OECD 2011: 7):

"The bundle of knowledge, attributes and capacities that enables an individual to successfully and consistently perform an activity or task, whether broadly or narrowly conceived, and can be built upon and extended through learning"

The core definition above offers a broad indication of a skill as it relates to knowledge, attributes and capacities, and further connects a skill to the ability to fulfil a job and introduces the possibility of undertaking skill development. In relation, a notion of a skill by the Confederation of British Industry (CBI) (2013) suggests a skill is a requirement for the ability to carry out a daily task, and relates to a specific role within the workplace. Similarly, a skill, and the range of different types of skills within the general literature, can be linked closely to a particular job or activity (Clarke and Winch 2006), tasks or 'productive tasks' (Shah and Burke 2005) to be carried out by an individual (Aggarwal et al. 2007), and connected to employability, or 'life skills' (Taylor 2005, Markes 2006), and linked to particular skills that are needed to fulfil a position in the work place (UKCES 2009). Furthermore, the measurement of possessing a particular skill can be connected to the experience (rather than a qualification), and the output of the job relates to an evaluation of whether the skill is present (Clarke and Winch 2006).

A similar view of a skill can be found within the construction literature, connecting a skill to knowledge and the potential to enhance a skill, as defined by Odusami (2002: 61):

"…an ability that can be developed which is manifested in performance. It can also be referred to as an ability to translate knowledge into action."

Seeking a much broader view, a skill can be described and defined through the individual's attributes (on occasions personal attributes), qualifications, a knowledge of the job / occupation required to be under taken, or the ability to perform the required tasks and utilise specific tools for the role (Clarke et al. 2013).

2.3.2 The classification of a 'skill'

There appears to be a number of ways to classify the different types of skills. A 'skill' can be classified as 'generic,' or 'specific' (possibly a mention of technical within this classification), 'existing' or 'new' and 'hard' or 'soft,' although there are particular skills that can be classified as a number of different skill types. Each classification will be discussed in turn.

1. Generic versus specific / occupation specific skills

A 'generic skill' can cover a wide area of diverse skills (UKCES 2009) and be associated with a range of characteristics (UKCES 2009, Felstead. A et al. 2012). Generic skills are categorised as numerical skills, professional communication skills, problem solving skills and computer skills (Felstead. A et al. 2012), and also associated with interpersonal skills (communication, team work, ability to negotiate), and the ability to use technology, particularly ICT (OECD 2011). It is interesting to note the mention of the ability to use technology under the generic skills classification, where 'technology' appears to be associated with computers and IT (OECD 2011). It is likely the element of time plays an important role in the skills definition, where more advanced technology may be included within the generic skills classification in the future. This overarching broad classification of generic skills can also include or be separated into basic / core skills (e.g. literacy and numeracy) (OECD 2011). Furthermore, generic skills can be referred to as 'employability skills,' which is linked to an individuals' ability to complete a job, tasks or, more extensively, a role within the workplace (UKCES 2009). In comparison to the generic skills classification, 'specific skills', also referred to as 'occupation specific skills' (Baum 2002), are connected to activities that are associated with individuals' specialist skills or 'speciality' (Edum-Fotwe and McCaffer 2000). Specific skills associated with construction projects, for example, can include the knowledge of specialist areas of expertise (e.g. water management) (Edum-Fotwe and McCaffer 2000), the construction of new builds or refurbishment, and the ability to understand and use new technology or methods of working (Gann and Senker 1998). The creation and development of specific skills are also connected to the NVQ qualifications, where training and assessment to gain specific skills is supported (Gann and Senker 1998).

2. Existing versus new skills

The skill classifications and separation of ‘new skills’ and ‘existing skills’ are highlighted in a number of investigations through discussions of the impact and need for training / training programmes / re-training (HM Government 2010) to gain various skills (Gann and Senker 1998). New skills are primarily related to an ‘up-skilling’ of the workforce to undertake new roles within the workplace, carry out different methods or techniques of working, and the use of more advanced equipment (HM Government 2010). The changing role of a project manager, for example, which requires the experience of new demands on the job indicates the need for new skills (Edum-Fotwe and McCaffer 2000). Similarly, new skills can be required for changes to tools and equipment, such as the ability to understand and use low carbon technologies (Construction Skills 2010, Home Building Skills 2013a). Existing skills are described as those that an individual / workforce already possesses, but can also be referred to in connection with the requirement for training to further develop these skills. New technologies and new methods of working, for example, can require a combination of existing skills and new skills, or an enhancement of existing skills through training (Home Building Skills 2013a), often referred to as a ‘multi-skilling’ of the workforce (Killip 2008, Construction Skills 2010).

3. Hard versus soft skills

‘Hard skills’ appear to be linked to the knowledge of carrying out an activity, possibly specific to a role, and requires a form of learning (e.g. training, skills development) (Rongraung et al. 2014). The need for hard skills, for example, can be in reference to the requirement of a literacy or numeracy skill. In contrast, ‘soft skills’ are suggested to be personable to the individual, associated with the building of relationships within the workplace, the ethics or culture related to a person (Ingason and Jónasson 2009) and occur though a more progressive manner. Soft skills, such as communication skills and interpersonal skills, for example, are primary to this classification, as well as the ability to work as a team and leadership skills (Rongraung et al. 2014).

What is noticeable and specific to the construction literature (compared to the general literature) is the more extensive range of skills and different classifications that are referenced, i.e. it is much more difficult to categorise each skill. Skill classifications are either very general, such as ‘high level skills’ (UKCES 2013) ‘high quality skills’ and ‘craft skills,’ or the other end of the scale, in reference to a specific type of construction (Gann and Senker 1998). As indicated by the above classifications, there are many different methods to classify the vast range of skills employed across different sectors. As a consequence, greater clarification of various skills terminology and meanings are required (Markes 2006). The focus of the next section is thus on the key skills required for the delivery of construction projects.

2.3.3 The required skills for the delivery of a construction project

More specific to the research that looks at skills required within the construction sector, there are a number of investigations that have a particular focus at the project level. The research at this unit level ranges from new build to retrofit projects, and refers to the various skill classifications described above in connection to the skills needed. The two dominant skills of focus within the construction literature are 'project management skills' and 'communication skills,' where the skill classifications discussed above (generic, specific, new, existing, hard and soft) can be connected to each of the skills (i.e. different authors state different classifications within project management skills and communications skills). Each type of skills will be described and critically reviewed in turn:

Project management skills

An emphasis on the requirement and use of 'project management skills' within construction projects is dominant to the discussions within the construction skills literature (Chen et al. 2008, Osmani and O'Reilly 2009, Hwang and Ng 2013, Zhang et al. 2013), where investigations seek to provide details of what the skill consists of. The importance of recognising the range of skills and fundamental knowledge associated with a project management role is highlighted (Dogbegah et al. 2011), and the identification of the potential for training to gain, or further develop, the required project management skills (Crawford et al. 2006). The challenge of defining project management skills is demonstrated within the literature. The value of gaining insight into the details of what project management skills consist of is stated (Fisher 2011), but due to the intricacies of different projects and roles of a construction project manager (Dainty et al. 2005a), this task can be difficult. This issue of describing the actual skills required for a project management role, due to a lengthy definition that encompasses the activities carried out, is emphasised by the International Project Management Association (IPMA), who state that "Project Management is the planning, organising, monitoring and controlling of all aspects of a project and the management and leadership of all involved to achieve the project objectives safely and within agreed criteria for time, cost, scope and performance/quality. It is the totality of coordination and leadership tasks, organisation, techniques and measures for a project. It is crucial to optimise the parameters of time, cost and risk with other requirements and to organise the project accordingly" (IPMA 2006: 128). The definition brings attention to the complex nature of the project management role and difficulty of explaining the vast amount of skills it may entail.

In an attempt to simplify the ideas surrounding project management skills, literature suggests that project management skills can be known as either 'technical skills' (involving technical expertise) or 'behavioural skills' (Dainty et al. 2005b). In contrast, project management skills can also be categorised into 'people skills, and the technical skills are associated to information technology (IT) and finance skills (Loo 2002). The technical skills appear to be vague within the literature, possible links to a knowledge of equipment or an expert in a technical system, whereas behavioural skills and people skills focus on 'leadership skills,' 'communication skills' and 'team building skills' (Loo 2002, Dainty et al. 2005b). It is important to note that communication skills are highlighted as the foundation for many other project management skills, i.e. communication is required for many of the project management skills to be effective (Dainty et al. 2005b). Project management skills can also be classified as both 'hard skills' and 'soft skills'. Hard skills, also known as the more traditional 'objective skills' (Ingason and Jónasson 2009), are associated with the technical knowledge required for the project, such as knowledge of the technology (Thamhain 2016), its implementation or the required tools, and further described as more recognisable due to its association with project performance. Whereas soft skills, or 'human skills' (El-Sabaa 2001), surround the management of the project (APM 2012) and key attributes of a project manager (APM 2014), which enable social interaction, the building of relationships and engagement with project stakeholders. Furthermore, linked to the management of the project, there is reference for project management skills to include the ability to control the budget, schedule and duration of the project (Winch et al. 1998, Thamhain 2016). It is unclear, however, whether tasks such as the management of the project budget and project duration are classified as hard skills, soft skills or a combination of both. Furthermore, previous research places an emphasis on 'specialist skills' that are tailored and essential to particular construction projects (not solely specific to project management roles) (Edum-Fotwe and McCaffer 2000, Briscoe et al. 2001). Much of the recent construction skills literature, however, suggests that due to little empirical evidence, there is a need to understand further detail and focus on the required 'soft project management skills' or 'subjective skills' (Ingason and Jónasson 2009) (e.g. leadership and social interactions) (Zhang et al. 2013).

In addition to the importance of understanding the specific type of skills, the ability to apply these skills is essential for an effective project manager, where both learning and experience are the vital components to gain the necessary project management skills (Odusami 2002). The emphasis on the need for experience is also important due to changes in demands and tasks for a project manager (Edum-Fotwe and McCaffer 2000). There are discussions associated with the need for 'new skills' that are connected to the experience gained through the changing project manager roles, and the requirement of skills that are specialist to a project manager role. The literature indicates, however, that the majority of project management skills required are 'existing' to the construction sector.

Even though literature attempts to distinguish a hierarchy and different classifications of associated skills (e.g. hard skills, soft skills, technical skills, and the importance of specific skills and expertise for a construction project), recent investigations indicate project management skills can be host to an entire range of skills (El-Sabaa 2001, Chen et al. 2008), which further complicates the idea of what these skills consist of. Ingason and Jónasson (2009) expand this idea to suggest that, due to the constant development for the project management position and duties of project manager, it may be impossible to understand the exact skills required and associated knowledge for a project management role.

Communication skills

As stated above in connection to a project manager role, and further indication as an aid to the development of project management skills, prevailing construction skills literature draws attention to the importance of 'communication skills' within a construction project (Egbu 1999, Chen et al. 2008, Fisher 2011), also known as a key 'soft skill,' 'behavioural skill' or 'people skill'. Communication skills are viewed as the capability to exchange information through the building of relationships (e.g. staff, client and supplier relationships) (IFF Research, 2011), where there is the need for the communicator to value and be aware of the receiver of information (Siriwardane et al. 2015). The current work investigating communication skills also focuses on the need to achieve 'effective communication' (Benson 2014, Janthon et al. 2015) and be aware of 'appropriate communication' (Siriwardane et al. 2015). Effective communication can also be known as 'communication management,' which is proposed a key element for construction projects, specifically for a project manager to inform all members of a project (Hwang and Ng 2013). Wang et al. (2016) expands the need for communication skills to provide information, referred to as information diffusion, not only to the construction sector, but all project stakeholders (e.g. clients and members of the public affected by construction projects). Similarly, Butt et al. (2016) mentions the more successful construction project outcomes occur where effective communication is gained through project stakeholder engagement, although this task is not without its challenges. There are further discussions around the requirement for 'active listening' (Fisher 2011) associated with communication skills, which indicates possession of the skill and a two-way communication responsibility (i.e. both the communicator and the receiver require communication skills). Furthermore, even though the distinction and meanings of the following terms can be vague, communication skills are closely connected to 'interpersonal skills' (Benson 2014) and 'social relationships' (Wang et al. 2016), emphasising the need for an ability to build relationships through forms of communication. Interpersonal skills are part of the broader 'social skills' classification, however, both are associated with an exchange of information (Riggio 1986), which draws attention to a communication skills relationship.

The construction skills literature places emphasis on the dominance of project management skills for a construction project, and further connection to the need for communication skills within the project management role. Emphasis is given to the success of communication by the project manager and those involved in the project to assist, and possibly underpin, a number of existing project management skills (Dainty et al. 2005a, Dainty et al. 2005b). Similar to the current project management skills thinking, literature also evidences communication skills are essential attributes of those involved in the construction project (Construction Skills 2010). Regardless of whether referring to a project manager or a different job role within the project, fundamental training to develop communication skills is encouraged (Loo 2002, CIOB 2013). It is worth noting, in terms of general skills training for the construction sector (no 'general' skills have been stated specifically), once the required skills have been identified, there are further complications to actually achieving training, which is due to appointing those responsible within the project or firm to provide the skills (Dainty et al. 2007).

A great deal of information has been presented in regards to the dominant skills, such as project management skills and communication skills, for construction projects. There has been little insight, however, to the value of other skills required by the construction sector and possibly its clients. The requirement of knowledge surrounding the project, the type of methods, tools or practices, for example, may require communication skills, but further additional research skills. Similarly, the hard skills associated with project management skills may be insufficient to understand a piece of technology adopted for the construction project, and training may be essential. Moreover, the descriptions offered to gain an understanding of the dominant skills provide little information in terms of skills definitions. Whether the required hard technical skills involve the use of technology (contrasting views within the literature), for example, or the type of knowledge required to develop project management skills. Similarly, the literature offers complex ideas in terms of whether technical skills are related to 'expertise' associated with renewable technology, IT or computer management systems. The identification and more concise definition of the required skills dominant to the construction literature, may draw attention to the requirement of skills other than project management skills and communication skills for the construction sector and its clients. There are also brief references to stakeholders of construction projects, but little information on the actual skills and how clients of the construction sector may embark on gaining these skills. Furthermore, there is a lack of explanation on how to gain effective communication, if it even exists with the communication skills bracket. To reiterate the ideas within the existing literature, the focus on skills is predominantly those required for a construction project, which highlights the dominance and broad meaning associated with project management skills, and lists a number of possible interrelated skills and areas of knowledge. The requirement of communication skills, both for a project manager and project stakeholders, is given purchase within previous investigations, but complexity is evidenced where communication needs to be 'effective,' 'appropriate' and recognised as a skill by both individuals interacting (e.g. the communicator and the receiver of information).

In contrast to the emphasis on specific skills, there are investigations that focus on more general skill challenges for the construction sector. Literature suggests, due to a number of different influences (MacKenzie et al. 2000), the UK construction industry often suffers from a shortage of skills (Chan and Dainty 2007, CIOB 2013), and there is a demand for an up-skilling of the workforce. The vital need to recognise a 'skills shortage,' and further understand the driving forces for this occurrence, can be linked to the influences of policies and advice required to introduce the possibility of training (Shah and Burke 2005). The term 'skills shortage' is explained as different to the term 'skills gap,' although in some cases both terms are used interchangeably (Shah and Burke 2005). A shortage of skills is connected to an insufficient supply of labour for the required skills (i.e. looking to attract workforce to the construction industry) (Bayliss. R 2015), which can be divided further by 'new skills shortages' (i.e. a new, emerging piece of technology has been introduced) and 'recurrent skills shortages' (i.e. associated with skill deficiencies in existing trades) (Green and Owen 2003). In contrast, a gap in the skills implies a sufficient supply of labour, but a lack of the correct skills (i.e. the need for training and potential new skills) (Bayliss. R 2015).

2.3.4 The skill requirements at a geographical level

Furthermore, there are investigations that tend to concentrate on skill requirements at a geographical level for the construction sector. Specifically in relation to house building, Ball (2005), for example, states the need to address skill shortages and variations at regional levels. The work explains the problem is due to the differing characteristics, assets and demands of regions (e.g. facilities, wages) (Ball 2005). Similarly, Killip (2008) and the Local Government Association (2013b) acknowledge the demand to tackle issues surrounding a lack of appropriate skills in regions. To address these skills shortages at a regional level, there is the need for effective regional strategies (training, skills and workforce development) (Dainty et al. 2004), and the encouragement of connections and actions between regional actors, such as government, regional development agencies, local authorities and clients (Glass et al. 2008). Furthermore, literature indicates the demand for human capital, i.e. skilled labour and appropriate skill sets for growth in employment, but on a wider geographical scale and broader than the regional boundaries. These literatures surround discussions associated with the development of skills in connection to sustainable communities (Dixon 2011) and indications of the link to sustainable cities (Eames et al. 2013).

Even though the prevailing literature is explicit in terms of acknowledging the challenges of skills shortages at a geographical context, there is little information in terms of the type of skills that are absent within the construction industry, i.e. project management skills, communication skills or technical skills. The discussions surrounding a skills shortage both within the construction sector and on a regional basis, indicate the skills required are available and existing, but there is a lack of labour or insufficient workforce to provide these skills. The mention of problems resulting from regional characteristics, for instance, further supports the need for the construction sector to gain similar skills (to other regions) that are of an existing nature. The use of the term up-skilling, however, does suggest an element of an enhancement in learning. Similarly, suggestions of the requirements to use different technology and integrate knowledge and skills connected to sustainability, indicates possibilities of skill development and the introduction of understanding new equipment, technology or materials. The development and implementation of technology, and the drive for sustainability in the built environment can often be connected to the need for energy reduction within buildings. These pressures are associated with the need for the construction sector and its clients to recognise the demands and deliver LZC buildings, which is discussed in the next section.

2.3.5 The skills required to deliver low and zero carbon buildings

The skills required to deliver LZC buildings can generally be grouped into 'new skills', 'green skills' and 'low carbon skills'. Each of these skills will be discussed in turn.

First, the need for 'new skills' for the delivery of LZC buildings has been recognised (DCLG 2006, Construction Skills 2010, Home Building Skills 2010). There is little definition and vagueness within the literature surrounding the meaning of what a new skill consists of. There are indications that new skills are linked to the changes occurring surrounding the building design and construction (Home Building Skills 2013a), for which an 'up-skilling' of the workforce is required (HM Government 2010, Home Building Skills 2013b). Furthermore, the requirement of new skills to deliver LZC buildings does not solely apply to the construction sector, but its clients involved during the development and the implementation of LZC buildings (SDC 2010). Many sources that state the requirement of new skills for the construction sector and its clients are sector skills councils (e.g. Home Building Skills and Construction Skills) who act as training providers. The interests of the skills councils, recommendations provided and methods employed are questioned. The Construction Skills (2010) offers little information on how the research was conducted, whereas Home Building Skills (2010) states the construction sector were questioned (focus groups and surveys). There is also little definition of terms referred to during the research, which may complicate the verification of findings, such as an individual participant's understanding of terms discussed.

Second, there is a requirement of 'green skills' (Bird and Lawton 2009, SDC 2010, Energy UK 2014) for the construction sector and its clients for the delivery of LZC buildings, and further connection of these skills to the adoption and the use of renewable technology (Aldersgate Group 2009). Green skills are described as a "broad understanding of the changes needed from businesses to reduce their emissions" (Bird and Lawton 2009: 8), with no discussion of what the 'changes' are. A green skill can also be categorised as 'generic,' (Bird and Lawton 2009), which differs from the meaning by Energy UK (2014) that indicates a green skill is more specialist in nature, due to its association with training the construction sector, as job roles, such as energy assessors and installers, require the appropriate skills. The requirement of training also implies green skills are not solely existing in nature, but there is also a need for new skills within the sector. Furthermore, a case study by the Sustainable Development Commission (2010) highlights the demand for green skills, with an explanation of the need for training being targeted to specific regions, and particular schemes created by an energy supplier. A green skills centre, for example, was created to enhance the skills of the local area (Energy UK 2014). It is also of value to highlight the construction skills literature that states the required skills associated with the delivery of LZC buildings, but does not specifically refer to these skills as green skills. Xu et al. (2015), for example, investigates the retrofit of hotel buildings using methods to enhance the energy efficiency of the properties. The investigation highlights the need for 'technical skills' for the construction sector and, even though there is no specific reference to green skills, there are indications the technical skills are related to the use and understanding of the 'advanced technology' for the retrofit of the buildings (Xu et al. 2015).Similar, in terms of implying a need for technical skills associated with the adoption of energy efficient measures (EEM), is the work by Gooding and Gul (2016). The investigation findings extend further and stress the need to gain an understanding of the policies surrounding the retrofit LZC buildings, which is referred to as a skill that requires a 'high level of expertise' (Gooding and Gul 2016). There is no mention of the required skills or knowledge being those of green skills, however, the 'expertise' employed by the construction sector are linked to the development of LZC buildings. Further concerns in terms of understanding the policies, energy plans and knowledge of how to actually achieve LZC buildings were found during a study by Caputo and Pasetti (2015). Again, similar to the above investigations, there is no indication that the challenges and required understanding of the building energy regulations are known as green skills. As a consequence of the diverse views and speculation of whether green skills actually exist, complications arise with regards to understanding the exact meaning and type of skills associated with the green skills classification.

Finally, there is a demand for 'low carbon skills' (RIBA 2008, HM Government 2010, Jagger et al. 2012) for the construction sector and its clients. Low carbon skills are defined as "knowledge, skills and competencies that support the design and delivery of low carbon new buildings and low carbon refurbishment projects" (RIBA 2008: 4). Furthermore, there is the link of low carbon skills to buildings, and reference to understanding the principles and practices for LZC buildings to carry out tasks, such as energy assessments (RIBA 2008). The Royal Institute of British Architects (2008) pay attention to buildings and more specifically the design stage of the building process, due to the interests of RIBA being architects and the target audience. There is further reference, however, to the need for low carbon skills for the procurement and construction process (economics of procurement and commissioning of buildings). For a more detailed account, Construction Skills (2011: 5) state low carbon skills are "…the skills and knowledge that support the planning, design and construction of new buildings and the refurbishment, redevelopment, management, use and ultimately disposal of existing buildings, which have the lowest possible carbon dioxide emissions taking into account of relevant constraints and regulatory requirements." Construction Skills (2011) emphasise the need for low carbon skills beyond the construction process, such as the management and use of retrofitted LZC buildings, which indicates the requirement of the skills for both the construction sector and its clients (e.g. end-users and facilities management). Although not specifically stated, the literature does indicate low carbon skills requires 'new skills' with the need for learning, but there is also the possibility of 'existing skills' needed by the construction sector (RIBA 2008). To cause further confusion, the required existing skills within low carbon skills are known to be the 'generic' skills, which also require enhancement (Aldersgate Group 2009). Further support is given by the Department for Business Innovation and Skills (HM Government 2010), who state low carbon skills are a combination of existing and new skills for which training is required, with little information provided on the type of training.

To further complicate the subject and to add to the uncertainty surrounding the required skills for LZC buildings, there is literature that simply states a requirement of 'skills,' both old and new. There appears to be a demand for knowledge of LZC technologies (Killip 2008, CIOB 2013), the understanding of green legislation and carbon management (Construction Skills 2010), professional skills (planners, urban-designers), skills and understanding required to market LZC homes (Zero Carbon Hub 2010a, Zero Carbon Hub 2010b), and environment and sustainability skills (CIOB 2013).

The construction skills literature specific to the delivery of LZC buildings emphasises the need for a new skill. Whether the skills be referred to as a green skills and / or low carbon skills, there is a connection to enhanced knowledge in the area of LZC buildings and, skills for the development and implementation of materials and technologies associated with these buildings. Even though there is a vague definition of what this new skill consists of, the link to the requirement for the construction sector and its clients to embark on an element of learning / training to achieve this new skill is highlighted. In comparison to new skills, green skills, low carbon skills and skills specific to LZC buildings capture the need for existing skills, possibly an enhancement of these skills, to deliver the projects. The further development of marketing skills, for example, such as the learning of different approaches to the marketing of LZC buildings.

The discussion of new skills, green skills and low carbon skills, along with little detail of what the skills consist of, highlight the need to focus on understanding the type of skills required by the construction sector and its clients, questioning whether the skills are existing, new, or a combination of both. The construction skills literature has contrasting definitions (or none at all) of a 'new skill,' a 'green skill' and a 'low carbon skill.' Furthermore, there is a lack of clarity of how a 'new skill' differs from the 'extremely broad' concept of a 'green skill' (Construction skills 2011) or 'low carbon skill,' and a vagueness of which (or all) is required to deliver LZC buildings. Even though there is little explanation surrounding the exact skills needed, the demand for LZC buildings is evident. It is important to briefly discuss the methods that can be employed to deliver LZC buildings, which may give indications on the type of skills required. The next section will introduce the term LZC buildings and elaborate on the number of ways in which the energy efficiency of buildings can be enhanced during the delivery of LZC buildings.

2.4 Low and zero carbon (LZC) buildings and the adoption of energy efficient measures (EEM)

As stated in chapter 1, the definition of 'zero carbon' is constantly changing, which relates to a lack of clarity surrounding the meaning of 'low and zero carbon' and hence, 'low and zero carbon buildings'. Certain debates for LZC buildings can relate to the type of emissions that are included, the energy source and the means of carbon reduction employed within, or surrounding, a building. At the time of writing, the achievement of a zero carbon building includes a form of fabric improvement to enhance building energy efficiency (see below section 2.4.2), on-site LZC heat and power (both in-line with Part L Building Regulations) and the use of allowable solutions (Zero Carbon Hub 2013). The vagueness surrounding a zero carbon building, the exclusion of unregulated energy use in the definition, and the use of LZC heat and power, highlights the potential difficulties of achieving zero carbon and complexity surrounding the term LZC buildings. The investigation seeks to study the delivery of LZC buildings, and states it is a building that has improved its energy performance to reduce a proportion of its energy use and carbon emissions, or its carbon emissions from energy use are zero.

Justification lies in-line with the current meaning attached to the term zero carbon and the possible challenges associated with the achievement of zero carbon and LZC buildings. Furthermore, it is valuable to the investigation and the LZC buildings justification to note the improvement of energy performance for buildings recognises both the application of fabric and technology (see below), in order to meet current regulations and guidelines.

When trying to achieve LZC buildings, it is suggested one of the first considerations should be an improvement in the energy efficiency of the building (EST 2010a), i.e. the adoption or implementation of an EEM. An EEM is a method or device that can be employed to save energy within a building (The Carbon Trust 2015). The Energy Saving Trust (2015a; 2015b) suggests an EEM can be a type of fabric or technology applied to the building, and further energy savings can be achieved through behavioural change, e.g. energy awareness and energy education.

The types of EEM can be assigned to one or more of the following:

2.4.1 Energy awareness

The raising awareness of energy use, the provision of energy information effectively and encouragement of 'pro-environmental behaviour' (Steg and Vlek 2009) are of value, and required as part of wider action plans to change energy use behaviour (Owens and Driffill 2008). There are a number of methods that can be employed to raise energy awareness and change behaviours within and around a building. The methods can range from simple measures (e.g. the use of signs) to more advanced measures (e.g. the provision of energy education through lessons and activities). The Energy Saving Trust and the Carbon Trust are two of the largest organisations helping to provide resources to inform and raise awareness for the availability of EEM for buildings, for both the construction sector and its clients. For education in relation to the adoption of an EEM, for example, The Energy Saving Trust (2015b) launched a database during 2015 consisting of a wide range of energy saving products (e.g. home appliances and lighting). Each EEM within the database has been endorsed, and verified, to provide information and advice regarding the most appropriate measure for the building and end-user. It is not always the case, however, where solely the provision of information encourages energy awareness and behaviour change. The development of a strategy that has assessed the many factors that affect behavioural change, such as motivations and human reasoning behind actions, can encourage effective behavioural change (Steg and Vlek 2009). In connection to the motivations behind behaviours associated with energy use, the work by Linden et al. (2006) indicates a strong link between the financial benefits and initiatives towards the adoption of an EEM. Furthermore, the investigation touches on a concern by end-users surrounding the requirement, or possibly lack of, user-friendly technology (Lindén et al. 2006), which suggests information to end-users plays a vital role.

Research suggests that end-users are paying more attention to energy efficiency within the home and EEM are being adopted, or have an interest in being up taken, at a greater rate than 10 years ago (EST 2015a; 2015b).

2.4.2 Fabric improvements

It is advised by the Energy Saving Trust (2010b) the need to improve the building fabric, providing measures such as loft and cavity wall insulation for instance, prior to installing technologies within the building. Insulation is one of the more widespread measures adopted and can be implemented within the loft, walls (internal and external) and floors of a building. A range of materials can be applied to the building for insulation. Loft insulation, for example, is usually fitted with a rolled material or insulation boards, where both methods can vary in type (mineral, fibre materials) and thickness fitted. Wall insulation material varies by the type of wall (internal / external), the installation method (solid / cavity) and thickness required.

2.4.3 Glazing

Single glazed windows can be upgraded to either double or triple glazed, and can vary by the type of glass, the gas within the glass and the material of the frame surrounding the glazed area to provide an energy rating of A to G (EST 2014b).

2.4.4 Lighting

Lighting upgrade within a building can refer to lighting systems, various building fittings, and controls within and surrounding the building. Incandescent and filament bulbs can be replaced with more efficient compact fluorescent lighting (CFL) or slightly more expensive light-emitting diode (LED) bulbs. By using energy efficient light bulbs it is possible to significantly reduce the wattage (up-to a quarter of the original), but still achieve the same brightness. Energy efficient light bulbs can last longer than incandescent light bulbs and use less energy, hence a cost-effective measure to reduce building energy consumption.

2.4.5 Low and zero carbon (LZC) technologies

The definition of a LZC technology within the literature varies with different actor perspectives. The EST and NHBC, for example, suggest LZC technologies can be part renewable and fossil fuel, and focus on the input and output to describe the technology. In comparison, Boardman et al. (2005) focus on whether the technology is implemented within or surrounding the building. This review will adopt the broad definition by Bevan and Lu (2012: 3) where a LZC technology is defined as “a technology that can provide heating, cooling or power (or a combination of outputs) and will be powered solely by renewable energy (zero carbon) or powered in part by fossil fuels (low carbon).”

There are a number of low carbon technologies that can be applied to buildings, some are more suitable than others depending on the building energy use, occupancy, building type and its surroundings. It is recommended that this type of EEM is usually the last to be considered, as many technologies allow the building to generate their own energy. There are specific technologies that are more dominant than others.

As evidenced within the literature, there are a number of options to consider for the reduction of building energy consumption, whether it involves changing the behaviours of building occupants, implementing fabric methods or integrating technology within the property. As well as the considerations of how to achieve LZC buildings and potential challenges (i.e. the choice of most appropriate EEM and the possible issues surrounding skills), the construction sector and its clients are required to recognise the additional pressures at the individual building level, local and regional levels and sustainable community demands (see sections 1.1 and 1.2). To further understand how these demands can challenge the delivery of LZC buildings, a regional level of analysis is required. The next section introduces the regional innovation systems (RIS) theoretical framework that is used within the investigation, and further explains the RIS key ideas and concepts.

2.5 Regional innovation systems (RIS)

To investigate the skills required by the construction sector and its clients to deliver LZC buildings within a region, a regional innovation systems (RIS) framework was adopted. The literature reviewed recognised the demand, and provided insights, into the delivery of LZC buildings. However, as policy pressures are at the individual building level, regional level and broader sustainability demands, the focus of the investigations offered partial accounts of how the construction sector and its clients can deliver LZC buildings. Furthermore, previous work indicates an issue in relation to the skills required by the construction sector and its clients to deliver LZC buildings. There appeared to be a lack of clarity within the existing literature surrounding the demand for ‘new skills’ and the identification of what the skills are. The research required the identification of key actors, processes and interactions to gain an insight into how LZC buildings are being delivered, the skills required and any challenges experienced by the construction sector and its clients. As explained below, the application of the RIS framework can guide the investigation in terms of what is required to address the gaps within existing research.

2.5.1 A regional innovation system

The RIS literature highlights innovation within a region and its innovative performance is connected to the surrounding RIS, i.e. the characteristics of the region and RIS (Doloreux 2002). Through the exchange of information, knowledge production and learning, a RIS generates a number of benefits both within a region and to the surrounding areas (Cooke et al. 1997, Chung 2002). The development of a RIS, or the building of a strong RIS, for instance, is linked to the improvement of economic activity, enhanced competition (Coenen and Díaz López 2010), social benefits within the region, and sustainable advantage (Wang and Eames 2010, De Laurentis et al. 2011).

There is no consensus within the literature to the exact definition of a regional innovation system. Definitions vary by including a range of core characteristics, components, functions and individuals or groups of individuals within a RIS, as argued by the authors below. There are a number of ways to categorise each definition, however, it is evident a RIS is predominantly defined by describing its actors, processes or stating its boundaries. Each definition is discussed in turn.

Doloreux (2003: 70) for example, defines a RIS as:

"A set of interacting private and public firms, institutions, and other organizations functioning according to organizational and institutional arrangements and relationships conductive to the generation, use, and dissemination of knowledge."

This definition describes actors and functions that are incorporated within a RIS. The sole emphasis on knowledge as a function or processes that occur around knowledge within a RIS, indicate this is key to the system. The work by Doloreux (2003) focuses on knowledge and its provision through interacting actors, suggesting a RIS cannot function without these elements (actors and knowledge).

Similar to this definition is that by Cooke (2004: 3) who defines a RIS as:

"Interacting knowledge generation and exploitation subsystems linked to global, national and other regional systems for commercialising new knowledge".

Cooke (2004) identifies a core characteristic of a RIS being that of interaction, not only within the region but also to external links. To gain or acquire knowledge by a RIS is also key within this definition by Cooke (2004), which explains the need for interactions on a number of scales.

Furthermore, a RIS definition suggested by De Laurentis et al. (2011: 7) consists of:

"A set of institutions, both public and private, which produces pervasive and systemic effects that encourage firms within the region to adopt common norms, expectations, values, attitudes and practices, where a culture of innovation is enforced and a learning process is enhanced."

This description of a RIS emphasises the importance of institutions within the RIS and, common to the research and findings by De Laurentis et al. (2011) and Wang and Eames (2010), the role of institutions for localised learning within the region. The definition focuses on actors and their contribution and various effects to the region and RIS, which connects to the idea surrounding the need to recognise regions as 'purposive actors' (De Laurentis et al. 2011).

In contrast to the above definitions, Chung (2002: 487) states a RIS as:

"A complex of innovation actors and institutions in a region that are directly related with the generation, diffusion, and appropriation of technological innovation and an interrelationship between these innovation actors."

Chung (2002) specifically uses the term 'innovation actors', stating the importance of their activities, such as interactions for interactive learning and innovation. Furthermore, there is a separation of actors and institutions, which suggests institutions may still be actors but not in terms of innovation, solely a support of innovation. The definition by Doloreux (2003) does not differentiate between firms, institutions and organisations in terms of innovation, which further compares to the definition by Cooke (2004) that does not specifically discuss any key actors within a RIS.

Similar to Doloreux (2003) a definition that links a combination of actors to knowledge, along with skills, for regional development is the definition by Paik and Ryu (2006: 4), which introduces a RIS as a:

"Network of institutions in the public and private sectors which creates, modifies, and disseminates new knowledge & skills needed for regional economic, social and organizational development."

In addition to definitions of a RIS focusing solely on actors and processes, there are authors (Asheim and Coenen 2005, Asheim and Gertler 2005) who highlight the boundaries surrounding a RIS. Asheim and Gertler (2005: 299), for example, state a RIS consists of "institutional infrastructure supporting innovation within the production structure of a region," where the RIS boundaries are the production structure (i.e. 'specialized suppliers' or subcontractors). There is indication that 'institutional infrastructure' is referring to public and private organisations within the region, such as regional governance, which enforce a 'regional culture' on the system (of influence by distinguishing specific values, norms and attitudes). Again, focussing on the boundaries, and perhaps more physical in this case, is the definition by Asheim and Coenen (2005: 1177) whereby a RIS is referred to as a “constellation of industrial clusters surrounded by innovation supporting organizations.” Both definitions suggest the boundaries act as a mechanism to support innovation, rather than a restriction or limit, and further, gaining an understanding of the boundaries (different structures, firms etc.) can be fundamental to generate innovation within a RIS.

It is relevant to touch upon the term ‘cluster’ as mentioned above by Asheim and Coenen (2005). The term can be described as similar to a RIS, where both can have similar aspects but should not be referred to as the same concept. Asheim and Coenen (2005) discuss how a RIS and cluster can belong to or function within the same territory (explained below), meaning they could both be within the same system. It is also mentioned, however, the key difference is that clusters are more focussed around the industrial sector, whereas there appears to be no one specific sector for a RIS. Charminade and Vang (2008) also highlight the term cluster within their work and state how the industrial clusters (or actors) extend further from firms, to customers and suppliers.

2.5.2 The characteristics of a regional innovation system

To gain in depth insights of the RIS for the research, the identification and understanding of RIS characteristics at greater detail is suggested. The RIS characteristics are considered as ‘elements’ and ‘mechanisms’ (Doloreux 2002), or components of the system (Autio 1998). This review has adopted the view by Doloreux (2002), but has incorporated the ideas of other authors to include the range of characteristics of a RIS. It is unclear as to whether all of the following characteristics are present, or whether they are the same for each RIS. Elements are discussed as the basic, more tangible aspects of a RIS, whereas mechanisms are the ‘dynamics,’ and intangible links between the elements to promote regional innovation (Doloreux 2002).

The four elements of a RIS (which may not be found in every RIS) are firms, institutions, knowledge infrastructure and policy-orientated regional innovation (Doloreux, 2002). The elements act as a support and to develop innovative activity within a system. Each element is discussed as follows.

Firms

A firm within the RIS can also be described as a ‘private-organisation’ (Doloreux 2004) or ‘economic agent’ (Doloreux 2002). Firms have the ability to aid the production of knowledge and transfer between various RIS elements (emphasis placed on interactions with other firms), and can be considered part of knowledge infrastructure (see below). There is no distinction between the entire firm and individuals within the firm, their interactions and significance to the RIS.

Institutions

An institution within the RIS can also be referred to as a 'non-firm organisation' or 'public organisation' (Doloreux 2002, Doloreux 2004). Key institutional actors are associated with universities, governments (particularly local authorities) (De Laurentis et al. 2011) and industrial R&D (Doloreux 2002). Institutions are similar to firms as they are also linked to knowledge infrastructure. It appears, however, institutions are connected more so to the transfer of information, (described as 'informational devices') (Johnson et al. 2002), not necessarily the transfer of 'knowledge.' Furthermore, institutions are associated with more formal roles within the system (Edquist 1997) and defined by their specific actions. The role of institutions within the learning process, specifically localised learning within the region (Wang and Eames 2010, De Laurentis et al. 2011) is key, as they can affect the entire innovation system, but through a number of different paths.

In combing both firms and institutions and broadening the definition, Chung (2002) introduces the term 'innovation actor groups' (also referred to as 'hardware' for the system), which are groups of actors from universities, industrial enterprises and public research institutions. The focus is on innovation actors and the criticality of them interacting and learning in order for innovation to occur within a region; with the development of a region being linked to the amount and type of innovation actors within it (Chung, 2002). The OECD (2010) refer to a similar term 'regional actors,' which include the entire range of stakeholders of a RIS, far broader than the 'innovation actor groups' term above. This literature review has adopted the term 'regional actors' as it is broader and can be of reference to the large range of actors involved within a RIS.

Knowledge infrastructure

Knowledge infrastructure within the RIS can be 'physical' and 'non-physical' infrastructure (Autio 1998, Doloreux 2002), and is presented as a support mechanism to the RIS for innovation (e.g. science parks), for the production of knowledge (e.g. universities and R&D institutions) and the diffusion of knowledge (e.g. advice units) between RIS elements. Physical infrastructure can be a support to produce knowledge flows and interactions within the RIS, whereas non-physical infrastructure can relate to organisational structure supporting knowledge (e.g. knowledge transfer). Knowledge infrastructure within a RIS aims to broaden knowledge generation and to include both tangible and intangible infrastructures that contribute to knowledge production within a RIS. Various roles can be derived from knowledge infrastructure and, as evident from the different types of infrastructure (universities, science parks), knowledge infrastructure can include a number of different regional actors within a RIS.

Furthermore, it is important to highlight the role of sub-systems involved with knowledge flow within a RIS. Two sub-systems are stated by Autio (1998), the knowledge application and exploitation subsystem, and the knowledge and diffusion subsystem, which interact with organisations to develop a RIS. Solely the physical components of knowledge infrastructure are discussed within the RIS literature.

Policy orientated regional innovation

Policy orientated regional innovation within the RIS can encourage and develop interactions between firms, institutions and knowledge infrastructure (Doloreux 2002). Policy orientated regional innovation appears to relate to components within the RIS that create policies and perhaps inflict them on actors within the surrounding RIS. The literature suggests policies within the RIS are linked to learning and knowledge diffusion between elements, with possibly the intention of policies being of benefit to the RIS.

There are four main mechanisms or dynamics of a RIS: interactive learning (Chaminade and Vang, 2008; Doloreux, 2002), knowledge production, proximity and social embeddedness (Doloreux, 2002). Each mechanism is discussed as follows:

Interactive learning

'Interactive learning' is defined as "the generation of learning between actors who participate in the innovation process" (Doloreux 2002: 249) and, "the acquisition of knowledge and competences through interactive collaboration with firms and knowledge providers" (Chaminade and Vang 2008: 1686). The above definitions emphasise learning as a process, which is primarily of an interactive nature (Lundvall 1992) that connects with knowledge, along with identifying interactions between various actors of a RIS. This mechanism is known as key to the innovation process (Simmie et al. 2002, Chaminade and Vang 2008), a primary characteristic of innovation in a RIS (Morgan 1997), and the 'centre of the RIS concept' (Doloreux 2002). The importance of interactive learning is emphasised as it is closely connected to the capability to innovate within a RIS system, i.e. an actor is thought to have an increased rate of innovation as there is increased learning and knowledge sharing (Doloreux 2002). This mechanism, however, requires further attributes for its success. Social capital, for example, is required within the process (Chung 2002, Chaminade and Vang 2008). 'Social capital' is connected to the values of society, and further links the relationships and interactions between people and institutions (Grootaert 1998). Trust, to encourage the formation of social capital between innovation actors, is also important for the process of interactive learning (Chung, 2002) to help build relationships between actors, potentially enhancing reliability and confidence towards information exchange.

Generally speaking, there are many links within the literature between learning and knowledge. There is an understanding that (interactive) learning can indicate the generation, production or output of knowledge. However, other forms of knowledge within a RIS, such as knowledge transfer or knowledge exchange, are also mentioned. RIS actors are primarily associated with interactive learning in order to gain or generate knowledge. More specifically, the interactions between firms and knowledge providers are emphasised within the RIS literature (Chaminade and Vang 2008). Knowledge providers appear to relate to any further elements in the RIS who generate or transfer knowledge within the system. It must also be noted that interactive learning, and possibly knowledge exchange, can be present, if there are no opportunities for it to be implemented, then it may be of no use to an innovation system or RIS (Morgan, 1997). It could be the case where interactive learning is taking place, but those gaining information or perhaps the knowledge they have acquired may not be aware of how to use it. In addition, the problem may lie with how information is passed, the connection, or whether it gets passed at all (Morgan, 1997).

Knowledge production

Knowledge production is described as one of the more complex mechanisms, and can take many forms, e.g. tacit and explicit knowledge. Tacit knowledge is defined as "knowing a thing by relying on our awareness of it" (Polanyi, 1962: 1). Polanyi (1962) states that tacit knowledge, which is a large proportion of a person's knowledge, is already embedded within an individual, group of individuals or in an organisation. Tacit knowledge can also be referred to as uncodified knowledge (Hall and Andriani, 2003), as it can be deep within the mind of an individual and cannot be communicated without "action, commitment, and the involvement in a specific context and locality" (Ernst and Kim 2002: 1423). Maskell and Malmberg (1999) discuss how tacit knowledge is important for competition between firms, and can increase competitive advantage, specifically as other forms of knowledge (such as knowledge that has been codified and therefore more easily tradable) become available. Maskell and Malmberg (1999) further emphasise the importance of knowledge creation in connection to a learning process (mainly problem solving), and very often there are elements of social interactions (Maskell and Malmberg, 1999). Interactions may also be considered a form of knowledge transfer, as knowledge maybe transferred from one person to another or from one form/type of knowledge to another. Howells (2002) also associates the generation of knowledge by learning, stating that knowledge can be using what one may already know, but there may be the need to generate other forms, for example, learning from others, for the innovation process. The literature suggests that knowledge is less organised or unstructured when compared to the process of learning (Doloreux, 2002; Maskell and Malmberg, 1999), this may be due to the complexity of the different types of knowledge (generation, transfer, sharing). It is unclear whether knowledge is encouraged to be generated by an actor, for example, or transferred or shared between different actors (i.e. there is no definite method that is promoted for innovative activity).

Further to the focus on knowledge production, primarily by the RIS literature, the general innovation literature brings attention to the challenges associated with the management of knowledge. From the discussion within the literature, the management of knowledge refers to how an individual or organisation applies the knowledge produced for a particular function, primarily connected to an understanding of the knowledge, where the main objective surrounds the need for the knowledge to be shared or transferred. The above explanation appears clear and comprehensible, and there is also little acknowledgement in the RIS literature of challenges associated with knowledge following its production. The general innovation literature, however, highlights the possibility of issues concerning the management of knowledge. The difficulty of sharing tacit knowledge, for example, is highlighted and referred to as being 'spatially sticky' (Morgan, 2001) (linked to areas), in the context that it needs to be communicated through interactions on more of a personal level (Lundvall, 1992). The work by Fernie et al. (2003) also evidences the need for a form of interaction in order to share knowledge, and presents the complexities associated with the management of knowledge, primarily that of a tacit nature. Bresnen et al. (2003) further supports the challenges connected to the management of knowledge, evidencing a number of barriers, but also enablers, associated with the transfer and sharing of knowledge. In agreement with Fernie et al. (2003), social patterns, such as social networks and interactions, are key indications for the transfer of knowledge within the work place.

In contrast to tacit knowledge, explicit knowledge or codified knowledge, which is "knowledge that has been captured in a code, or a language that facilitates communication " Hall and Andriani (2003: 145), is suggested to be more easily available. Being codified, it can be stored and retrieved or transferred from one source to another (Ernst and Kim, 2002: 1423), unlike tacit knowledge. Therefore, it is thought that tacit knowledge can be codified to become more explicit, allowing the knowledge to be easily transferred and shared. Koskinen et al. (2003), however, evidence the implications associated with tacit knowledge and sharing, and indicate a number of 'facilitators' are required, such as interactions and relationships, for the codification, sharing and successful management of knowledge. Moreover, Ernst and Kim (2002) state that explicit knowledge, even though appears more easily available, is only useful by those who have the knowledge of how to use it (e.g. the individual must have a form of tacit knowledge to be able to understand the explicit knowledge that has been communicated).

The above issues are raised as the management of knowledge literature brings attention to the challenges for the appropriate social setting for knowledge transfer (Fernie et al. 2003), the issues following knowledge production, such as different understandings, interpretations (Howells 2002), and the inability by individuals and organisations to use the knowledge produced (Ernst and Kim 2002). The above investigations (Ernst and Kim 2002, Fernie et al. 2003, Koskinen et al. 2003) offer insight into the issues surrounding knowledge production, the management of knowledge and what actions may be beneficial to encourage the transfer, sharing and diffusion of knowledge between actors. With the exception of the work by Bresnen et al. (2003), which states the need for 'personal skills' associated with the communication and building of social networks to enhance the sharing of knowledge, much of the management of knowledge literature provides little insight on the skills or further training for the ability to manage knowledge. Furthermore, in the context of the construction innovation and construction skills literature, there are indications that the difficulties surrounding the management of knowledge can have connections to the type of skills required for construction projects (i.e. project management skills or communication skills), or the delivery of LZC buildings.

In terms of insights from the RIS literature, a broad perspective of knowledge production is provided, which states the requirement for knowledge production within the RIS, and its further need for innovation within the region. Knowledge can be generated, diffused, shared and transferred in association with other mechanisms, for example, (i.e. the importance of links to interactive learning), but further required by RIS elements, such as firms and institutions, and regional actors. The ability to manage the knowledge produced, however, is very much taken for granted within the RIS literature, where the focus is on the need for knowledge production, as oppose to how knowledge is used following its generation, to predict and enhance innovation within a region. There is also little insight on the types of knowledge that can be generated or transferred within a RIS and region, and whether one form of knowledge is more complex in terms of its management in comparison to others (i.e. explicit vs tacit knowledge). Furthermore, the RIS work appears to be neutral in terms of little empirical insight into the skills associated with knowledge production. The links to the interactive learning mechanism are stated, and need for a method of interaction, however, there are few studies that demonstrate how knowledge is generated and skills required to integrate both mechanisms within the RIS. There is also a lack of recognition within the RIS literature towards the problems associated with the management of knowledge, and there appears to be insufficient empirical work on the possible skills required following knowledge generation. Information is needed to give insight on the management of knowledge within a RIS and the type of skills required, if any, following the production of knowledge. Can different types of knowledge, such as explicit and tacit knowledge for example, have an influence on the management of knowledge, and the skills required for the process (following the production of either explicit or tacit knowledge)? An understanding of the challenges for the management of knowledge would be valuable in terms innovation within a region, and provide further knowledge on the skills required for a construction project (i.e. project management skills and communication skills), and the delivery of LZC buildings (for both the construction sector and its clients).

Johnson et al. (2002) suggest that in order to gain a greater understanding of knowledge and details of how it may be stored and shared, it needs to be classified differently. It is proposed that knowledge can be grouped into four categories: 'know-what,' 'know-why,' 'know-how' and 'know-who' (Jensen et al. 2007). It is noted that they are usually explained at the individual level, but can be applied at other levels such as organisational (Johnson et al. 2002). In simple terms, 'know-what' refers to facts or information; 'know-why' is similar to codified knowledge in terms of it can be within the human mind or society; 'know-how' is whether someone has the correct skills to apply it to a task or job (theoretical and practical); and, 'know-who' relates to who the individual knows and how they communicate and interact with others (Johnson et al. 2002). The latter category of know-who is less clear within the literature.

With regards to analysing the performance of regional innovation across Europe, Wintjes and Hollanders (2010) refer to a region as being a 'knowledge based economy,' highlighting the access, absorption capacity and diffusion of knowledge a primary determinant. Furthermore the work demonstrates that knowledge can affect different regions in different ways, for example, poorer and wealthier regions. It is the relationship with knowledge and technology within the region that impacts on regional innovation and the economy, which in turn drives future policy (Wintjes and Hollanders, 2010). This is in contrast to Doloreux (2002) who stated interactive learning was the most important process to drive innovation within a RIS.

To summarise, the types of knowledge discussed above have a vital role to the innovation process. Its connections to other mechanisms within a RIS to develop them, along with innovation development, emphasise the need for knowledge production. Within a RIS, knowledge production can relate to knowledge being used, transferred and generated by elements. It is a fundamental requirement to be aware of the type of knowledge in order to understand how to use it (transfer, share or codify it). As highlighted within the prevailing literature, the management of knowledge, i.e. how it is shared or transferred following knowledge production, is a challenge that can be experienced by firms, institutions and various other actors. The RIS literature, however, does not provide insight on the processes involved, or further issues, in relation to the management of knowledge. As knowledge production is a key mechanism of a RIS, and knowledge transfer appears to be vital to regional innovation, an understanding around the management of knowledge is essential to gain information on the challenges associated with the delivery of LZC buildings. Examples of knowledge production can range from simple informal conversations, to more complex situations, such as project meetings surrounding the delivery of the LZC buildings. Furthermore, it would be of value to gain insight into the required skills for RIS actors associated with the ability to manage knowledge following its production, and whether the skills needed are associated with other skills, such as project management skills, communication skills or green skills.

Proximity

Proximity is defined as:

"The fact, condition, or position of being near or close, nearness, (of relation, in space or time, etc.)." (The Oxford English Dictionary 2007: 2385).

Proximity can be known as an ambiguous term due to its use by a variety of actors and within different contexts (Torre and Rallet 2005). It is used in reference, including but not exclusively, to the distance between actors, processes or objects. Proximity is also described as meaning 'near to' (Torre and Rallet, 2005). The term proximity with regards to its impact or context within a RIS is described in two ways: physical proximity (e.g. Doloreux, 2002) (geographical) and spatial proximity (Maskell and Malmberg 1999, Autant-Bernard et al. 2013).

Physical proximity (geographical)

The 'physical proximity' is the physical geographical distance (many instances referring to the area between firms or organisations), which is important to a RIS to enable communication and knowledge exchange (Doloreux, 2002). Simmie et al. (2002), for example, indicates the impact of geography on a RIS in terms of the proximity to resources, supply chains and attracting labour that have specific qualifications and knowledge. It refers to material objects or individuals which give the impression that a physical area is being discussed. Howells (2002) refers to the 'physical proximity' as 'geographical proximity' (geographical space). The focus is how proximity can affect the interactions with knowledge and hence innovation within an area, both directly and indirectly. How geography effects knowledge however, depends on the characteristics of the knowledge itself (Howells, 2002). Tacit knowledge, for example, may be more geographically contained as it cannot be easily transferred. This degree of 'tacitness' indicates the complexity associated with physical proximity (Morgan, 2001). In contrast, explicit knowledge has the potential to be 'free' and passed from the individual, firm or organisation more easily and hence, not strictly restricted to a specific area or region. The process of codifying the knowledge can indicate less influence or limitations by the geography of an area, i.e. the ability for knowledge to expand over greater regions.

Through the assessment of a RIS to create a guide for future policy, the Council on Competitiveness (2005) refer to innovation being a 'contact sport' to emphasise the importance of proximity. The discussion is around proximity being a crucial element for contact and interaction to be made between individuals, firms and organisations, with reference to the physical role and advantages of proximity. This is referred to as 'relative proximity' (Council on Competitiveness, 2005), yet this term could encompass both types of proximity above.

There is an emphasis on the geography of and within a RIS, the link to innovation and how it is formed (Asheim and Isaksen, 1997; Simmie et al., 2002). This is very similar to physical proximity as it discusses a tangible area, geographical distance or part of land. Geography, in terms of the area of the region, can affect the capabilities of that region, which are attractive to certain firms. This is linked to the work by Maskell and Malmberg (1999), who discuss localised capabilities. Firms will locate in areas where there are local capabilities; for example, natural resources, knowledge and skills, or a structure and environment attributed to that region that is desirable by a firm or organisation (Maskell and Malmberg, 1999). These capabilities described above are desirable to the firm with regards to competitive advantage, which are linked to the ability of a firm to enhance and upgrade its knowledge (Maskell and Malmberg, 1999). Howells (2002) as mentioned above, uses the term geographical proximity, however, the underlying argument of the work is linked to the geographical location or geography. It is the case where geography and geographical proximity are similar or used in the same context. In addition to the physical geography having an influence on a RIS in terms of it being more attractive, geography can highlight diverse characteristics within a RIS where two regions are different (e.g. rural and urban). However, it is also worth noting that a RIS can have differences even if the regions have similar features (similar structures, resources) (Doloreux, 2003). In contrast to the above arguments that geography is connected more to the physical space and proximity, Morgan (2001) suggests geography should be related to relational space. This indicates the role of interactions, communications and more intangible elements of the term.

Spatial proximity

The 'spatial proximity' refers to a distance between elements within and around a region or network, but is linked more to intangible or less physical actions, such as the exchange of knowledge and interactions (Maskell and Malmberg, 1999). Spatial proximity is highlighted by Autant-Bernard et al. (2013) when studying previous findings on local knowledge flows, and their impact on innovative activity. The evidence focuses on patent citations and the effect on knowledge flows regarding the distance from the region. It was found that the diffusion of knowledge with regards to patent citations did have an effect with proximity, i.e. local knowledge flows having a positive effect on the region. However, the effect of proximity is not as dominant as first perceived, due to many knowledge flows unable to be classed as local (many flows are outside the region) (Autant-Bernard et al. 2013).

The contrast between spatial and physical proximity is evident when discussed in terms of actors and the space between them during communication within a system (Maskell and Malmberg, 1999). However, it can be difficult to understand which 'type' of proximity is being discussed. In some cases the author does not make a clear distinction and refers to proximity in very general terms, or refers to both 'physical' and 'spatial' in the same context (Autant-Bernard et al. 2013) (this may be an indication of reference to the physical area and undefinable distance between two elements within the region). The direct and indirect influences of proximity may also be the source of difficulty in identifying the type(s) of proximity that is affecting a system.

Further references to proximity: relational and organisational proximity

Asheim and Gertler (2005) introduce the concepts of 'relational proximity' and 'organisational proximity' indicating the connection to knowledge within an innovation system, along with suggesting this type of proximity could be more important than the physical proximity. The term 'relational' implies actors, communications and their relationships is the focus (Hauser et al., 2007). Organisational proximity, employed in a similar if not the same context by Asheim and Gertler (2005), is used at more of a firm level to describe the use of a shared language or codes during practice (Morgan 2001). Both relational and organisational proximity may also be referred to as a virtual community (Asheim and Gertler 2005).

The justification behind the importance of proximity and how it affects other mechanisms (i.e. knowledge exchange and learning) is explained in two parts. First, at an individual level, it is suggested that as the distance of communication exchange becomes shorter between individuals, the process will be easier and cheaper. Second, in a cultural sense there will be greater trust and understanding between the individuals exchanging knowledge (Maskell and Malmberg 1999). For either explanation of proximity, the physical distance or in the cultural sense, there is the idea of a greater possibility of knowledge transfer and increased reliability of information. Both 'types' of proximity are required, there is not one more important than the other, however, it is key to examine how they both develop as learning, knowledge and interactions become complex (Morgan 2001). Further, proximity can be connected to the work by Todtling and Trippl (2005), which suggests the criticality of international, national and local links from a RIS to other systems and actors within them.

To summarise, physical proximity is associated with the geographical / physical distance between elements components (e.g. firms) within the RIS. Whereas spatial proximity appears to be identified with communications and exchanges between actors, indicating it relates more to the relationships of actors. Understanding the proximity between actors and processes will give insight into the distance and scale of communication and actions, such as local level interactions as oppose to interactions outside of the region. This research will adopt the more dominant types of proximity discussed within the RIS literature, both physical and spatial proximity.

Embeddedness

The term 'social embeddedness' or 'embeddedness' (Granovetter 1985, Lyons 2000), refers to relationships, social interactions or networks within a RIS (Doloreux 2002).

There is little on how to identify embeddedness within a RIS or how to distinguish the mechanism from others. However, the mechanism is linked to a greater rate of learning and exchanges within a RIS, which may help identify embeddedness surrounding the elements (Andersson et al. 2002).

2.5.3 Summary of the RIS theoretical framework

The prevailing RIS literature provides various insights of RIS elements and mechanisms, both detailed and vague, to offer a vision for the current framework and a description of how it can be applied to predict the innovativeness of a region. Figure 2.1 below, outlines the current understanding of the framework, created primarily from the work and ideas by Doloreux (2002). It is essential to stress that both 'elements' and 'mechanisms' can have several connections to each other, but there is little information for the identification of the connections and their link to RIS actor interactions (Doloreux 2004).

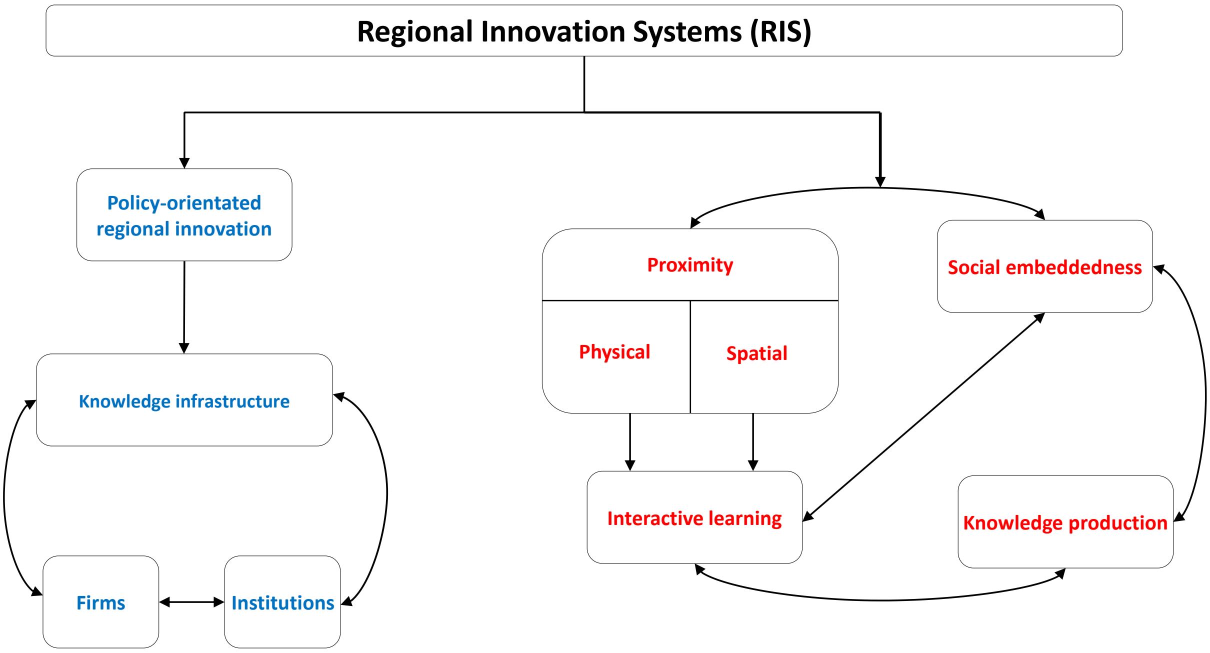

Figure 2.1: RIS framework (Doloreux 2002)

As shown in the RIS framework (figure 2.1), emphasis is placed on the connections that occur within each of the elements and mechanisms themselves, rather than between elements and mechanisms. The RIS literature focuses on the interaction between the elements 'firms' and 'institutions,' for example, and the role and influence of the mechanism 'proximity' to the mechanism 'interactive learning.' To add to the complexity of understanding the RIS framework, there are no indications that all four of the elements and mechanisms will interact together with the system. To highlight the key ideas from the RIS literature and explain figure 2.1, a short vignette of the RIS framework is provided:

The focus of the RIS framework surrounds both the elements and mechanisms (or components) of the system, how they connect and interact within and around the region itself. It is important to state the difficulty in defining a boundary of a RIS and region within the literature, and further, the analysis of a RIS should not be restricted to elements and mechanisms within the region.

RIS elements

The elements of a RIS are described as the more tangible components of the system, and are key to how the RIS and region develops. The ideas linked to the importance of elements for RIS development are associated with the support given through the production of knowledge within a region, where the elements, more specifically firms and institutions, play a key role in knowledge and information transfer. Firms are linked more so to knowledge production and knowledge transfer, whereas institutions are connected to the transfer of information. Furthermore, both firms and institutions appear to be part of the element knowledge infrastructure, which acts as a support for both the production and diffusion of knowledge within the individual firms and institutions (and possibly the 'regional actors' within these elements). Knowledge infrastructure is discussed in terms of both the physical and the non-physical components of the RIS elements, however, the physical functions of the elements are the focus within the RIS literature. The importance of facilitating interactions and knowledge flows between universities and science parks (i.e. the physical components), for example, are given more attention within the literature. Furthermore, the joining of all three elements (firms, institutions and knowledge infrastructure) is a fundamental characteristic of the policy-orientated regional innovation element. The value of the policy-orientated regional innovation element is emphasised through its ability to encourage interactions between the firms, institutions and knowledge infrastructure elements, as it creates policies for the RIS. It is important to stress that the RIS literature suggests the policies enforced are of value to the region, where there are connections made to elements and regional actors learning from policies.

RIS mechanisms

The mechanisms of a RIS are known as the dynamics of the system, as they are the more intangible, active components that appear to drive interactions within a region. The most detailed mechanism within the RIS literature is known as interactive learning, and a key component for innovation within a region (as highlighted by the number of connections to other mechanisms within figure 2.1). The primary emphasis of this element is the interactive concept, where learning is essential, but may not be as effective to firms, institutions and innovation actors without interaction occurring. To simplify the main ideas around interactive learning, it can be described as the mechanism that drives learning, linking learning to the generation and transfer of knowledge, to promote innovation within the region. In order for interactive learning to be successful (i.e. knowledge production and regional innovation), however, there is a need for a degree of social capital between the regional actors involved. Social capital is discussed in terms of relationships, which can encourage many other attributes, such as trust between firms, institutions and actors within the system. The mechanism knowledge production is known to be the most complex component of the RIS, however, there is a degree of clarity of its strong connection to the interactive learning mechanism. The complexity of this component surrounds the different types of knowledge that can exist (e.g. tacit and explicit), and whether discussions are linked to the generation, transfer, diffusion or sharing of knowledge. It is evident knowledge production is essential for a region to innovate, but the type of knowledge, how it can be used within a RIS and which is vital for regional innovation, is unclear. The mechanism proximity, which can be further separated into physical proximity or spatial proximity, is detailed in a number of previous RIS studies. Physical proximity is associated with the geographical distance between regional actors, such as the area of land between two firms communicating within a region. Whereas spatial proximity, the more complex of the two proximity mechanisms, denotes the more intangible separation between regional actors, in terms of relationships, trust and frequency of communication. There is an understanding that both types of proximity are strongly connected to the interactive learning mechanism and the social embeddedness mechanism, however, there is uncertainty over which proximity is more dominant and important to innovation (if any), as both are used interchangeably within the RIS literature. The further and last mechanism, social embeddedness, appears to be the least understood by the RIS literature and previous investigations. There is evidence embeddedness describes the relationships within the RIS, and further links to greater interactions and interactive learning through stronger relationships between regional actors within the system. To address the research aims and objectives, the RIS framework helped to identify the RIS surrounding the LZC building projects during data collection. The RIS approach provided further guidance during the data analysis as the framework indicates the value of exploring the roles of RIS actors (elements) and processes (mechanisms) in relation to the delivery of LZC buildings with the region, and possible insights into the skills required.

Chapter 3 Methodology

3.1 Introduction

This chapter will present the research methodology adopted for the investigation. The research philosophy and approach will be explained, the theory behind the adopted research methods, a detailed account of the research design and how the data was analysed will be described. The validation strategy employed for the investigation will also be explained.

3.2 Research philosophy: interpretive approach

There are a number of philosophies that can be adopted to guide empirical research within the built environment. Lee (1991) for example distinguishes between the adoption of a 'positivist' and 'interpretive' approach when carrying out research, both opposing views in terms of methods for data collection. The positivist approach is "objective and value free" (Brydon-Miller et al. 2003: 11), which suggests only what is observed and able to be verified is of importance in natural science (Gillham 2000). In simple terms, when using a positivist approach, assumptions or definitive ideas about the data are made prior to data collection. This approach is primarily adopted for use in experimental work or testing a hypothesis (Lee 1991). In contrast, an interpretive approach recognises that "people, and the physical and social artefacts that they create, are fundamentally different from the physical reality examined by the natural science" (Lee 1991: 347). This approach considers social elements that may have an effect on the research, such as people and their opinions, decisions and actions. The research is not led by a set of hypotheses, but has aims to be achieved to guide the research.

An interpretive approach, where the required knowledge is connected to the interpretation of a social setting (e.g. how human behaviours shape low carbon buildings and the skills surrounding them), was considered the most appropriate philosophy to adopt for this research. A positivist approach would be relevant if the research was seeking to test a cause-effect relationship, derive research findings from laws (Neuman 2006), or prove or disprove a hypothesise or set of criteria. A positivist approach also down plays human agency in regards to greater emphasis on external influences of human behaviours and actions. In comparison, an interpretive view encourages the capturing of social actions within the investigation and, as the approach permits a number of flexible data collection methods within the field, there was the opportunity to witness and understand human behaviour in the context of the research aims and objectives. Interpretive researchers, for example, can adopt a wide range of data collection methods. Such methods are more associated with qualitative data, to gain an in-depth understanding of social influences, and have the ability to explore further ideas that emerge during the fieldwork. The investigation has adopted the socio-technical network analysis (STNA) as methodology to guide the data collection. The key principals and how the socio-technical network (STN) mobilised the research framework, regional innovation systems (RIS) (see section 2.5), is discussed below.

3.3 Deductive-inductive approach to research

A mix of both deductive and inductive methods were adopted for the investigation (see table 3.1). First, a deductive approach was employed for a review of the construction innovation literature, which highlighted the policy pressures for the construction sector to deliver low and zero carbon (LZC) buildings. Recurring themes within the literature gave insight into a focus on specific skills needed within construction projects (e.g. 'project management skills,' 'communication skills' and challenges surrounding the management of knowledge), and further requirement of skills for the construction sector and its clients to deliver LZC buildings (e.g. 'green skills,' 'low carbon skills' and 'new skills').

Second, an inductive approach was adopted by the research during the collection of data within an empirical setting (e.g. interviews, observations and a review of relevant organisational documentation). The policy pressures for LZC buildings on the construction sector and its clients related to demands at the individual building level, local and regional levels, and wider sustainable community levels. Therefore, to gain knowledge and understand the challenges for the construction sector and its clients, there was a need to study the development and the implementation of LZC buildings at a regional level (i.e. the empirical work concentrated on innovation within a region). The inductive approach also allowed the research to become immersed within the social setting (five school retrofit projects) to explore the challenges associated with the required skills to deliver of LZC buildings. In addition, the approach permitted the identification of the type of skills needed to deliver the buildings, such as the possibility of new skills, green skills, project management skills, communication skills and further insight on the management of knowledge associated with project delivery.

Finally, the research applied a deductive method through the adoption of the regional innovation systems (RIS) theoretical framework, which was a guide during data collection and data analysis. The framework states the fundamental 'elements' and 'mechanisms' within a RIS to predict the innovativeness of a region. The investigation also applied the socio-technical network approach (STNA) to mobilise the empirical work (i.e. an indication of actors, interests and negotiations) and the production of network diagrams (the socio-technical network - STN). Both the RIS and STNA aided data collection and analysis in relation to understanding the required skills for the delivery of LZC buildings for the construction sector and its clients. Table 3.1 provides a summary of the application of the deductive-inductive concepts adopted within the research, the data collection and data analysis methods.

Table 3.1 research design – deductive and inductive methods

	Ontological phases		
	Deductive	**Inductive**	**Deductive**
Design stage process	• Policy pressures that demand the construction sector to deliver low and zero carbon (LZC) buildings. • Challenges surround the requirement of skills for the construction sector and its clients (e.g. 'green skills,' 'low carbon skills' and 'new skills'). • Literature also focuses on skills for a construction project ('project management skills,' 'communication skills' and the 'management of knowledge').	• The need to study the delivery of LZC buildings at a regional level. • Investigating five school retrofit projects, exploring the social setting to study the skills required by the construction sector and its clients. • Possible insight for the requirement of 'project management skills', 'communication skills' and 'green skills', and meanings associated with these skills.	• The research adopted a regional innovation systems (RIS) framework, which seeks to describe, explain and predict the innovativeness of a region, to investigate the delivery of LZC buildings at a regional level. • The research also applied the socio-technical network analysis (STNA) methodology to mobilise the empirical work (highlighted within the socio-technical network (STN) diagram).
	• A literature review of the prevailing construction innovation literature. • A focus on the response to the delivery of LZC buildings, and skills required by the construction sector and its clients. • A review and critique of general skills and construction skills literature, skills required for construction projects and skills specific to the delivery of LZC buildings. • A review of the possible types of energy efficient measures (EEM) in order to deliver LZC buildings. • A review and understanding of the RIS framework.	• Semi-structured interviews conducted with those involved in the school retrofit projects. Twenty interviews face to face and four interviews conducted during telephone conversations. • Participant observations conducted which studied the actions and discussions of those involved in the school retrofit projects (e.g. energy audits, project meetings). Sixteen observations in total. • A review of relevant organisational documentation surrounding the case study (e.g. LA reports, end-user guides).	• Data collection was guided by the RIS theoretical framework adopted for the research (as a regional level of analysis was required). The RIS framework stated the fundamental RIS 'elements' and 'mechanisms' required for innovation within a region. • Data collection was further guided by the STNA methodology to mobilise the empirical work. STNA offers the ability to study interactions, exchanges and possible negotiations surrounding the delivery of LZC buildings (i.e. the school retrofit projects).
	• During content analysis and thematic coding of data each interview transcript was analysed in relation to themes and topics surrounding the research question, aim and objectives (i.e. the skills required for the delivery of LZC buildings). • Thematic coding consisted of three 'levels' of coding using Nvivo 10, guided by the RIS framework ('elements' and 'mechanisms') and STNA methodology (actors / actor groups' interests and negotiations). Level 1 consisted of the actors / actor groups involved in the project, level 2 coded the actors / actor groups' interests, and level 3 coded and detailed the skills required by the actors / actor groups for the delivery of the school retrofit projects.	• For data analysis, interview transcripts, observation notes, organisational documentation and photographs were uploaded and stored within a programme known as Nvivo 10, which allowed data to be organised and further explored in terms of emerging themes. • The data was used for both content analysis and thematic coding. Analysis was guided by the RIS framework and STNA methodology, but the opportunity was given for an inductive approach to explore themes emerging from the data collected.	• The findings from thematic coding, such as the actors / actor groups' key interests and negotiations within the network, and required skills, were used to produce network (STN) diagrams. • Each network diagram was guided by the key principles from the RIS framework and STNA methodology. One network diagram was produced for each school retrofit project (five in total).

3.4 Socio-technical network analysis (STNA) method

The socio-technical network analysis (STNA) was adopted as methodology for this research. The RIS framework (i.e. the theoretical framework) (see section 2.5), indicated what was required for analysis (such as actors and processes), and the STNA methodology was applied to mobilise the investigation (i.e. state how to carry out the investigation). The STNA allowed the identification of key actors, along with their interests, interactions and negotiations that surround the delivery of low and zero carbon (LZC) buildings within the region. In particular, and similar to previous investigations that highlight the value of the STNA bounded network during data collection (Bevan and Lu 2012, Downey 2014), the identification of actors by the STNA methodology provided this boundary and focus for the investigation (a socio-technical network, STN). The establishment of a boundary, and hence the identification of key actors surrounding the development and implementation of the LZC buildings was required as this information was absent from the RIS framework. The RIS literature, for example, indicated that in certain investigations only specific 'elements' and 'mechanisms' may be identified or applied to the RIS. In addition, the actors' interests, and further interactions and negotiations identified by the STNA methodology, offered insight and further explained a number of the skills required by the construction sector and its clients. By adopting the RIS theoretical framework and STNA methodology, the investigation was able to analyse the RIS surrounding the development and the implementation of LZC buildings (at a local / regional level). The combination of RIS and STNA provided guidance on the key characteristics (actors and processes) of the RIS, and further interactions and negotiations between key actors within the RIS.

A socio-technical network (STN) is defined by Schweber and Harty (2010: 658) as "an analytic tool or method … been developed to explore a range of different research questions … features include a focus on the interactions between social and material entities, and the practices through which they are developed and mobilized." The STNA investigates a 'social' network of actors (Elzen et al. 1996), studying actors' interests, interpretations and exchanges within a network (Elzen et al. 1996). The key concepts of a STNA are artefacts, nodes, intermediaries and interpretative flexibilities (Elzen et al. 1996). Each concept is briefly described below.

Artefacts

An artefact can be a physical / material object, a non-physical element / action or a mixture of both physical and non-physical elements within a network. An artefact identified within the investigation can be a tool (e.g. training device for actors) used to develop skills. Examples of artefacts used within the projects were non-physical tools to aid the development of the energy efficient measures (EEM), and a mix of physical and non-physical tools, such as training workshops for the provision of EEM adoption and further implementation.

Nodes

A node is an actor or group of actors within the network. Attention was given to whether the actor or actor group will be represented within the network and of what value the representation will be to the research. Examples of individual actors identified within the investigation were the EEM estimator, the EEM designer and the LA energy assistant. While actor groups were recognised as the EEM contractors, the school community and the local authority (LA). Further detail of how to represent actor groups within the network were also considered. It was of value to present the actor group known as the local authority as two separate actor groups, for instance, the LA energy team and the LA building management team. Sensitivity to the representation of the actors / actor groups is demonstrated within the RIS / STN diagrams, more specifically the representation of the school actor groups within figures 5.4 and 6.3. To gain detailed information on the interactions and skills required for the delivery of school retrofit projects 2 and 3, it was advantageous to separate the actor group known as 'school end-users.' Project 2 (figure 5.4), for example, in comparison to the remaining four projects, the school pupils and parents had a greater involvement in the type of EEM adopted for the building, and a part of 'Eco-School' activities to raise awareness of energy reduction. A separation of the 'school end-users' to 'school staff' and 'pupils and parents,' was required to identify interactions and explore the possibility of a variation in required skills during the development and implementation of the school retrofit building project 2. Similarly, for project 3 (figure 6.3), it was valuable to acknowledge the contribution and possible influence of the 'school community' towards the adoption of EEM, interactions with other actors / actor groups and the required skills during the delivery of the LZC building. Therefore, sensitivity was needed towards the inclusion of those surrounding the school within the actor group 'school community' to gain insight of their involvement for the school retrofit project 3.

Intermediaries

Intermediaries, or exchanges, occur between actors within the network. Intermediaries can be both tangible (e.g. emails of contracts or documents of meeting minutes) and intangible (e.g. conversations relating to meetings / actions). Investigating the intermediaries within the network, such as various email exchanges between actor groups, can offer further detail of the skill requirements and the action(s) taken by actors to address any challenges.

Interpretative flexibilities

Interpretative flexibility relates to how individual actors can have different interpretations of the same artefact within the network. The local authority, for example, can have a different meaning / opinion of a skill / skills required to deliver a LZC building than a contractor. It is the contrasting interests and interpretations of actors that give rise to negotiations within the network. Negotiations identified within the network can highlight the reasons for outcomes and key decisions surrounding the delivery of LZC buildings, e.g. the negotiation surrounding the type of EEM for the building. In some instances, these types of negotiations can give rise to specific skills required and lead to the decision of a certain EEM contractor.

Limitations of STNA

Similar to other methods that could have been applied to the research, there are limitations associated with the adoption of STNA. In reference to the original investigation and roots by Elzen et al., (1996), specific concepts within the analytical framework were borrowed from the social construction of technology (SCOT), actor network theory (ANT) and systems approaches, and further adapted (Elzen et al. 1996). Borrowed from SCOT, for example, is the notion of actor interaction with the artefact and interpretative flexibility, where different actors (relevant social groups) attribute different meanings to the artefact. However, in contrast to SCOT, the limitation and adaptation lies with the need to recognise how actor meanings of the artefact can change. Roots of STNA are also associated with ANT in terms of the recognition of instability (constant change) within the network and of actor interaction with other actors, but also interaction with the artefact within the network. However, in contrast, STNA focuses more on a network that promotes human agency, where technology is not classified an actor. It is important to be aware of how the approach and its concepts have been adapted within the investigation by Elzen et al. (1996) to illustrate the STN and analyse the network of interactions. Further detail on the origins of STNA state the longitudinal nature of the case study (i.e. a number of years), implying short-term changes within the network may be more difficult to analyse. In acknowledgement of this time scale limitation, however, an investigation by Downey (2014), applies the STN and key concepts of STNA to study the adoption of LZC technologies in two housing developments (i.e. two networks). The research also adopts the multi-layer perspective (MLP), which looks at the landscape, regime and niche levels. By combining the MLP approach and the STNA methodology, even though the investigation cannot comment on the stability of the network, the STN provided a bounded focus to investigate the research aim and objectives for the short-term study (Downey 2014). A final potential challenge surrounds the nature of changes within the network, where Elzen at al. (1996) suggests minor changes within the network are most appropriate for the approach. More extreme, rapid network changes, however, are possible through the development of a new network. The process of how a new network is formed and expands is a little unclear.

The STNA methodology adopted had the ability to mobilise the research in terms of guidance for the data collection, i.e. which actors / actor groups (nodes) within the project to involve. This method was able to create an STN surrounding the investigation, also referred to as a network diagram (section 3.4.1 below). The STN provided an essential boundary for the individual case studies (demonstrated in each of the five school retrofit projects) and offered insights on actors / actor group interactions, interests, exchanges and negotiations.

3.4.1 Socio-technical network analysis (network diagram)

The STNA methodology mobilised the empirical work and gave insight into the interactions and negotiations within the network surrounding the delivery of the school retrofit projects. The interactions between key actors / groups of actors allowed the identification of principal interests, and negotiations offered further insight into the required skills for those involved in the development and implementation of the LZC buildings. The use of STNA and production of a network diagram (i.e. a STN) was from the following processes:

- Data collection
- Data analysis

Table 3.2 demonstrates examples of the use of interview data by key actors within the retrofit building project. Quotations by interviewees were used to gain an insight of actor / actor groups' interests and identify the required skills for the delivery of the LZC building. Figure 3.1 shows how the data was analysed and the creation an actor / actor group interaction within a network (STN).

Table 3.2: analysis of interview data

Actor / actor group	Interview quote	Interests	Skills
Local authority energy officer (LA energy team)	*'We are required to meet our energy and carbon reduction targets by looking at energy use within the local authority owned buildings.'*	LA energy team to ensure the implementation of energy efficient measures (EEM) within schools to reduce energy consumption of the building and meet LA energy targets (1).	Energy management skills (3)
School finance manager (school end-users)	*'The price of our electricity bills and understanding how technology works.'*	School end-users to reduce energy use within the school and gain knowledge of how to operate the EEM (2).	Research skills (4) Communication skills (5)
Local authority energy assistant (LA energy team)	*'I conduct an energy audit, gain an idea of energy use and decide the most appropriate energy efficient measure for the school.'*	LA energy team to adopt the most appropriate EEM for the school retrofit project to reduce energy consumption (1).	Energy management skills (3) Communication skills (5)
School head teacher (school end-users)	*'I used google to look at the different type of renewable technology available, and asked the local authority and installers for advice.'*	School end-users to research different types of EEM through the use of media, and liaising with the local authority and EEM installers (2).	Research skills (4) Communication skills (5)

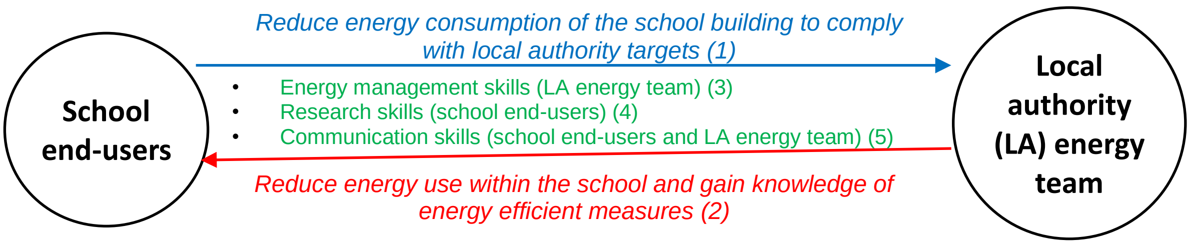

Figure 3.1: the production of socio-technical network (STN) diagrams

3.5 Case study approach

A case study approach (Yin 2003) was adopted for the research. In simple terms, a case study gathers descriptive material to capture the complexity of social situations as they are occurring within the case study (Yin 2003). This approach, and the case itself, can further be defined by using a number of different topics (institutions, events or processes), i.e. the focus of the definition can vary by author (Yin 2003). It is common within case study research for an individual unit and its attributes to be the centre of observation, such as a person or an organisation (Blaxter et al. 2006).

For a more in depth and technical definition (technical being viewed as the 'technically critical features' of the approach) Yin (2003: 13) states the case study approach as:

"…an empirical inquiry that investigates a contemporary phenomenon within its real-life context; when the boundaries between phenomenon and context are not clearly evident; and in which multiple sources of evidence are used."

The terms 'phenomenon' and 'context' are emphasised by Robson (2002), which states that the physical setting is as important as the social setting, where the researcher must be aware of the site and features surrounding the case study. The term 'site' can be used to refer to this physical setting. The case study approach and 'setting' can offer a number of sources for data collection, and in some cases act as a guide for the researcher. The case study approach allows the research an opportunity to employ a theoretical framework (such as the RIS), which can be an advantage for the investigation (Meyer, 2001). Further benefits that can be gained from the adoption of a case study approach are associated with the opportunity of the researcher to study the complexity of social situations, and the attainment of specific data regarding the case and situation. Furthermore, as the data is related to experiences, it is likely participants will be more willing to volunteer or participate in providing further information (Blaxter et al. 2006). It is important to recognise, however, that each case study can offer intrinsic details in which the researcher may become too interested and ignore the wider information of the case as a whole (Blaxter, et al. 2006).

To expand further on concerns when employing the case study approach, there are a number of limitations that need to be considered. First, the research needs to recognise the possibility of a "lack of rigor of case study research" (Yin, 1989: 21), which implies it is the responsibility of the investigator to be aware of influencing data collection. An investigator, for example, can affect the data by taking a bias approach to interviewing (although unaware of doing so). The aim is to demonstrate that the data collection methods have been checked correctly to ensure the findings are valid (Robson 2002). Gray (2004) states that the researcher must not use their own 'interpretative filters' in terms of posing questions and interpreting the answers given by the interviewee. Second, defended by Yin (1989), is the issue of the time it can take to collect data for a case study approach, and the instance where there may be a large set of documents to analyse. A possible suggestion could be to begin with a precise and defined research question, and be aware of the appropriate period of time to stop the data collection process. Finally, dissimilar to the views by Stake (2000) that promote the concept of 'naturalistic generalisation,' Yin (1989) states that there is much negativity regarding the generalisation of the case study approach. There are criticisms over the use of one or few case studies, and then generalising the results (Gray 2004). Generalisations that are analytical are acceptable, but statistical generalisations are seen as less valuable to the research (Yin, 2003). It is suggested, the researcher should aim to reveal unique qualities of a case, to reduce the possibility of generalising the data (Hammersley and Gomm 2000). The criticism of generalising is defended by a suggestion that case studies can be applied to many other forms of research methods. It can be the case where two or more case studies can be studied (and possibly compared), with the researcher aware of the limitations of this approach. Multiple case studies can add credibility to the results as there is less chance of generalisations (Meyer 2001), but there is also the risk of having too many case studies and divergent results (Gray 2004). The challenge of generalisability associated with a case study approach and research findings is deemed as a weakness that requires consideration (Hammersley and Gomm 2000). To defend, and provide an opportunity for the investigator to recognise the disadvantages with the method, there are ways to encourage the applicability and credibility of the case study findings (Guba and Lincoln 1981, 1989, Lincoln and Guba 2000). Emphasis is given to the components, for example, the processes and procedures under taken within the research, which are required to be rigorous and valid (Guba and Lincoln 1981). The methods of data collection need to be reliable, and the appropriate data analysis techniques to be employed (Guba and Lincoln 1981). To promote the rigor of the data and evaluate the 'trustworthyness' of this research, the following four criteria were met (Guba and Lincoln 1989): credibility, where a number of data collection methods were carried out (e.g. interviews, observations and a review of relevant organisational documentation) to establish the 'truth value' and support the confidence of the findings; transferability, through a detailed description of each of the five cases to identify the characteristics that may be applicable to other retrofit projects and regions; dependability, as the investigation employed a sampling strategy for data collection and data analysis techniques for consistency within the research, and clear guidance should future research want to repeat the investigation; confirmability, where each interview was recorded, transcribed and checked by the interviewee to confirm the recorded conversation and observation was correct, i.e. no claims made and all findings emerged from the data collected to support the neutrality of the research. It is also important to understand that a case does not need to be completely unique or, the other end of the spectrum, completely generalised (Lincoln and Guba 2000). Furthermore, generalisations can be considered in terms of both the investigator and the audience, whereby the audience themselves will have opinions towards the meanings and the applicability of the findings (i.e. beyond the investigator's control) (Guba and Lincoln 1981).

Similar to other approaches and techniques that could have been employed for the research, it was important to be aware of the primary issues, specifically the concerns surrounding a generalisability of case study findings, and understand the need to adopt the methods described above to encourage rigor and credibility within the investigation. A case study was appropriate for the investigation as this method was flexible in its approach to data collection, i.e. having many different methods to adopt and elements to apply for the research to gather relevant data. The use of a case study also offered the opportunity to gain in-depth details surrounding the case that can allow the reader to experience the events for themselves (Stake 1998). Furthermore, the research was interested in gaining the complexities that can surround a research problem, and capture real-life events of the study, often emphasised by the adoption of a case study (Yin 1989). This research was aware of the concern surrounding generalisability and understands that the case study findings (i.e. the required skills for the construction sector and its clients that emerged during the investigation), cannot be applied to the development and the implementation of every LZC building beyond the study. Moreover, the research results cannot be generalised to every region, and RIS beyond the study. The research results, however, can be used to contribute to the current understanding of required skills for the delivery of LZC buildings, and further understanding of the RIS theoretical framework.

3.6 Case study design

The case study design describes in detail the case under investigation. This section will establish the research object, unit of analysis and level of analysis, which will offer specific information as to what was being investigated, and how and why the specific case was selected. This section will also explain the sampling strategy behind the selection of the case, and the data collection methods carried out within the investigation.

3.6.1 The case study

The cases under investigation can be single or multiple (more than one case adopted for the research), and the unit of analysis can consist of a single level (holistic) or multiple levels (embedded) (Gray 2004). The adoption of an embedded approach, i.e. multiple units of analysis, relates to an investigation that can predominantly focus on a particular unit (individual, place, event), but further investigate sub-levels or other components (i.e. the embedded units) of the case during data collection and analysis (De Vaus 2001). It is important to stress, however, that when using embedded case studies the researcher does not lose focus on what is being analysed.

A single case study of a local authority (LA) (Wokingham Borough Council) was selected within the region of Wokingham. The selection of Wokingham was guided by the RIS literature. Wokingham has similarities to the definition of a region by Cooke et al. (1997: 480):

"…territories smaller than their state possessing significant supralocal governance capacity and cohesiveness differentiating them from their state and other regions."

The Borough of Wokingham is located within the county of Berkshire and has unique characteristics in relation to the surrounding five regions (Reading, Slough, Bracknell Forest, Windsor and

Maidenhead, and West Berkshire). Wokingham has specific governance powers in terms of its council tax, i.e. a different ‘band’ of tax to Reading and West Berkshire, which are both in close proximity to Wokingham. Additionally, Wokingham has its own planning policies for developments within the Wokingham region, such as a recent ‘neighbourhood plan’, and a budget that is specific to the local authority. Furthermore, Wokingham Borough Council has its own integrated social housing allocation and register, i.e. those from the Wokingham region are likely to achieve the first available allocation.

The local authority under investigation, more specifically the LA energy team, were in the process of developing a number of LZC building projects, including LZC school retrofit projects, local energy scheme projects and an Energy Service Company (ESCO) project. The research focus was the LZC school building projects being delivered within the region of Wokingham, where the research object was to explore the skills required for the development and the implementation of the LZC buildings. More specifically, the research studied the type of skills required, such as the possibility for the need of ‘project management skills’, ‘communication skills’, ‘green skills,’ ‘new skills’ and, following knowledge production, how knowledge is managed within the RIS to deliver the school retrofit projects. Furthermore, the investigation aimed to explore how the RIS, its elements and mechanisms, can be operationalised during the development and the implementation of the LZC buildings. .

A unit of analysis is defined by De Vaus (2001: 18) as:

“…the ‘thing’ about which we collect information and from which we draw conclusions. Often this is a person (e.g. divorced person)…‘things’ such as organizations (divorce courts), a family as a whole, events (e.g. divorces), periods (divorce in different years), places…the question we can answer will depend on the unit of analysis.”

The unit of analysis for the investigation was the LZC building projects. The local authority were required to reduce energy use within the school buildings, through the retrofitting of a number of energy efficient measures (EEM). The investigation focussed on how the LZC buildings (at the individual building level) were being delivered within the region, i.e. the development and the implementation of school retrofit building projects.

3.6.2 Strategy for sampling design

Five school retrofit projects (see table 3.3) being implemented by the local authority were selected for the investigation. The use of school buildings provided the empirical space for what the research aimed to explore (i.e. the required skills for the development and the implementation of LZC buildings within a region), and were chosen as they met the following criteria. First, the school projects were retrofit projects where energy efficient measures (EEM) were being adopted to achieve LZC buildings.

In order for the LA energy team to meet the required local authority energy and carbon emission reduction targets, the energy consumption of local authority owned buildings within the region needed to be reduced. The local authority owned buildings that were identified were those that had potential for energy reduction or classified as high energy consumers. Primarily the local authority owned schools within the region were the focus for energy reduction by the LA energy team, for which five were selected for the investigation. It must be noted that six were selected initially (see table 3.5 for an additional energy audit), but due to issues with time and availability of data, five schools were investigated within the research. Due to the insufficient use of EEM and high energy consumption within the school buildings, the school retrofit building projects offered the potential to study the adoption of a variety of appropriate EEM options, and evidence the required skills for both the construction sector and its clients.

Second, schools are distinctive buildings to study as owned by the local authority. The operations and logistics surrounding schools and the development of facilities are unique to other buildings (e.g. diverse occupancy times, a variety of end-users occupying the building and the local authority procurement process). The school retrofit projects were also able to incorporate the roles, activities and interactions with the supply chain (e.g. EEM estimator, EEM surveyor, EEM installer and EEM supplier) to offer an insight on the required skills for a number of different actors / actor groups involved in the delivery of the LZC buildings. The school retrofit projects within the investigation were also located within the region (i.e. the local authority region) and part of the RIS. The school retrofit projects incorporated the interaction of RIS 'elements' such as 'firms,' 'institutions,' 'knowledge infrastructure' and 'policy orientated regional innovation,' and further potential to study the RIS 'mechanisms.' The location of the school buildings, i.e. within the region and RIS, allowed the research to explore and gain a greater understanding of the role of RIS characteristics, during the delivery of the LZC building projects. The description and characteristics of this region were also similar to the region definition within the literature (see section 3.6.1).

Third, the current construction literature that investigates the retrofit of school buildings evidences a range of challenges, for both the construction sector and its clients, specific to school buildings. Concerns are associated with the safety and need to provide a good quality environment for staff and pupils occupying the school building, logistics for those working on the project (Dimoudi and Kostarela, 2009), the availability of funding resources (Dall'O and Sarto, 2013) and the ability to monitor energy performance of the property (Becker et al., 2007). The construction innovation literature also investigates the retrofit of a number of different building types in terms of the building structure (e.g. terraced / detached / semi-detached housing, high rise offices and flats) and use / occupancy (e.g. office buildings, housing). The range of building types investigated within studies suggests that there is not one single model of all building types. Therefore, there is a need to investigate the retrofit of a range of diverse building types (and associated required skills), including the retrofit of school buildings.

Finally, the ability to gain access to fieldwork was a consideration. The collaboration with the local authority provided the consent to carry out data collection for the development and the implementation of the school retrofit building projects, in order to explore the research aim and objectives. The availability of data sources allowed the investigation to gain information from key actors / actor groups involved in the projects, actor / actor group interactions and further explore the required skills for the delivery of the LZC buildings. Contact was made with the LA energy team, principally the LA energy officer, who was interested in collaborating with the University of Reading and the research topic under investigation. Further communication and initial meetings were held with the LA energy officer (see appendix A) to discuss the potential for collaboration and the provision of documentation. The exchange of documentation consisted of an explanation of a potential collaboration and the proposed focus for the research, i.e. the local energy schemes (see Appendices B and C). Data collection comprised of the gathering of information related to the majority of those involved in the five projects (e.g. school end-users, the local authority, the EEM contractors), and access was permitted to conduct interviews, observations and review relevant organisational documentation for the investigation. A number of other retrofit projects within the region were observed during the early stages of the project, but access to the schools and project individuals were not achievable.

Table 3.3: profile of five case studies (school retrofit projects)

School	Project description	Existing EEM	Areas for improvement	EEM adopted
School 1	• Medium sized primary school (394 pupils) • Located south west within the region • 3 main single storey buildings	• Oil supply updated to gas (2013) • Part insulated • Solar PV array (2010)	• Loft insulation • Energy efficient lighting and sensors • Energy education	• Double glazing • Lighting upgrade • Half hourly meter installation • Cavity wall and loft insulation survey
School 2	• Nursery and primary school (471 pupils) • Located west within the region • Building approx. 30 years old • Eco-schools programme	• Part insulated • Energy efficient lighting • Solar PV array (2010)	• Loft and cavity wall insulation • Building heating system • Glazing area • Energy education	• Double glazing • Half hourly meter installation • Cavity wall and loft insulation survey
School 3	• Nursery and primary school (592 pupils) • Located south within the region • Building redeveloped during 1980s and 1990s • On-site swimming pool	• Solar PV array (2011) • Solar thermal unit (2011)	• Building heating system • Insulation survey • Energy efficient lighting • Energy education • Swimming pool heating system	• Smart meter installation • Heating system and heating controls (BMS) updated • Cavity wall and loft insulation survey
School 4	• Medium sized primary school (302 pupils) • Located south within the region • School built 1855 and redeveloped 1989 • Eco-schools programme •	• Loft insulation • Solar PV array (2012)	• Loft insulation • Glazing area • Energy efficient lighting • Building heating system • Energy education	• Smart meter installation • Sun / solar pipes • Cavity wall and loft insulation survey • Lighting survey
School 5	• Small primary school (98 pupils) • Located north within the region	• Part insulated • Energy efficient lighting • Double glazed • Solar PV array	• Energy efficient lighting • Glazing area • Building heating system • Energy education	• Double glazing • Lighting upgrade • Smart meter installation • Heating system and heating controls (BMS) updated

3.6.3 Sampling strategy for interviews

The interview process and interviews (see table 3.4) started with the case study under investigation, the local authority, more specifically the LA energy team. This process was essential to gain background information about the local authority, the LZC building projects, and to become familiar with the school retrofit project process. Speaking to the LA energy team, more specifically the LA energy assistant, further information and contacts of those involved in the projects were gained. Furthermore, the adoption of the socio-technical network analysis (STNA) methodology highlighted the network of actors / actor groups surrounding the school projects, for data collection, i.e. potential interviewees. The LA energy assistant, for instance, emphasised a high degree of involvement with school head teachers, finance managers and EEM contractors during the development and the implementation of the school projects. Where possible, the actors / actor groups within this network were selected for an interview. There were occasions, however, where actors / actor groups were unable to attend an interview due to time and resource constraints. When this was the case, observations involving the actors / actor groups and informal conversations were looked at as possibilities to gain an insight into the skills required. The STNA methodology further provided a network boundary surrounding the LZC building projects, which indicated the sufficient level of detail required for the project, and highlighted an appropriate place to bring the interviewing process to a close.

3.6.4 Sampling strategy for observations

Similar to the interview sampling strategy, observations (e.g. such as meetings, EEM installations and energy audits) surrounding the case study (see table 3.5), were selected. Potential observations became apparent during interviews with actors / actor groups within the network surrounding the school building projects, and selected in terms of value to the data, i.e. observations that would offer greater detail and further clarity to the skills required for the delivery of the LZC building projects. Again, the adoption of the STNA methodology identified the network surrounding the school projects that expanded on actor / actor group details (e.g. interests, intermediaries), and further indicated the observations to select and focus on during data collection.

Table 3.4: profile of interviewees for each project (projects 1-5)

School retrofit project	Date / interviewee	Interview type / place / duration
Project 1	(EA11) 24.07.14 LA energy assistant	Interview (face to face) / on-site / 1 hour
	(EO11) 15.01.15 LA energy officer	Interview (face to face) / on-site / 1 hour
	(EO12) 6.08.14 LA energy officer	Interview (telephone) / 1 hour
	(OM11) 7.08.14 Operations manager	Interview (telephone) / 0.5 hours
	(SU11) 15.08.14 Insulation surveyor	Interview (face to face) / services / 1.25 hours
	(PVSU11) 03.09.14 PV surveyor	Interview (face to face) / local café / 1.5 hours
	(BM11) 25.09.14 School business manager	Interview (face to face) / on-site / 1 hour
	(PVSM11) 08.10.14 PV sales manager	Interview (face to face) / on-site / 1.5 hours
	(EE11) 12.11.14 Electrical engineer (lighting)	Interview (face to face) / on-site / 1 hour
	(SC11) 20.11.14 School site controller	Interview (face to face) / on-site / 1.5 hours
	(WI11) 20.11.14 Window installer	Interview (face to face) / on-site / 1 hour
Project 2	(ES21) 27.08.14 Estimator (insulation)	Interview (face to face) / site offices / 1 hour
	(HT21) (BM21) 10.08.14 School head teacher and school business manager	Interview (face to face) / on-site / 1 hour
	(TR21) 27.08.14 Trainer (renewable technology)	*Informal conversation / training academy / 0.5 hours*
	(SU21) 12.12.13 Surveyor (insulation)	*Informal conversation / on-site / 0.75 hours*
	(II21) 19.02.14 Installers (insulation)	*Informal conversation / on-site / 0.5 hours*
Project 3	(ES31) 15.07.14 Estimator (insulation)	Interview (telephone) / 0.5 hours
	(SPM31) 04.09.17 Smart meter project manager	Interview (face to face) / site offices / 1.5 hours
	(SC31) (MM31) 06.11.14 School site controller and school maintenance manager	Interview (face to face) / on-site / 1 hour
	(MM31) 06.11.14 School maintenance manager	Interview (face to face) / on-site / 0.25 hours
	(HE31) 07.11.14 Heating engineer (air source heat pump)	Interview (face to face) / local site installation / 0.5 hours
	(SMI31) 18.12.14 Smart meter installer	Interview (face to face) / local site installation / 1.5 hours
	(HT31) 18.09.14 School head teacher	*Informal conversation / on-site / 1 hour*
Project 4	(FM41) (SC41) 01.10.14 School finance manager and school site controller	Interview (face to face) / on-site / 1 hour
Project 5	(HT51) (FM51) 9.10.14 School head teacher and school finance manager	Interview (face to face) / on-site / 1 hour
	(EM51) 27.10.14 Energy manager (lighting)	Interview (telephone) / 1 hour
	(SMI51) 11.12.14 Smart meter installer	Interview (face to face) / local site installation / 1.5 hours
	(HC51) (HA51) 24.11.14 Heating contractor and heating assistant	Interview (face to face) / site offices / 1 hour
	(FM51) 9.08.14 School finance manager	*Informal conversation / on-site / 1 hour*

Table 3.5: observations conducted for data collection of projects 1 - 5

Purpose	Date / time / location	Present	Key points	Further discussions / comments / outcomes	Observation code
School 1 meeting to discuss EEM adoption	• 14.08.13 • 10am (1 hour) • School 1	• LA energy officer • Headmaster of school 1	• First look (very briefly) at the measures that have the potential to be implemented within school 1, technical and project management skills required. • Walk around the temporary and permanent buildings, communication skills required.	• An energy audit will need to be under taken by WBC. A number of measures can be applied- mainly lighting within the temporary and permanent building. • Key: funding from WBC and possibly school 1, WBC prefer to use their suppliers (cheaper).	OB1
School 1 energy audit	• 30.08.13 • 12noom (1.5 hours) • School 1 •	• LA energy assistant • School finance manager	• Energy audit of school 1. Identify the specific measures that are a priority and have the potential for implemented, technical and communication skills required. Possibly a green skill surrounding an understanding of the energy efficient measure.	• Lighting and insulation appear to be the more urgent measures to implement.	OB2
Green Deal event for local authority	• 1.10.13 • 10am (6 hours) • Local leisure centre	• LA energy officer • LA energy assistant	• Promoting the Green Deal / Eco to the over 50. • Discussions around the Green Deal; advantages, disadvantages, and further providing information and leaflets.	• Very few people interested in the Green Deal due to insufficient information known (a lot asking the qualification process). • The Green Deal loan being 7%. Many residents having insulation already and satisfied with their house. • There were questions about what insulation is and how to make a property warmer.	OB3
Meeting between EEM contractor (SU11) and LA energy officer	• 3.10.13 • 10am • WBC offices	• LA energy officer • EEM contractor (SU11)	• The EEM contractor will undertake the initial survey for all of the 84 WBC buildings (62 schools), to reduce energy loss and increase efficiency. • Initial survey needs a contractor (The LA energy team investigates 3 potential contractors (stage 1). • Hiring contractors is a complex process. Contracting interests / negotiations surround money (profit and loss) the approach taken to the survey by contractors. For the contractor, decisions for contracting surround reliability, trust and the relationship. • Sourcing materials by contractor is different- how much the materials cost and location carries more weight. Try to use local as a moral obligation and convenience. • The construction process looks at time (hence money) and what the client wants is important, project management skills required.	• The LA energy team looked at 3 contractors for the initial survey. 3 contractors need to be looked at if the project is 50K plus. One local supplier, one national and one from the internet (or preference). • The Localism 'rule' will be used where possible and the energy team have an interest in this- not solely because is it promoted but it can also: ➢ Reduce budget ➢ Enhance the project as it is more likely the supplier / installer will have knowledge of the local area (know what WBC is about for example). • Have more responsibility, i.e. closer to the project is something goes wrong.	OB4
School 1 identification of EEM measures	• 09.10.13 • 9.30am • School 1	• EEM contractor (SU11) • Various members of staff at school A (head teacher, finance manager, site controller)	• Initially school staff were apprehensive about insulation (fitted 4-5 years previously). Site controller worried about cabling issues for loft insulation. In the semi-permanent buildings, even though cabling was present in the loft, there may be the potential of insulation (simpler type). Drilled holes in the outside wall of the main building that indicates insulation has been fitted previously. • Communication and a walk around with the site controller, communication and technical skills required.	• In the main hall the contractor suggested insulation was not possible due to rafters.	OB5

Energy audit of a school within the region	• 18.10.13 • 9.30am • School within the region	• LA energy assistant • School finance manager	• The primary school is generally very energy efficient and appears to be doing all it can to save energy and have a better environment for the students (stickers by the lighting, part of an 'eco-schools with energy teams, eco-committee with partnership). • The school energy performance certificate (EPC) has been updated (10.13), D band (94). • The majority of the school has double glazing (3/4 windows the glazing isn't working correctly), communication skills required. • Much of the lighting T8s, technical skills required. • Room for improvement: the heating needs controllers on radiators, 2 thermostats in the school, complaints of hot/cold over different parts, zoning needed. Black out blinds needed and possibly window cover and shading (library). Possibly passive ventilation system in the IT room- becomes very hot (recent ventilation system). Possibility of PV on the library roof- sufficient roof gradient and little shading.	• Infant hall light covers could be cleaned and replaced. This experiences heat gain and hot periods but also very cold periods during winter. • Any T12s need to be upgraded (a few) and possibly T8s with T5s. • Heating is the priority. • ECO committee and eco-schools really encourages the students to get involved. They litter pick around the school and have education on environmental issues.	OB6
School 4 energy audit	• 14.11.13 • 10am • School 4	• LA energy assistant • School finance manager	• School 4 requires lighting; boilers are old and need replacing. Double glazing is an option but private funding from the school will be needed (LA11 may be able to part fund). Library is also key to the school – technology, under floor heating, glass / lighting.EA11 is trying to get part funding for double glazing communication skills required, School 4 has PV panels but this was provided by ENS41, technical skills required.	• EA11 spoke to the maintenance and compliance manager about funding towards double glazing. LA11 can only fund windows that are in 'poor condition' this means letting in drafts or not working as they are intended. • There may be the potential for new doors as these are letting in a lot of cold air.	OB7
LA sustainable environment and climate change partnership meeting (SECC)	• 05.12.13 • 9am • LA offices	• LA energy team • SSE, transport department, energy team, local business representative, local resident, WRAP representative.	• Discussions surrounding the best actions for the region: residential viewpoints, business viewpoints, local authority viewpoints and further action plans, communication and research skills required.	• Each representative has different activities to focus on for the next meeting. The local authority, for example, are required to update their website and provide details on energy efficiency within the region and advice.	OB8
Insulation survey School 2	• 12.12.13 • 8.30am • School 2	• EEM contractor (insulation surveyor) (SU21) • School head teacher	• School 2 is approximately 30 years old with various extensions (library) and a rollalong. The main building consists of an infants, middle and upper school. The nursery is 'brand new.' They had 6kW of PV fitted in February 2010. At present (December 2013) it has generated 15.34MWh of electricity. It had a D band rating on its DEC (91 points). MC21 has already given an initial price and 'won' the work. However, during this survey, SU21 measured the dimensions of the building and looked in detail at the loft areas at the existing insulation, i.e. whether it has any insulation and its thickness. One section of the school had no insulation (middle school). A report will now be produced by SU21 and sent to the commercial department MC21 and a price will be given to LA energy team, technical skills required.	• The rollalong is unable to have insulation as the ceiling is too low (health and safety issues). The normal process would be to put insulation in there, depending on the age of the rollalong. • The 'normal' process is usually not an initial quote until a SU21 has been out to site (but on some occasions a 'blind' quote is given). • SU11 of EC11 has already been to the site and did much the same process for the potential implementation of insulation.	OB9
Meeting with LA energy team for school project update	• 10.01.14 • 3.30pm • LA offices	• LA energy officer • LA energy assistant	• One of the chosen contractors is unable to do the work from the survey. Encapsulated insulation cannot be fitted by them. • Explanation of project processes within the local authority and role of other LA departments, e.g. the activities and communication with the schools of the LA building management team.	• Actions for the LA energy officer to look at initial survey by SU11, and investigate insulation / contractor options.	OB10

Meeting with LA energy team for school project update	• 27.01.14 • 2.30pm • LA offices	• LA energy officer • LA energy assistant	• Installations taking place at 3 schools, lighting projects will be next to be up taken at the other 2. GPS buying scenario explained- they will need to be mapped for the analysis. Deciding factors for the LA is price and product. • Many decisions are driven by funding- where it is coming from and who is providing the funding, communication skills required.	• The LA energy assistant has the action to arrange lighting projects, i.e. the priority schools and funding.	OB11
LA meeting: climate strategy review	• 30.01.14 • 12 noon • Outside of the region	• LA energy officer • Local enterprise partnership • 6 local authorities	• Key discussions were around funding for region, from the end-user (25m) and from the UK government (single growth fund) for 'shovel ready schemes.' EU funding is based on the strategic economic plan. • Funding is also discussed as not just cash. There are a number of goals for the local area for all sectors (low carbon, jobs, skills, STEM expertise). • There are discussions of the science park - "Local jobs for local people." • Responsibility for encouraging SME involvement and engagement is directed towards the LA.	• Objectives are really emphasising the local area, low carbon economy and skills. Recognise the need to engage with SMEs, they need to be encouraged to want to be aware of resources people/workforce and land resources such as the 'natural environment.' • An investigation of the demand for skills within the area. The priority is emphasised in connection to the demand rather than what the area can supply.	OB12
Installation of loft insulation for School 2	• 19.02.14 • 8.30am • School 2	• EEM contractors (insulation) (II21) • School head teacher	• There was little communication from LA energy team to school 2 regarding insulation and the contractor, communication skills required. • The installers were not exactly sure where the insulation was to be fitted. • The loft insulation could not go ahead due to the correct tools, i.e. communication was incorrect or insufficient to the installers from the surveyor / estimator, technical skills required	• Insulation needs to be rescheduled for another date / time. • Possibility that a different team (same contractor) is required to install the insulation due to the suspended ceiling.	OB13
Meeting and brief energy audit School 5	• 10.09.20 14	• LA energy assistant • School finance manager	• Brief look at the start of the double glazing being implemented and chat around views of the EEM communication skills required. • Discussion surrounding the funding for the double glazing (the school is paying a percentage), project management skills required. • Discussion of the current EEM within the school and any further work required.	• Action on the LA energy assistant to agree the funding for the school and percentage the local authority is paying. • Action on the school finance manager to monitor energy consumption / use within the school and state any problems to the LA energy assistant.	OB14
Meeting and tour of School 3	• 18.09.20 14 • 9.30am • School 3	• School head teacher	• School 3 is a nursery and primary school. Primary school is part of the old original building and part of the new 1970s building. The nursery was built in the 1980s. • The school uses gas as its main heating supply, although there are a number of electric heaters within classrooms and the rollalong. The school has a swimming pool, which uses electricity. Problems within the school consist of classrooms being too cold and classrooms being too hot. The boilers were been replaced over the summer (2014) • The smart meter was installed as the electric consumption was incorrect.	• Keep monitoring the energy use of the school. • The heating system to be upgraded and understood by the head teacher. • Look into an air source heat pump for the swimming pool. • Advice and actions regarding the overheating and cold temperatures within the different classrooms, communication skills required and the importance of knowledge management surrounding the energy efficient measures was observed.	OB15
Observation of school heating system for School 3	• 06.11.14 • 10am • School 3	• School maintenance manager	• Observation and discussion surrounding the heating system and heating controls (new building management system – BMS) within the school. • The school maintenance manager mentioned confusion around the system and its use, the timers and temperature (general controls of the heating). A description given of the procedure if the system has a breakdown or requires maintenance, i.e. the LA building management team are called out the fix the problem. Little interaction with the school on how to fix problems or make changes to the system.	• The possibility of gaining a greater understanding of the heating controls, technical skills and possibly green skills required. • Advice from the LA building management team, communication skills required.	OB16

3.7 Data collection methods

From the data sources that were available for the investigation, it was of interest to gain information that was up-to-date and most relevant. The use of several sources of data can strengthen the research through the likelihood of a greater understanding of the data (Baxter and Jack 2008). It was important, however, not to become overwhelmed with too much data. Data collection methods adopted for the research consisted of a literature review, semi-structured interviews, observations, and a review of relevant documentation. Prior to data collection (observations, documentation analysis and semi-structured interviews), ethical approval was gained by the School of Construction Management and Engineering Research Ethics Committee.

3.7.1 Literature review

A literature review can "attempt to integrate what others have done and said, to criticize previous scholarly works, to build bridges between related topic areas, to identify the central issues in a field, or all of these" (Cooper 1998: 3). By studying the relevant literature, the research was able to be put into context, i.e. looking at previous investigations within the field to offer a platform for the study (Blaxter et al. 2006). Each literature review can be different and cover a wide range of topics (Cooper 1998). The research has reviewed relevant topics within the regional innovation systems (RIS) literature (theoretical framing), construction innovation literature and construction skills literature that included general literature (e.g. skills), specific construction literature and the subject area of LZC buildings.

3.7.2 Semi-structured interviews

The adoption of interviews as a data collection method was to gain qualitative data and in depth knowledge of the school retrofit projects. In simple terms, an interview can be defined as (Ruane 2005: 147):

"A personal exchange of information between the interviewer and interviewee … the researcher takes time to contact the research subject, to build a rapport with the research subject, and to listen to, interact with and "get to know" the research subject."

More specific to what should be discussed and what interview conversations should aim to achieve (Lindlof and Taylor 2011: 173):

"…bear a relevant, truthful and reliable relationship to empirical facts…understanding the social actor's experience, knowledge and worldviews."

Interviews can be structured, semi-structured or unstructured, depending on what data the interviewer wants to gain, or the type of response needed and its depth (Robson, 2002). Semi-structured interviews were employed for the investigation. Semi-structured interviews allow questions around specific topics and themes, but offers the interviewee freedom to discuss or expand on relevant areas of the case that may have not been considered (Denscombe 2007). Prior to the semi-structured interviews, an interview protocol was prepared and pretested (see appendix D). In contrast to an interview schedule used primarily for structured, formal interviews (Lindlof and Taylor 2011) encouraging quantitative data (Ruane 2005), a protocol can breakdown the interview into specific sections and offer guidance through the process. The choice of interview questions were important to ensure a relation to the research aim, the creation of a dialogue to act as a support should the interviewee be nervous (Lindlof and Taylor 2011), and a focus for the interviewer. The semi-structured interview protocol was divided into the following three sections:

- Section 1 - background: designed to ease the interviewee into the interview with discussions specific to their history of employment and interests.
- Section 2 - the low carbon building project: more focussed on the school projects, the interviewee's involvement in the projects and specific skills used and required for the delivery of the project.
- Section 3 - reflect on the interview and close: designed to give the interviewer the chance to reflect on the interview, bring the discussions to a close and offer the interviewee the opportunity to ask or add anything to the interview.

More specific to the interview process, potential interviewees (those identified as involved in the project) were contacted via email to seek the possibility of an interview through an explanation of the research project and the interview process (e.g. confidentiality and voluntary participation). Once an interview was secured, a brief description of the project and the interview protocol was sent to the interviewees prior to the interview. This process can help the interviewee feel more at ease for the upcoming interview, and possibly give them time to prepare for the interview topics. Prior to the interview it was essential to ensure the interviewee understood the procedure, check any concerns or questions, and enquire how much time the interviewee could dedicate to the interview.

Interviews were approximately one to one and a half hours in length and, with permission by the interviewee, the interview was recorded and notes were taken. Following the interview, the recording was transcribed verbatim, and a transcript sent to the interviewee to check for accuracy before being analysed. Each interview was then made anonymous (names and places) prior to data analysis (see appendix E for an example of an interview transcript). Furthermore, there was also the option of follow up interviews and emails with key actors involved in the case study. A second interview or discussion offered the opportunity to gain greater in-depth knowledge of certain concepts or further examples of actions that took place around the project (e.g. training and learning to gain the required skills). A number of emails were exchanged with the LA energy assistant, which captured the involvement of the LA energy team and the school, and helped to clarify the activities discussed during the initial interviews (e.g. verification of the LA energy team involvement in energy education for the school).

A total of twenty semi-structured interviews were conducted face to face and four semi-structured interviews conducted during telephone conversations. Five observations also presented the opportunity to have informal conversations (see table 3.4) with those involved in the projects, which were valuable to the data collection to gain further understanding of the skills required. An informal conversation during the implementation of loft insulation for project 2, for example, offered greater in-depth understanding towards the use of tools and knowledge required for the EEM, (see table 3.5 observation 13).

3.7.3 Observations

In general, observations look to study the behaviours and interactions of participants (Boulton and Fitzpatrick 1997). This data collection method allows the researcher to gain direct evidence first hand of what is actually happening (Denscombe 2007), understanding the important aspects of the investigation, and producing more rigorous data (Meyer 2001). The aim of observations is not solely for the interests of the researcher, but the creation of 'public knowledge' that can possibly provide information to highlight certain issues and behaviours (Foster 1996). The main types of observations that can be adopted are systematic (Denscombe 2007) and participant (Atkinson and Hammersley 1998) observations. 'Systematic observation', associated more so with quantitative data collection, refers to observations that have a system in place, such as a number of different observers that may produce different results (Denscombe 2014). 'Participant observation', known to be "central to all social sciences" (Vidich 1955: 354), refers to the observer having an active role in the setting being observed (Atkinson and Hammersley 1998). An advantage of observing, more so to this research as interviews were also adopted as a method of data collection, is that this method can complement many other forms of data collection. Observations are also of benefit within the research as it signifies 'real-life' situations and is very direct (Robson 2002). The primary disadvantage of observations is the possibility of the observer affecting the situation, with those being observed being aware of the situation and acting differently (Robson 2002). It is important for the participant to be mindful of this potential issue. Furthermore, to counteract this disadvantage, a researcher who is very much involved in the setting can encourage the fellow participants to feel more at ease (Dooley 1990).

Specific to the investigation, participant observation was adopted, where the observer was the participant (Denscombe 2014) for the data collection and was able to be involved in the research setting being observed. The behaviours and interactions that surrounded the delivery of LZC buildings within the region were observed. In relation to the research aim and objectives, communications, actions and negotiations that surround skills required to develop and implement LZC buildings (i.e. the school retrofit projects) within the region, were observed. Guided by the RIS framework, the research looked to observe the 'elements' and 'mechanisms' (those that were present within the RIS). Furthermore, observations of the key actors / actor groups within the socio-technical network (STN), and further interactions between actors / actor groups and the 'artefact' were closely observed. The use of tools or strategies, for example, which could be employed to develop skills within an organisation.

In simple terms, observations consisted of observing incidents (e.g. what is happening and what follows on from it) (Bryman 2012) surrounding the case study. Observations were primarily energy audits of the school buildings and installations by the energy efficient measure (EEM) contractors within the school retrofit projects. Furthermore, on occasions, there were opportunities to observe local authority project meetings or informal discussions surrounding the implementation of EEM to deliver LZC buildings within the region, such as the local authority Sustainable Environment and Climate Change (SECC) partnership meeting (see section 3.6.4, table 3.5). The meeting observation provided detailed information of local authority sustainability and energy targets, and the understanding of local authority roles and the skills required within the LA energy team. If permission was granted by participants involved in the observations, which was the case for the majority of local authority meetings and EEM installations, relevant information was captured through note taking and site photographs were taken. A total of sixteen observations were conducted (see table 3.5).

3.7.4 A review of relevant documentation

A review of organisational documentation (see table 3.6 below) consisted of analysing relevant reports and information from the case study, such as reports produced by the local authority (e.g. local authority strategies) and other key actors (e.g. resource support, skills development). The analysis of relevant documentation enhanced the data collected from interviews and observations by expanding on the interests of key actors and actions previously identified, and clarifying the justification of activities surrounding the school retrofit projects.

Following data collection, or in some cases during data collection, the interview transcripts, observation notes and relevant company documentation were analysed using the methods explained below.

Table 3.6: documentation reviewed surrounding the project (1-5)

Document reviewed	Document author(s) / date	Key points
Wokingham Borough Council: Sustainable Environment Strategy 2010-2020	• Wokingham Borough Council • 2010	• The main message is that the local authority (LA) needs to engage, take action and prepare. Communication skills required. • A broad strategy that has several action plans within the document (e.g. Carbon Management Plan and the Sustainable Environment Strategy). • The LA is required to engage in a number of categories described within the strategy: ecological footprints, carbon emissions, renewable energy and energy efficiency. Energy management skills required.
The Carbon Management Plan: brief overview	• Wokingham Borough Council; Carbon Trust • 2012	• The plan is in-line with the LA's strategy for carbon reduction and fuel efficiency. • The document is adapted from 4 primary legislations (all Carbon reduction acts): the Carbon Reduction Commitment, the Home Energy Conservation Act, the Energy Performance of Buildings Directive and the Nottingham Declaration (encourages others to reduce emissions). • The plan proposes areas for the LA to focus on (street lighting, buildings etc.) and the costs and savings. Project management skills required.
Energy audit: school 1	• LA energy assistant • August 2013	• The school is doing well in terms of being energy conscious and conserving energy within its buildings. • There can be many improvements that will save energy and improve the working environment for pupils and staff. • The main considerations are lighting upgrades, insulation and education on the environment and energy (i.e. energy education). Energy management skills required.
Energy audit: school 2	• LA energy assistant • October 2013	• The school is conscious of energy saving within the building. • The primary recommendations are heating (specific to the library), windows updated, insulation survey required and energy efficient lighting is required to further improve energy use. Energy management skills required. • The continuation of high levels of energy education within is also encouraged by the local authority. Communication skills required, knowledge production and transfer required.
Energy audit: school 3	• LA energy assistant • June 2013	• The school is doing well in terms of energy saving, with staff and pupils being involved in the school activities. • The main areas recommended for energy improvement are swimming pool heating (possibly air source heat pump), energy education, heating, lighting and insulation surveyed and potential instalment. Energy management skills required.
Energy audit: school 4	• LA energy assistant • November 2013	• The school has impressive measures and attitudes to energy saving within the building. • The principal recommendations from the local authority are lighting, glazing area improved, insulation survey and possible installation, and energy education. Energy management skills and communication skills required.
Energy audit: school 5	• LA energy assistant • February 2011	• The school has a good range of energy savings measures in place, but with advice and actions from the local authority, a number of significant changes can be made. • Primary recommendations for energy savings are lighting upgrades and behavioural change in terms of awareness of lighting and equipment. Energy management skills, communication skills and knowledge production required.
Energy audit: school within the region	• LA energy assistant • October 2013	• The school has made energy saving a priority and staff and pupils are encouraged to be energy conscious. • Priority actions are heating, lighting and energy education. Energy management skills required. • Solar PV is recommended, more specifically, the library roof.

3.8 Data analysis methods

The content analysis technique was adopted to analyse the data collected for the research. This technique can be applied to analyse documentation and texts whereby the researcher systematically studies their content through different themes, classifications or categories (Bryman 2012).

The software programme Nvivo 10, which is one of the many methods that can be adopted due to the flexibility of the content analysis approach (Bryman 2012), was used within the investigation. Nvivo allows the organisation of data in one place, i.e. the location of interview transcripts, written word documents, PDF files, images and audio files, all of which can be uploaded onto the programme. It is then possible for the researcher to analyse the many forms of data.

For this investigation, interview transcripts, documentation from observations (note taking), relevant case study documentation (e.g. the Carbon Plan) / review of organisational documentation, and photographs were uploaded onto the Nvivo programme (see figures 3.2 - 3.4). The anonymised interview transcripts and observation documents were then coded. The use of coding and content analysis technique within Nvivo was a method of managing data for it to be analysed. Guided by the RIS framework, each interview transcript was coded in relation to themes and topics surrounding the research question and aim, i.e. the identification of the skills required to retrofit the school building projects. Similarly, coding was guided by the research aim and objectives to further investigate the challenges and issues surrounding the required skills to deliver the LZC building projects. Each actor / actor group within the network was identified, and their interests and skills used / required to retrofit the schools were coded. Three 'levels' were used within the Nvivo programme for the coding (see figure 3.2), which consisted of the actors / actor groups involved in the project (level 1), and the actors' interests and skills required (levels 2 and 3). Similarly, relevant observation data was coded using the themes to enhance and expand on the findings within the interviews. The coding of data from observing an EEM installation, for example, enhanced the data in terms of gaining further knowledge and understanding behind the interviewee's account of the EEM procedure. Furthermore, additional relevant documentation, uploaded in Nvivo, was used during data analysis to expand on details described throughout the interviews and observations. Following the coding, a number of reports were created to view the various codes, their replication and themes within the coding (see figure 3.4).

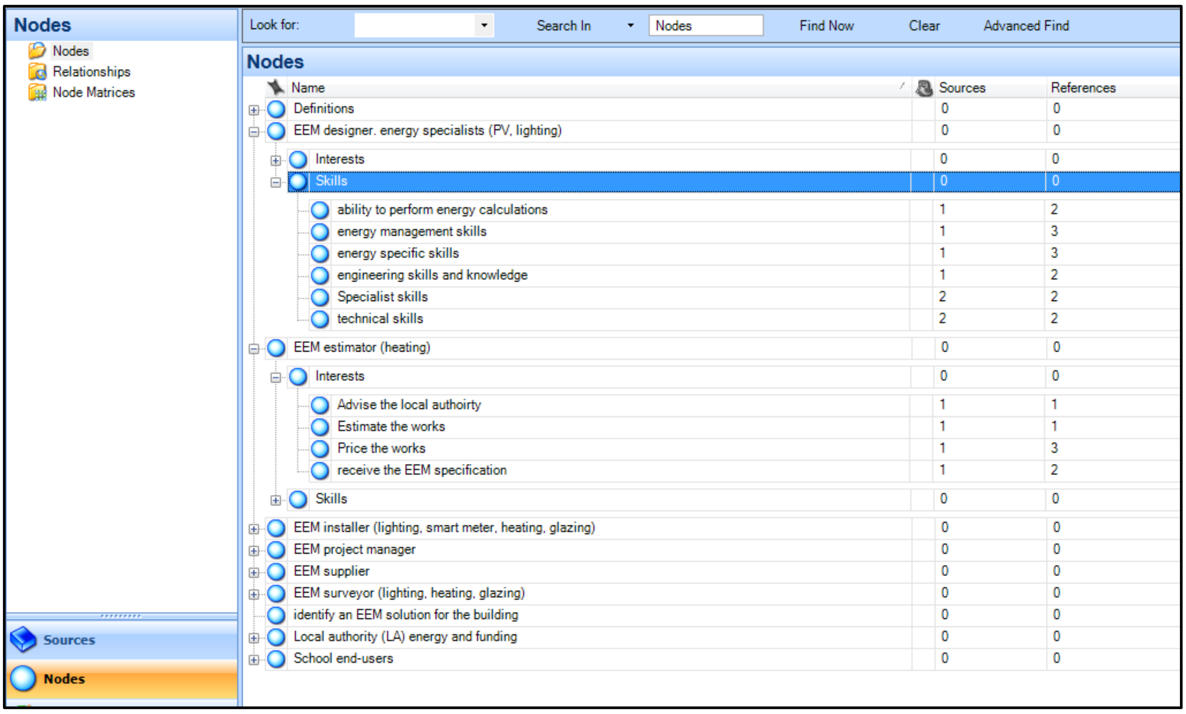

Figure 3.2: the three levels of coding used for content analysis within Nvivo

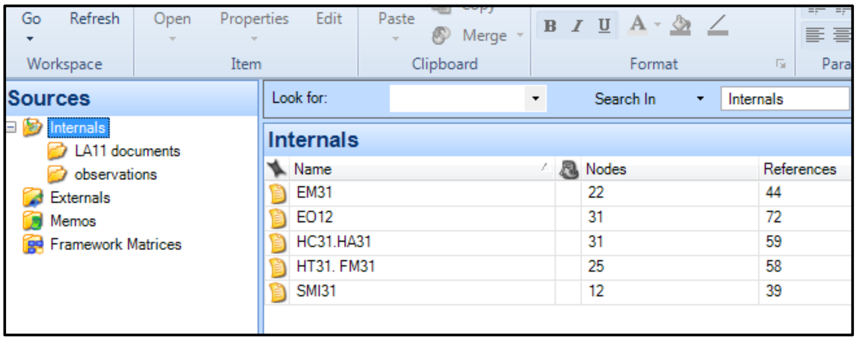

Figure 3.3: the storage of documentation within the Nvivo programme

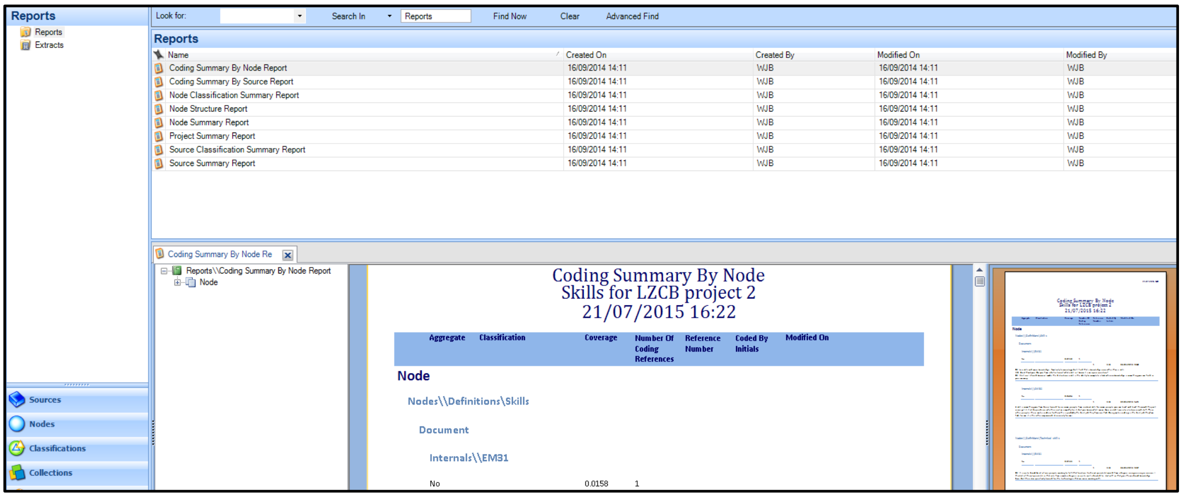

Figure 3.4: the design of reports within the Nvivo software programme

Two limitations can occur through the adoption of this method of data analysis. First, the analysis relies upon on the interviewee's account of their involvement within the project. To help clarify and further understand the details given in interviews, interviewees were asked to expand and explain the actions and viewpoints relating to the EEM adoption and the LZC building projects (i.e. the retrofitting of the schools). Data collection through observations, and observation notes uploaded onto Nvivo, also verified specific actions surrounding the delivery of the school retrofit projects that were stated by interviewees. Second, the analysis is based on the researcher's interpretation of the data. As discussed earlier, this limitation encourages the investigator / researcher to be aware of their 'interpretation filters' when analysing the data sources. The recommended use of combining a number of different validation techniques (Creswell 2014) to mitigate the limitations of data analysis, and further enhance the accuracy of the research findings, are presented below.

3.9 Generalisability

Generalisability, or the generalisation of research results and findings, is associated with 'external validity' (Bryman 2016). In simple terms, the subject of generalisability questions the possibility of whether the findings from an investigation can be generalised outside of the scope of the research conducted, i.e. populations beyond the case study. In terms of qualitative research, Bryman (2016) explains the idea to consider the generalisation of the theory or theoretical framework of the research, rather than the application of findings to populations beyond the investigation. Generalisation is part of the broader technique known as validation. The application of validation, and the ability to ensure the data is reliable, is an important process that is highlighted as one of the advantages of qualitative research investigations (Creswell 2014). Validation for this investigation was concerned with the procedures and methods employed to enhance the reliability of the findings and support consistent data collection methods. The triangulation strategy or process (Creswell and Zhang 2009, Creswell 2014) was used to examine the validation of the key findings within the investigation. The triangulation strategy can be referred to as the "process of using multiple perceptions to clarify meaning, verifying the repeatability of an observation or interpretation" (Stake 1998: 97). In simpler terms, triangulation is the gathering of a number of viewpoints surrounding the data (Neuman 2006). There are a number of different methods that can be employed to carry out triangulation (Janesick 1998, Neuman 2006), such as the use of different types of data, changes to the investigator and interdisciplinary triangulation. Triangulation through the use of different data sources was most applicable for this investigation.

To achieve validation the research was required to become familiar with four key terms that relate to the subject: validity, reliability, generalisability and representativeness. First, validity concerns the credibility in relation to the description of the qualitative data (Janesick 1998), such as the interviewee's account of events / involvement provided within the interview transcripts. Validity was achieved by allowing the interviewee the opportunity to check the interview transcript to ensure it was coherent with the information given during the interview, and gave an accurate account of their involvement in the project(s). The majority of interviewees also offered the opportunity to make further contact via email or telephone following the interview, which allowed clarification and a greater understanding (for the interviewer / investigator) of activities discussed during interviews and observations. In addition, to support the 'truthfulness' of the findings and the extent of the investigator's understanding of the data (Neuman 2006), a number of observations surrounding the project were conducted.

Second, reliability of the data, i.e. was the data consistent and dependable, was considered by investigating each actors' account of the project and whether interviews with different actors / actor groups appeared consistent. Gaining a description of the project from different viewpoints, hearing each actors' version of activities and further skills required for the retrofitting of the schools strengthened both the reliability and the validity of the results. Moreover, the LA energy officer, who had a project manager role for all five projects, was interviewed towards the end of data collection to allow a different prospective and account of the projects.

Third, generalisability (see above and section 3.5 for further detail), described as an 'unconscious process' where the researcher needs to be aware of the information drawn from the findings and what is shared with the reader regarding the case (Stake 1998), can be one of the weaknesses of case study research (as discussed in section 3.5). The research was mindful and attempted to mitigate the generalising of the case study by investigating five cases (e.g. five retrofit school projects) within the case study. Each school project had a wide range of EEM implemented, all at different, but early initial stages of development, and each school was located in a different area across the region. In terms of the generalisability of the findings (e.g. the key required skills evident for the five schools retrofit projects) the research recognises that they cannot be generalised to every school retrofit project beyond the scope of the research, but are representative of those projects within the investigation. The research however, can contribute by placing the findings in the context of the current skills theory, concepts associated with RIS theory, and possibly comment on methods adopted during the use of STNA methodology.

Finally, representativeness, whether a high or low degree is achieved, is connected to reliability in the sense that the data is consistent across different actors / cases (Neuman 2006). Again, from the network (the STN) established by the STNA methodology, a range of actors / actor groups were interviewed and observed to represent different actors' involvement and stages of each project. Furthermore, five cases were observed to represent different projects, a range of EEM across the schools and a variation in actors / actor groups across the projects.

Chapter 4 The case study and school retrofit project 1

4.1 Introduction

This chapter will introduce the case study under investigation, the local authority (LA) known as Wokingham Borough Council (WBC). A description of the LA departments involved in the projects will be given, and detailed information on the LA energy team, the key actors, their roles and involvement in the projects. Project 1 will also be introduced, a description of the project and school under investigation will be given, and the required skills identified for the delivery of the project will be outlined. Furthermore, an explanation of the mechanisms evident within the project will be stated.

4.2 The local authority

The local authority under investigation, Wokingham Borough Council (see section 3.6.1), spans a region located in south-east England, and neighbours five regions to form the county. The case study focuses on the LA sustainability department, more specifically the energy team within the local authority, who instigate and are the primary drivers of the school retrofit schemes. To meet energy reduction targets, the LA energy team are required to assess and look to reduce energy consumption of buildings that are owned by the local authority. The LA energy team consists of an energy officer and energy assistant, each having different responsibilities and roles during the development and implementation of the low and zero carbon (LZC) building projects. Other departments within the local authority are in communication with the LA energy team, and form part of the network to deliver low carbon schools during different stages of the projects. The buildings unit, for example, offer support to the LA energy team and will intervene with projects that require immediate work to energy systems or building facilities.

The local authority is responsible for sixty-two schools within the region. In order to meet LA energy reduction targets (e.g. reduction of energy and carbon emissions within LA owned buildings), the aim of the LA energy team was to reduce energy consumption in schools within the region, through the implementation of energy efficient measures (EEM). Not all schools were selected by the LA energy team for retrofit projects. School projects were selected in terms of 'priority / emergency' cases within the region, i.e. those that had high energy consumption and had the least EEM within the building. Schools without loft and cavity was insulation were seen as a priority. Schools were also proposed for retrofit projects where the head teacher had contacted the LA energy team for help and advice regarding energy reduction, and were considered for EEM implementation.

The funding of each school project varied within each of the projects. There is, however, a generic process by which the LA energy team follow (figure 4.1 below). The general procedure for the school retrofit projects at each stage and implementation of the EEM within the schools was as follows.

At the planning stage for the projects, driven by the LA energy reduction target, the LA energy team make contact with the school to organise an energy audit. Following an energy audit, the potential for the adoption of EEM is assessed and priority is given to those schools that are in urgent need of energy reduction. Ideally those schools that are deemed as 'emergency schools' have priority of EEM adoption / building work, but in reality the progression of the school retrofit projects rely on the engagement and co-operation with the school staff, accessibility to the school and funding for the various EEM. Furthermore, the LA energy team prioritise the more appropriate and beneficial EEM for the school (e.g. greatest energy reduction, reduce energy bills and convenience for the school staff / pupils). Low cost fabric measures, such as cavity wall / loft insulation and lighting are a first choice, followed by changes to the heating and cooling methods, and finally the implementation of renewable technology within the building. In contrast to this generic process of EEM adoption by the LA energy team, the school may also contact the LA energy team to discuss the possibility of EEM implementation within the school. During these early stages of enquiry, the school staff may research the EEM available for implementation, the different types of EEM for adoption and decide the EEM funding options that are most appropriate for the school. The LA energy team may also have input to this process and offer advice and information to the school in terms of building energy use and reduction. Following the initial meetings to discuss the EEM required for the building and possibilities of energy reduction, decisions surround the amount and source of funding for the projects, i.e. whether the EEM will be funded by the local authority, funding bodies, the school or a combination of all three options. The discussions relating to funding can be on-going throughout the project, where different EEM are planned and designed, encouraging negotiations between the local authority and the school.

During the design stage, following the decisions surrounding the EEM for the projects, the LA energy team assess, identify and appoint EEM contractors for the EEM. Three different companies for contractors are considered to compare the quality of work and prices. To hire a contractor for an insulation survey, for instance, the LA energy team consider a national and local contractor, plus one other contractor of choice. The contractor is chosen on price, preferably the cheapest, the perceived quality of work and reliability. All contractors are 'subject to survey,' which means they can visit the site and quote differently. Although, once the work has started, the contractor must abide by the agreed quote. At this design stage, the EEM contractors are predominantly EEM designers, EEM estimators or EEM surveyors, depending on the chosen EEM for adoption.

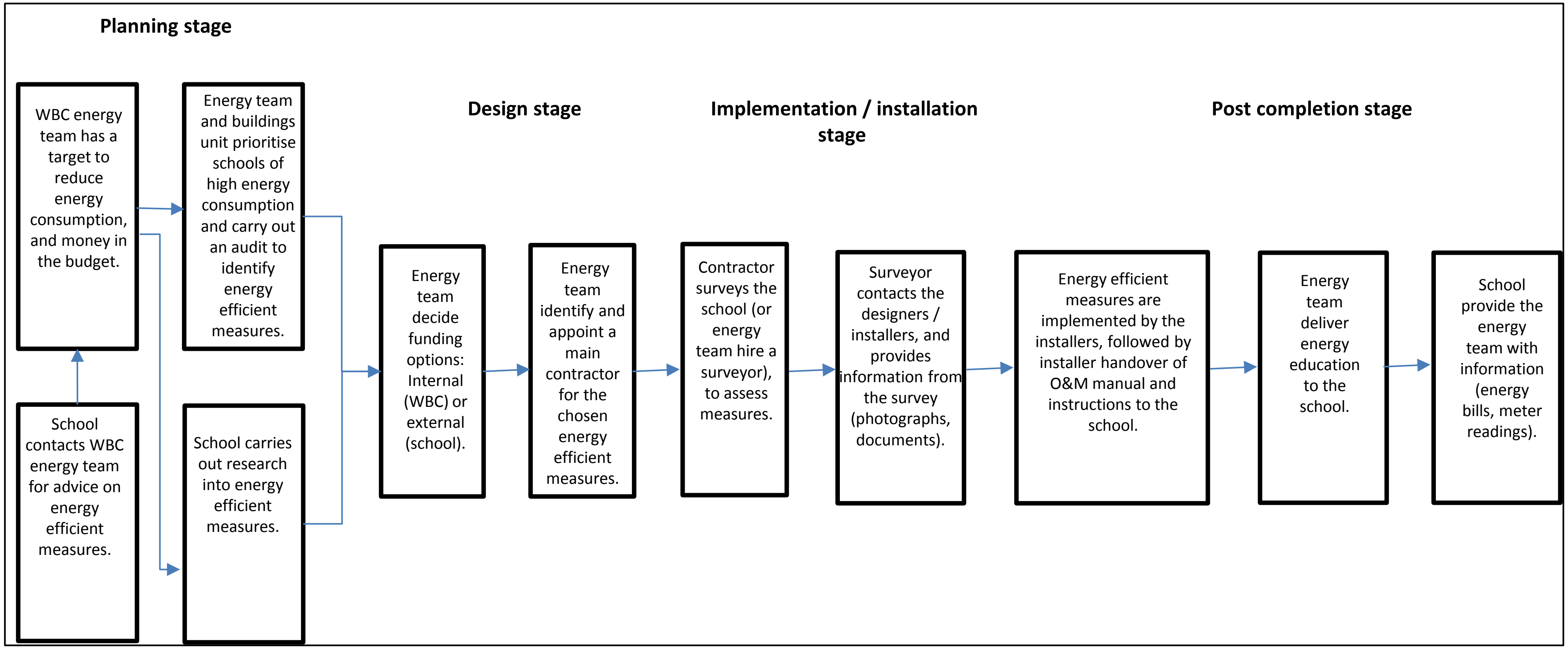

Figure 4.1: LA energy team school retrofit project process

During the implementation / installation stage, the chosen EEM contractors (primarily the EEM surveyor) assesses the building (e.g. conducts EEM surveys), the potential for EEM, and make further contact with EEM contractors (e.g. EEM installers) for the following EEM adoption stages. The EEM are implemented by the relevant EEM contractors and a handover is provided to the end-users. A handover can be instructions, booklets or explanations of the adopted EEM and its use.

4.3 School retrofit project 1

4.3.1 Description of school 1

Project 1 is a medium-sized primary school (figure 4.2) (three hundred and ninety-four pupils) in a village located south-west within the region. The school buildings and playground are surrounded by a local church, a number of houses and flats, and in close proximity to local businesses. The school has three main single storey buildings. First, a permanent structure containing classrooms, staff offices, toilets, a large hall and a staff room. Second, two temporary structures, referred to as a rollalongs, which consist of eight to ten classrooms each, both approximately twenty-two years old.

Figure 4.2: school retrofit project 1

4.3.2 Description of existing energy efficient measures / technologies

The heating system for the building was upgraded from oil to a gas supply during 2013. The permanent building has insulation (evidence of cavity wall insulation possibly 2010-2011), and a solar PV array (figure 4.2), which was installed during 2010 by a local renewable energy company. Both the staff and the head teacher at the primary school appeared to be conscious of energy use and proactive in terms of energy education, e.g. 'environmental lessons,' saving energy and creating a better environment for the pupils.

4.3.3 Areas for improvement identified by the energy audit

An initial energy audit indicated the permanent building of the school has much potential to enhance its energy efficiency. Loft insulation, for instance, required measurement in parts of the building, along with a lighting upgrade within a number of rooms and further development of energy behaviour was advised.

4.3.4 The implementation, or in the process of adoption, of EEM

Following the energy audit, energy efficient lighting (figure 4.3), double glazing (figure 4.4), and a half hourly meter were implemented within the school building, along with energy education to school end-users. Cavity wall and loft insulation was advised and a survey was conducted (August-October 2014). There were plans and discussions to implement loft insulation during spring / summer 2015 during the school holidays.

Figure 4.3: energy efficient lighting for project 1

Figure 4.4: double glazing for project 1

4.4 The regional innovation system (RIS) and socio-technical network analysis (STNA) for project 1

The RIS and socio-technical network (STN) that surrounds school project 1 is shown in figure 4.5 (below).

4.4.1 RIS elements

The research findings indicate there are seven key actor groups within the network, and each can be distinguished by their role within the RIS as follows:

Institutions

- Local authority (LA) energy team: respond to energy supply issues and concerns of local authority owned buildings, and monitor energy consumption within the buildings.
- Local authority (LA) building management team: provide funding and EEM support for local authority owned buildings.
- An external funding body: provide finance for project 1.
- School end-users (the school headmaster, business manager and site controller): monitor building energy consumption and co-operate for the implementation of EEM.

Firms (EEM contractors)

- EEM surveyor (loft / cavity wall insulation, lighting solar PV): provide an initial survey for the measure(s) and assess the potential for installation.
- EEM installer (insulation, double glazing, lighting, solar PV): install the desired measure(s) and (on occasions) provide information during the handover.
- EEM supplier (solar PV): provide materials / information to the PV installer.

Knowledge infrastructure

- LA energy team: provide training (e.g. energy auditing) and information (e.g. decisions around the EEM) to departments within the local authority, and information / awareness regarding the EEM to the school staff and (on occasions) to school pupils.

Policy orientated regional innovation

- LA: implement energy reduction targets for the local authority, such as the carbon emissions reduction target of 15% by 2015 and 40% by 2020. As stated in the Carbon Management Plan and the local authority Sustainable Environment Strategy, energy and sustainability targets are required to be met by the LA energy team.

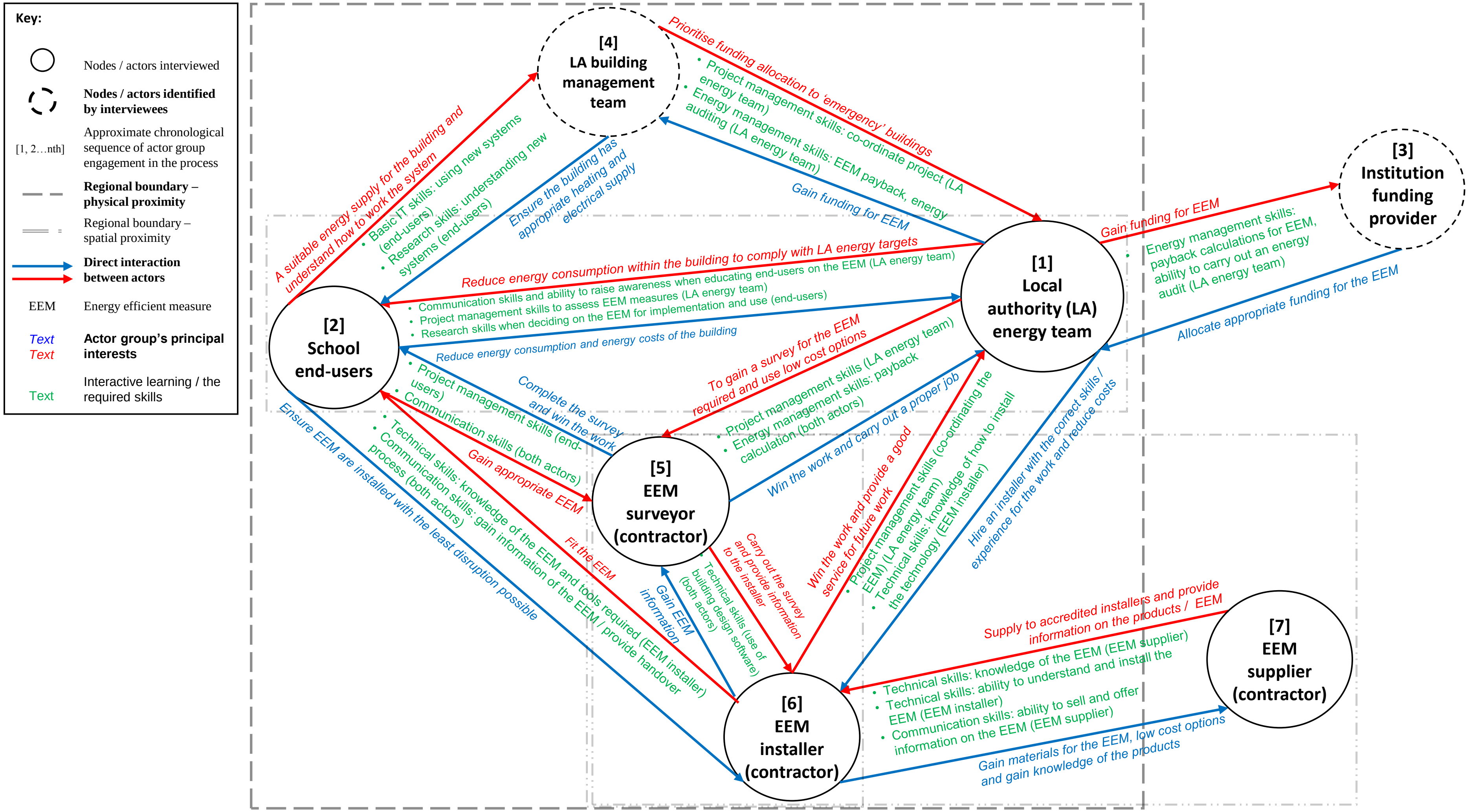

Figure 4.5: school retrofit project 1 - adoption of EEM and surrounding RIS / STN

4.4.2 RIS mechanisms

Definition of key skills required

Skills

The meaning of a 'skill' was unclear by certain actors involved in the delivery of project 1, the lighting electrical engineer (EE11) found it difficult to define the term, as commented that: *"It is tricky to say what an individual skill is."* A 'skill' was conceived by other actors in the project as the ability to perform a particular function at an individual level. The LA energy officer (EO11), for example, stressed that a skill was: *"….an ability to perform a particular function…your skill is the ability to deliver a particular thing. So for me, what I think of as skills, have been learnt over my 15-20 year history."* Furthermore, the school site controller (SC11) stated a skill consisted of getting the right end product, a mixture of physical and non-physical skills, and the ability to learn from previous experience: *"[A skill consists of] getting the right end product regardless...You can plan ahead with any sort of project. Plan ahead, make sure you have got it right as it's easier to put it right before it is in than after the event so… Hands on skills, more mental skills, you learn a lot more that is kept in your head. You know when you make a mistake, the old thought is you learn not to do that again."*

Energy management skills

Energy management skills (in the case of the LA energy team) were viewed in association with the ability to conduct and understand the energy auditing process for the property, i.e. evaluate building energy consumption and the potential to reduce energy use, and further assess a suitable EEM for the school (i.e. the ability to perform payback calculations for the EEM). This was highlighted by the LA energy assistant (EA11), by stating: *"…[I have looked at] energy management and the skills you need to calculate paybacks…And also things like detailed energy audit projects."*

Project management skills

Project management skills, in the case of the LA energy team, were connected to the co-ordination and organisation of the entire project, from planning and design to implementation and post completion, for each EEM being installed. Project management skills were further defined as the sourcing, costing and management of EEM products and EEM contractors, as explained by the school site controller (SC11) as stated: *"…I am good at project managing and sourcing, costing, what is best value for money with the ranges of products that are out there…You can plan ahead with any sort of project. Plan ahead, make sure you have got it right as it's easier to put it right before it is in than after the event so."*

Communication skills

Communication skills were described as the ability to effectively communicate, interact and hold conversations (surrounding the EEM process) with other actors / actor groups involved in the project to raise awareness and provide information, in regards to the EEM. More specific to the local authority, communication skills were related to the ability to educate and provide valuable information to the school end-users.

Research skills

Research skills were viewed as the ability to independently source EEM information, either using media such as the internet or the interaction with experts within the field, as mentioned by the school business manager (BM11) by expressing: *"certainly research skills I think looking at alternatives…google is your friend. It will tell you all about your product, there are great videos as well… then picking the brains of people who come in for the quotes."*

Technical skills

Technical skills were defined in connection with an individual's knowledge of technology as captured by the LA energy assistant (EA11) who expressed: *"I associate it [a technical skill] more with the technology, so in depth knowledge surrounding the technology."* Furthermore, the electrical engineer (EE11) extended the meaning of a technical skill to include the ability to understand and possess knowledge of the specific EEM adopted by stating: *"You have to have good electrical knowledge for the whole thing to work out what light fittings you can and cannot do… you have to have and be aware of and do is lighting design."* The definition of technical skills can be further extended to include knowledge of how to fit the EEM (possibly previous experience with the measure), the understanding of tools and specialist software. This view was captured by the PV surveyor (PVSU11) as expressed: *"When we do the installations [for which a technical skill is required] we [installers] need NICEIC [National Inspection Council for Electrical Installation Contracting] registered electricians. You can't just take a Part P qualified household sparky, they won't know about conduit trainwork… we do use some specialised software in design… you would have to learn how to use it. We have another package they [installers] use for actually doing the roof layouts, and it's basically a CAD package but has been tailored to PV."*

Interactive learning: evidence of skills required through negotiations

Through the identification of the principal interests of the key actors / actor groups and the key skills required for project 1 (see below), interactive learning, a RIS mechanism, and negotiations between actor groups within the network were highlighted. Negotiations also gave further insight to the meanings and definitions of key skills required for the delivery of the project. There are ten key interactions surrounding the delivery of project 1:

Interactions between the key actor groups

1. Interactions between the LA energy team [1] and the school end-users [2]

(1) Principal interests

The key interest of the LA energy team was to comply with the energy targets stated by the local authority in order to reduce energy consumption of the building (see figure 4.6 below of the socio-technical network (STN) showing principal interests of the LA energy team). Further interests were to encourage energy efficiency, reduce energy costs and provide energy education for school 1. The energy assistant (EA11) for example, stated that:

"So if we can save them [schools] money that's great but we also save them energy even better for us to meet our targets…I look at long term costs financially and how much they [schools] will save off their energy bills….we help with energy advice… we need to make sure they are energy efficient products…its all about energy education, the same in schools as well."

The key interests of the school end-users were to reduce energy consumption within the building and the cost of the school energy bills (see figure 4.6 below for the key interests of the school end-users). Further interests of the school were to gain knowledge / skills on how to use the EEM, and achieve energy savings.

During an observation (OB2) of the school energy audit, and during a meeting with the energy officer and headmaster (OB1), advice was given in relation to the adoption of different EEM (those available on the market). The school were interested in the EEM that had short payback periods (e.g. paintwork and insulation), those that were quick and easy to implement (e.g. lighting) and the EEM with funding availability. The meeting also allowed the energy officer (EO11) to look at how the school was using the solar PV, (e.g. the energy generated annually). During the energy audit, the energy assistant (EA11) offered advice on how to assess a faulty system and the correct paperwork required for the school to receive income from the government feed-in-tariff.

Furthermore, when speaking to the school business manager (BM11) it was stated that:

"We [school] had some sort of assistance and advanced knowledge [from the local authority]…So we identified what we thought was the best place for them [PV panels]…We looked at the different types of panels, some will feed in. I think what we were looking for was the FIT [Feed-In-Tariff] and that was the information we got from the energy officer."

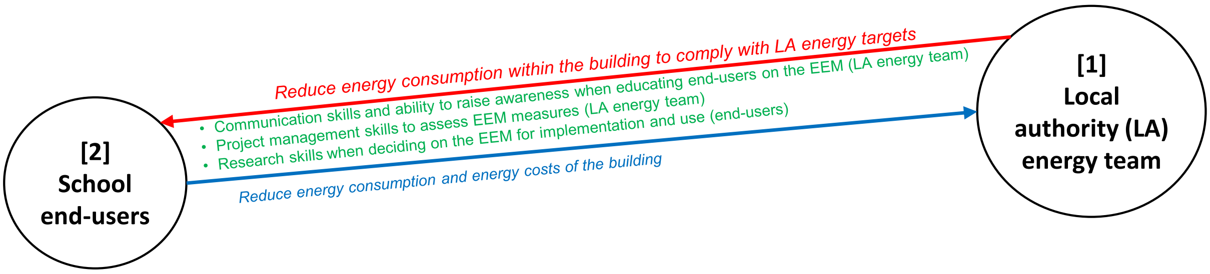

Figure 4.6: the STN showing principal interests, negotiation issues and required skills between the LA energy team and school end-users

(2) Key negotiation issues

Two principal negotiation issues were raised (see figure 4.6 for evidence of negotiation issues and required skills for the LA energy team and school end-users). The first negotiation was linked to the choice of the EEM through its suitability and the funding available. Those that were simple to install, and could be used and understood easily by the school (i.e. users had the appropriate skills and knowledge) were of preference.

The negotiation was highlighted during an observation (OB1) of a meeting between the LA energy officer (EO11) and the school headmaster for particular measures. Of particular concern were the correct use and accuracy of the existing PV installation and PV array within the building.

The communication between the school and LA energy team, and advice of EEM, were further highlighted by the school business manager (BM11) who stated:

"We looked at the different types of panels, some will feed in. I think what we were looking for was the FIT and that was the information we got from the energy officer and the school governor. That was the sort that we needed as that would give us more assistance moving forward."

The second negotiation issue surrounded raising awareness within the school of EEM through communication and education for end-users, particularly the children.

The need for communication and education was supported by the energy assistant (EA11), who mentioned:

"…its all about energy education, the same in schools as well…I get the children to be as interactive as possible. I ask them where the big energy sources are within the school and as what can you do."

2. Interactions between the LA energy team [1] and the institution funding provider [3]

(1) Principal interests

The interest of the energy team was to gain funding for the EEM, and achieve the required payback period. The interest of the institution funding provider was to allocate appropriate funding for measures (i.e. a payback period of 5-7 years).

During an observation (OB1) of a meeting between the energy officer (EO11) and headmaster of school 1, the details of funding availability and its allocation from the institution funding provider, along with the 5-7 years required payback period, was explained to the school.

(2) Key negotiation issues

Two key negotiation issues were raised. First, the allocation of funding to the energy team and second, the ability of the energy team to meet the payback period for project 1. Linked to the assessment of payback periods, the calculations involved and the need to gain further knowledge of energy auditing, the energy assistant (EA11) required the attendance of an energy management course, provided by an energy institution outside of the region.

The energy assistant (EA11) highlighted the need for training to gain skills by stating:

"I have learnt a lot about the insulation basics like what can and can't be done…I had the energy management course last year…in London…The course maybe honed in on my skills a bit…As I don't have skills in project management, I can't fully get involved in any project…I've requested to do some prince two training for project management skills that would be great."

The observations (OB10 and OB11) of meetings with the LA energy team and different local authority departments (OB12) further evidenced this. An explanation was given with regards to the insulation for schools, stating the primary means of funding (i.e. the institution funding provider), along with insulation being the first energy efficient measure adopted, due to its short payback period.

In addition, the energy assistant (EA11) stated:

"[I looked at]…in depth about energy management and the skills you need to calculate paybacks – a lot of maths. And also things like detailed energy audit projects."

3. Interactions between the LA energy team [1] and the LA building management team [4]

(1) Principal interests

The key interest of the energy team was the gain funding for the EEM.

During an initial meetings (see appendix A) and meetings / observations (OB11 and OB12) with the LA energy officer (EO11), the process of gaining funding for local authority buildings was explained, where the energy team are required to justify the costs and assess EEM payback periods. This was supported further by the energy officer (EO11), who stated:

"So payback came in year 3 or 4 and bear in mind I'm tied into a 7 year payback. So for me I have slashed it in half, great. That then makes it better for me in terms of getting funding for the future, because the council love that sort of thing, invest a savings initiatives."

The key interest of the LA building management team was to prioritise funding allocation to 'emergency' buildings within the region. Again, this was highlighted during meetings and observations (OB10 and OB11) with the energy officer (EO11) (see appendix A) where it was explained that the LA building management team can issue funding to those 'priority' buildings.

(2) Key negotiation issues

One negotiation issue was raised that surrounded the justification of funding and allocation for the building. As indicated in the principal interests of the LA energy team, there was the negotiation regarding the ability of funding for EEM and allocation of funding for the project.

4. Interactions between the school end-users [2] and the LA building management team [4]

(1) Principal interests

The key interests of the school end-users were to gain a suitable energy supply for the school, along with understanding the new EEM installed (see figure 4.7 below of the STN for principal interests of the school end-users). This was evidenced by the school site controller (SC11), who mentioned:

"The electrics, the heating, the solar panels. We do a, keep an eye on them, look at the clock and the timer there. You got to look at everything, from how the boilers work to how it affects what time the heating in the school is going to come on. Obviously the school is a big place, there is no good for them to be kicking in at 8 o'clock in the morning because the kids come in at 9, they need to be on a lot earlier. So things like that you have to learn.

The interest of the LA building management team was to provide the school building with an appropriate heating and electrical supply (see figure 4.7 below of the STN highlighting this principal interest). The interest was captured by the site controller (SC11), who stated:

"We have our new heating system now that is more energy efficient. We put it on gas. We were on kerosene, but we had that upgraded [by the local authority] 18 months ago."

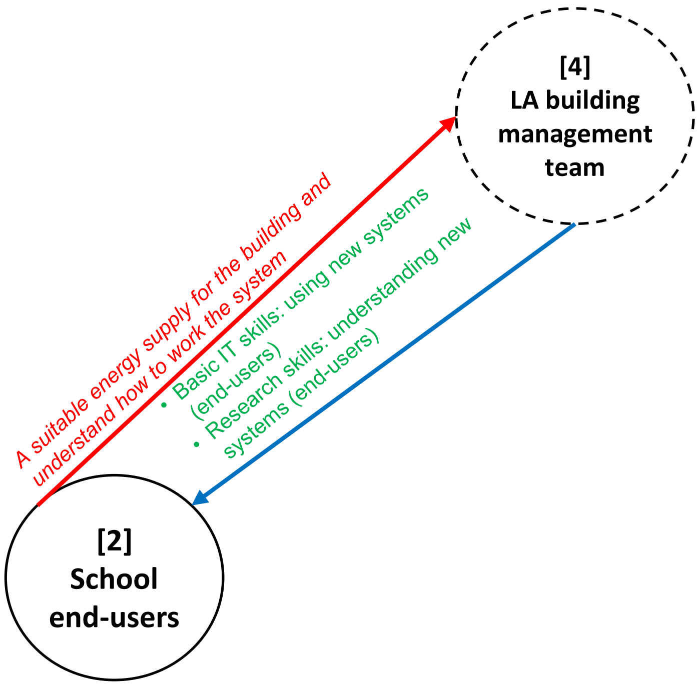

Figure 4.7: the STN showing principal interests, negotiations and required skills between the school end-users and the LA building management team

(2) Key negotiation issues

One negotiation issue was raised that surrounded the use of the new energy [heating] system in place, primarily the skills required to understand and operate the system (see figure 4.7 for evidence of negotiations and the required skills for the school end-users and LA building management team). As explained by the school site controller (SC11), who expressed:

"But that [new heating system] is all done now on the computer system, so you need new skills there to go into the timers to set it up in case you have an event one night and need the heating to be on a little longer. There are new skills on that…I'm good with my hands but not very good with computers. So it is learning all of them skills, and learning and understanding how all of them work. We got 2

boilers and they both don't need to be on at the same time, so they transfer over and, so you need to find out how they are working and how they are generating the hot water for the kitchens. It is a totally new system, so I had to learn a lot from there."

5. Interactions between the LA energy team [1] and the EEM surveyor [5]

(1) Principal interests

The key interests of the energy team were to gain an accurate and extensive survey for the EEM required, and use low cost options.

During a meeting with the energy officer (EO11), it was explained the chosen insulation surveyor would be the surveyor who produced an accurate survey, along with the method used to survey the building. A surveyor that came out to site, for example, would be preferred over those that performed a 'desktop' (GIS) exercise.

To further test the accuracy of the survey and method used by the surveyor, the energy officer (EO11) explained the process of hiring the EEM surveyor, by stating:

"I sent out a document that had 2 errors on it, I did it deliberately to see if the errors were picked up on. The errors weren't picked up on and they were quite technical errors."

The energy assistant (EA11) explains the preference of low cost options by the LA energy team, more specifically lighting materials in this case, as mentions:

"LED's were not really an option 4 years ago. But now as pricing has come down its quite competitive with the normal fluorescent lamps now. A lot of schools are actually going down the LED route…"

The key interests for the EEA surveyor were winning the work and carrying out the job correctly to gain further work with the local authority. The insulation surveyor (SU11), for example, states the priorities when surveying and key skills required for the work:

"The biggest thing is that I do a proper job. …when I quote a job I sit down and I work out any material involvement and I and work out how long it's going to take to do it properly…I live and die on the quality of my last job…It's just about being thorough careful and conscientious…to remove a suspended ceiling and reinstate it is something that takes a little bit of time and care. No great level of skill, you have to just approach it with a slightly different mind-set."

(2) Key negotiation issues

Two negotiation issues were raised. First, the EEM job to be carried out, more specifically the decisions surrounding the type of EEM required. In this case it was the lighting upgrade where the electrical engineer (EE11), both surveyor and installer, explains the level of involvement in choosing the measures and negotiation with the local authority, by stating that:

"We specify the light. Actually we get some advice, it all depends on the councils. For instance, the local authority are very pro LED lights… cause it's the latest technology as such, so they want to go that way. Although it's not always the best for payback if you see what I am saying."

The second negotiation issue surrounded the cost of the survey in terms of which surveyor to choose for value for money and a good job. The school business manager (BM11), supports this negotiation regarding the surveyor and price, as explains:

"We contemplated all types and varieties but decided that this was what we wanted. This was a fairly big project at the time…They did a survey yes, we got quotes from all of the upgrades over the summer."

6. Interactions between the school end-users [2] and EEM surveyor [5]

(1) Principal interests

The key interests of the school were to gain an appropriate EEM and gain information about the measure, i.e. learning from others. The school business manager (BM11), for example, stated that:

"They [the surveyor and energy officer] came and did the survey and agreed that was the best place. The angle was correct and the aspect was correct and we worked towards that really."

Furthermore, the school business manager (BM11) explains:

"[the school end-users learn by] picking the brains of people who come in for the quotes. You know, you ask them questions and you learn from them as well. It is almost free advice isn't it?"

The school business manager found it key to learn from both the surveyor and energy officer in order to gain knowledge regarding the choice and implementation of the EEM.

The interest of the EEM surveyor was to complete an EEM survey and win the work. This was evident by the solar PV surveyor (PVSU11), who stated:

"…the school contacted my company to do the survey, the quote and everything, and I was the surveyor on site. I did the original survey, and helped get the information to be able to do that."

Furthermore, the school business manager (BM11) explained the process of the surveyor winning the work by stating:

"So they [EEM surveyors] came and did the survey and agreed that was the best place. The angle was correct and the aspect was correct, and we worked towards that really."

(2) Key negotiation issues

One negotiation issue was raised between both actor groups. The issue involved the type of EEM required for the school, and on occasions the site controller (SC11) and energy officer (EO11) helped to make an assessment due to their existing knowledge and skills.

The lighting surveyor / installer (EE11), for example, highlighted that:

"I have been walking around the school with the energy officer. So we take a site man [site controller] of the school, he looks at the areas he wants for energy saving. We make a note and measure up the areas, make a note of the light fittings that are there, and I come up with the alternative."

The site controller (SC11) further mentions his use of knowledge and skills required for the assessment of measures:

"…I am good at project managing and sourcing, costing, what is best value for money with the ranges of products that are out there. It is not always best to go cheapest… [on the need for a project management skill] yes, for what they pay me I do."

7. Interactions between the LA energy team [1] and the EEM installer [6]

(1) Principal interests

The key interests for the energy team were to hire an EEM installer with appropriate skills / experience to install the EEM and minimise costs.

The energy assistant (EA11), for example, highlighted the level of experience and specific qualifications are key for the choice of installer, as stated:

"…for windows they have to be Fensa registered [window installer qualification]…I guess experience, have they worked with other authorities, have they worked with other schools, have they had a CRB [Criminal Records Bureau] check…have they done successful projects. With lighting we need to make sure they have success in what they do…"

The key interests of the EEM installer were to win the work, provide a good service and an install of high quality for future work with the local authority.

(2) Key negotiation issues

Three negotiation issues were raised. The cost of the install (value for money), the details / type of EEM being installed and times of installation.

The energy officer (EO11), explained the potential issues of an installation and reasons behind the emphasis on skills and capabilities of an installer, as explained:

"Like I say, even for these lighting pilot projects that we are doing. I am having to take a contractor out…it's a huge project. There are all sorts of if, buts and maybes, towards if you rip the product out what is behind it you know. So how are you going to pay? What are you going to do to make sure the school services as in the kids are not interrupted? Are you going to do it when the school is there, are you going to do it in half term?"

Furthermore, the PV surveyor (PVSU11) explained the requirement of knowing how to install the EEM, in relation to the use of a technical skill, by stating:

"My boss, the technical director, took them to a site they were working on and said OK off you go. Watched them. Rejected 8 of them as they didn't know what they were doing really, just making it u as they go along…there is the second level, the more technical level so with PV the electrical side of it, the regulations and how you should wire that in…you have the nuts of bolts of how to fit it, but you also need to understand how to set it up properly and explain to the customer how to keep it going."

8. Interactions between the EEM surveyor [5] and EEM installer [6]

(1) Principal interests

The EEM surveyor was interested in carrying out the survey correctly and providing the correct information for the install. The principal interests for the installer were to gain appropriate information from the surveyor of the EEM to be installed (e.g. photos of the building and detailed survey), and provide a good service to carry out further work with the surveyor.

This was highlighted by the PV surveyor (PVSU11), for example, who stated:

"It also doesn't instil the customer a lot of confidence when they are having to ask the customer or standing around having sort of conversation, or left the form in the office. They [surveyor, architect, designer and installer] should have a set of drawings, photographs, a checklist and some sort of procedure."

(2) Key negotiation issues

One negotiation issue was raised, which surrounded the work that was required for the EEM, i.e. the skills and knowledge required.

The skills required for the installer, for example, were illustrated by the PV surveyor (PVSU11):

"When we do the installations [for which a technical skill is required] we [installers] need NICEIC [National Inspection Council for Electrical Installation Contracting] registered electricians. You can't just take a Part P qualified household sparky, they won't know about conduit train work…"

9. Interactions between the EEM installer and EEM supplier

(1) Principal interests

The key interests for the EEM installer were to gain the correct materials for the work, at the cheapest price and gain knowledge on the product.

The key interest for the EEM supplier was to supply to those EEM installers who were suitable to install their products (i.e. accredited installers) and possibly provide information on the product.

This was evident by the solar PV supplier (PVSM11), who explained the process of supplying materials for the PV install and communication with the EEM installers:

"…we will go and sit down with the partner, installer and the end user. It maybe they just want to know the sort of brief history of the PV supplier company, why is it so expensive, talk about the technology that goes into it and why it is so different and the most efficient product on the market."

The PV supplier further explains some of the skills (i.e. soft skills) needed when selling the product:

"People are different, its being about being personable. Sometimes you will go into a meeting with a partner and you won't talk about PV at all. You'll say how the wife, how are the kids."

(2) Key negotiation issues

Two negotiation issues were raised, which were associated with the suitability to work with the installer (i.e. the installer capabilities, skills and willingness to learn), along with the price of the materials required.

This was highlighted by the PV supplier (PVSM11), who expressed:

"…there are certain criteria they [installers] have to meet to become a [solar PV company] partner…so we give a lot of training, marketing support and sales support…we support the partners [installers] with training and given the talks to be able to answer those questions. We also have a technical team so if it's something I couldn't answer we have a point of reference and say look guys can I get some

help with this…We also have an installation guide manual that they [installers] use, so they know how to install the product…We have a senior trainer…He comes to the UK and we run training events, we invite partners along, he comes in and we talk about the advantages of RS13[the EEM supplier's company], why it's a different technology, common mistakes, cable sizes, all the technical bits and pieces."

It is interesting to note that the EEM supplier refers to the EEM installers as 'partners' as installers become trained, accredited and part of the EEM supplier team before they are able to install the EEM. The process is explained as important by the EEM supplier and possibly unique to the company.

10. Interactions between the school end-users and EEM installer

(1) Principal interests

The key interests of the school end-users were to have the EEM installed and gain information / skills on the EEM.

When asked about the skills needed for the PV install and whether anything new was learnt, the school business manager (BM11) stated that:

"Oh yes. Obviously I learnt quite a lot but it's not something I use every day. I could perhaps give somebody advice in the future."

The site controller (SC11) further suggested that:

"You have a better rapport with the guys, you get a better job out of it. They don't just want to come here, throw something in and run."

The EEM installer was primarily interested in getting the job done, i.e. fitting the EEM, the handover process (information and documents for the EEM), and school co-operation.

The school business manager (BM11) stated that:

"I think they [the PV installer company] put the panels in for us and they were extremely helpful. If I have any issues I will phone them up and they will explain to us. They gave us a little booklet with all the information in."

(2) Key negotiation issues

One negotiation issue was raised, which involved discussions surrounding an appropriate date and time for the install.

To explain previous experience in a school, the insulation surveyor mentioned:

"*We had gone in the kitchen and accessed the loft while the school was open. Stuff wasn't being prepared whilst we were going up and down…[an inspector] said we couldn't work like that, creating dust and stuff. So we stopped for two hours whilst they prepared lunch.*"

Summary of the skills required

Project 1 evidenced a number of key skills required for the principal actor groups involved in the project. The required skill set for the local authority were project management skills, energy management skills and communication skills. For the EEM contractors, technical skills were a principal requirement, followed by the need for a communication skill to interact with other EEM contractors and school end-users (mainly school staff). The dominant skills required for school end-users were communication skills, the ability to carry out research for the EEM, and project management skills (project management more specific to the initial planning stages of EEM adoption).

Knowledge production

Both tacit and explicit knowledge were captured within the network surrounding project 1. Explicit knowledge, for example, was evident though the observation (OB1) of a meeting that involved the school head teacher and LA energy officer, and energy audits (OB2) by the LA energy assistant. Explanations were provided by the LA energy team in regards to the EEM funding options and most appropriate EEM for adoption by the school. Linked to knowledge management, even though the LA energy team provided knowledge and information regarding the choice of the EEM, the school end-users, primarily the school staff, required additional research skills to understand what to do and how to maximise the EEM knowledge. Furthermore, the EEM suppliers (solar PV) stated it was standard procedure to provide information and further training to the EEM contractors that installed their products. Project 1 captured the use and further challenges experienced with the solar PV, by both the end-users and possible the installers. This indicates the importance of the explicit knowledge in the network, but also how the EEM suppliers may have provided tacit knowledge, or are required to offer further information through the supply of the EEM products. In contrast to explicit knowledge evident within the network, tacit knowledge was noted in connection to the post-installation of an EEM. The solar PV, for example, caused much confusion for the school site controller in terms of the information given by the visual display unit and the standard procedure for issues with the system. There were further issues for the school business manager in terms of payment from the electricity generated. Project 1 evidenced the value of knowledge management due to further understanding around the EEM by the school end-users and EEM contractors. Both explicit knowledge and tacit knowledge was not sufficient to fully install or use the EEM.

Proximity: physical and spatial

Project 1 highlights a network where the majority of actors / groups of actors were located within the region, emphasising the small physical proximity between those involved in the delivery of the project. The EEM suppliers were based at a national level and the only EEM contractors located outside of the boundary. In terms of spatial proximity, the school appeared in close communication and frequent interactions with both the LA energy team and a number of EEM contractors. The site controller, for example, referred to a number of EEM contractors on first name basis and used their services on previous projects. These strong relationships could be linked to the location and physical proximity of the EEM contractors. Furthermore, spatial proximity was also evident between the EEM contractors, where exchanges of information, training and conversations were captured.

Embeddedness

Project 1 indicated high levels of embeddedness both within the local authority and within the LA energy team. Close relationships and social interactions were captured by the energy assistant and energy officer, learning from, and supporting, each other (the only two members of the LA energy team). Embeddedness was also evident within the school between the school staff, primarily the school site controller and other members of staff.

Chapter 5 School retrofit project 2

5.1 Introduction

This chapter will introduce project 2 of the research. A description of the project and the school under investigation will be given. The required skills identified for the delivery of the project will also be outlined. Furthermore, an explanation of the mechanisms evident within project 2 will be stated.

5.1.1 Description of school 2

Project 2 is both a nursery and a primary school (four-hundred and seventy-one pupils in total), located in a small town towards the west of the region. The school is predominantly surrounded by houses, and situated in close proximity to the boundary of the region. The building is approximately thirty years old, with various extensions (e.g. library approximately twenty years old) and a number of temporary structures known as rollalongs. The display energy certificate for the building is ‘D’ rated, i.e. a score of eighty-seven (figure 5.1), which is above the ‘typical’ building energy rating of one hundred. The school appeared to be conscious of its energy use, having an eco-schools programme and eco-team in place, along with being in the process of gaining the Green Flag award.

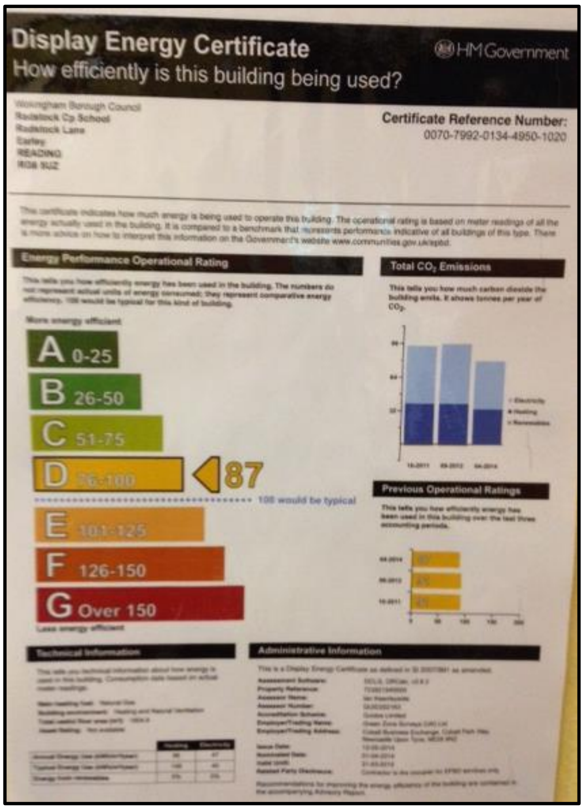

Figure 5.1: display energy certificate (DEC) for project 2

5.1.2 Description of existing energy efficient measures / technologies

The main building has been fitted with loft insulation and a number of rooms having had T8 light bulbs installed, as oppose to the less efficient T12 light bulbs. The school also has a solar PV array (6Kw) (figure 5.2), which was installed during February 2010. See figure 5.3 for the solar PV display unit, taken December 2014.

Figure 5.2: an example of the solar PV array installed within the school building

Figure 5.3: solar PV display unit

5.1.3 Areas for improvement identified by the energy audit

To enhance the energy efficiency of the building, an energy audit identified additional loft and cavity wall insulation, specifically to those classrooms towards the centre of the building. It was mentioned during an initial survey that loft insulation implemented within the rollalongs would cause health and safety issues, and not advised. Further areas for improvement included an evaluation of the building heating system, changes to the glazing area and advice for energy behaviour within the building. The primary concern by school end-users were the extreme temperatures of the building, which ranged from cold to very hot throughout the year. The implementation of the above energy efficient measures (EEM) and improvements to the building were suggested to mitigate and reduce these building issues.

5.1.4 The implementation, or in the process of adoption, of EEM

Improvements were made to the building in terms of changes to the glazing area, i.e. double glazing, and the installation of a half hourly meter. A cavity wall and loft insulation survey was carried out for the building, and loft insulation was planned. In spite of the plans for insulation, due to complications associated with the fitting and incorrect tools on-site, installers were unable to implement the insulation. The future install was planned for summer (i.e. school holidays) 2015.

5.2 The regional innovation system (RIS) and socio-technical network analysis (STNA) for project 2

The RIS and socio-technical network (STN) that surrounds school project 2 is shown in figure 5.4 (below).

5.2.1 RIS elements

The research findings indicate there are nine key actor groups within the network, and each can be distinguished by their role within the RIS as follows:

Institutions

- Local authority (LA) energy team: respond to energy supply issues and concerns of local authority owned buildings, and monitor energy consumption within the buildings.
- Local authority (LA) building management team: provide funding for local authority owned buildings.
- Institution funding provider: provide finance for LA energy team projects (e.g. project 2)
- School staff (the school head teacher, business manager and caretaker): monitor building energy consumption and co-operate for the implementation of EEM.
- School pupils and parents (the school pupils and parents of school pupils): participate in school activities associated with eco-week and the Green Flag award.

Firms (EEM contractors)

- EEM estimator (loft / cavity wall insulation): provide an estimate and manage the process for the measure(s).
- EEM surveyor (loft / cavity wall insulation, double glazing): provide an initial survey for the measure(s) and assess the potential for installation.
- EEM installer (insulation, double glazing, half hourly meter): install the adopted measure(s) and (on occasions) provide information during the handover.
- EEM supplier (insulation, double glazing, half hourly meter): provide materials / information for the install of the adopted measure(s).

Knowledge infrastructure

- LA energy team: provide training (e.g. energy auditing) and information (e.g. decisions around the EEM) to departments within the local authority, and information / awareness for the EEM to the school staff and (on occasions) to school pupils.

Policy orientated regional innovation

- LA: implement energy reduction targets for the local authority, such as the carbon emissions reduction target of 15% by 2015 and 40% by 2020. As stated in the Carbon Management Plan and the local authority Sustainable Environment Strategy, energy and sustainability targets are required to be met by the LA energy team.

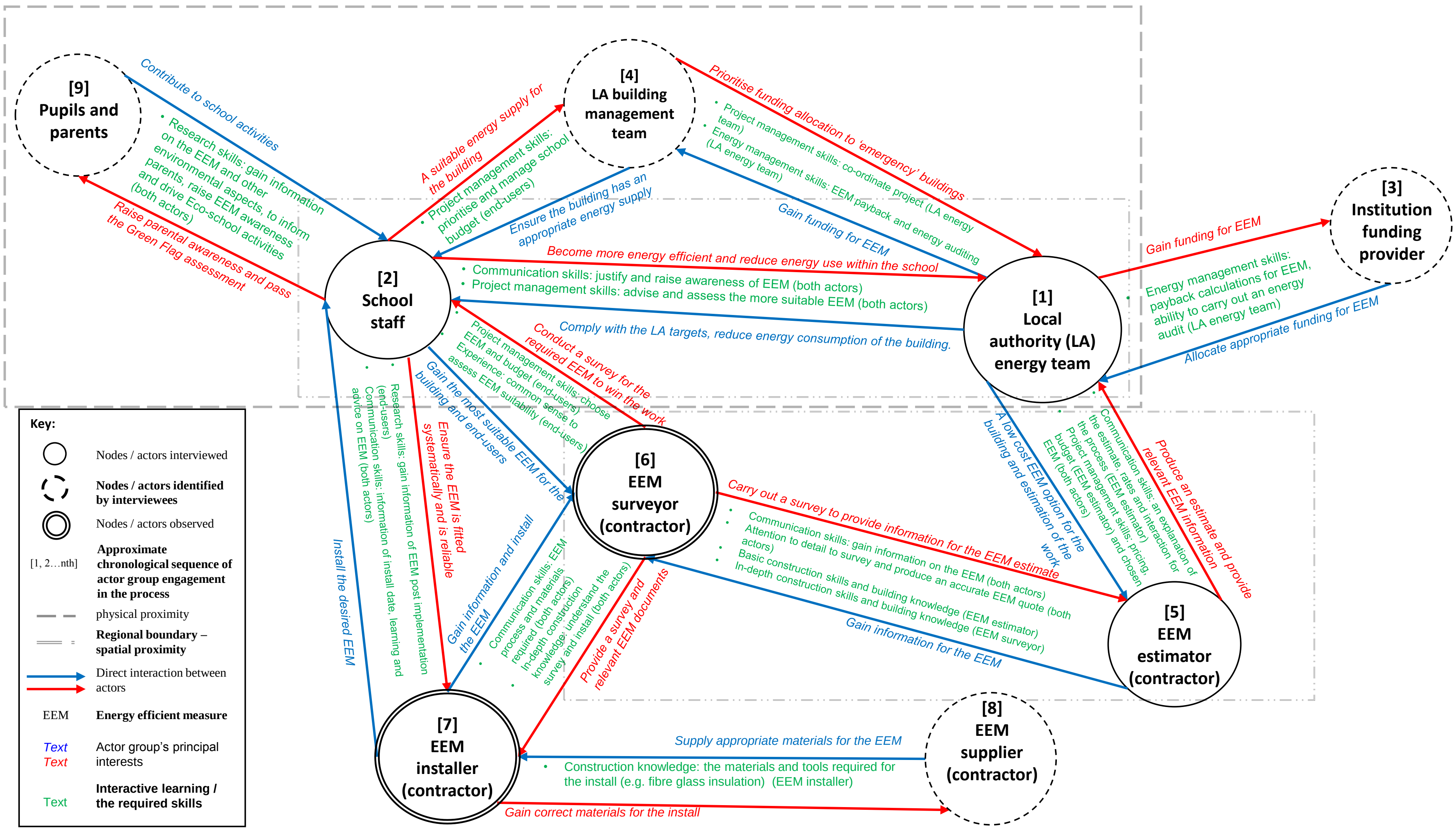

Figure 5.4: school retrofit project 2 - adoption of EEM and surrounding RIS / STN

5.2.2 RIS mechanisms

Definition of key skills required

Technical skills

Technical skills were associated with an individual's knowledge of the technology and understanding in detail of how the technology operates. This view was supported by the estimator (ES21), who stated: *"It [PV knowledge] can be a lot more technical. The same with external wall insulation it's a lot more in depth than cavity wall…if it is to save energy and perhaps the more technical side, we can let them know how much they are saving perhaps in a year."*

Interactive learning: evidence of skills required through negotiations

Through the identification of the principal interests of key actors / actor groups and the key skills required for project 2 (see below), interactive learning, a RIS mechanism, and negotiations between actor groups within the network were highlighted. Negotiations also gave further insight into the definitions of key skills required for the project. There are eleven key interactions surrounding the delivery of project 2:

Interactions between the key actor groups

1. Interactions between the LA energy team [1] and school staff [2]

(1) Principal interests

The principal interests of the LA energy team were to comply with LA targets and reduce energy consumption of the school building (see chapter 4). This view is supported by the school head teacher (HT21) who explained, due to cold classrooms, the adoption of EEM measures by the LA energy team for the school, as stated:

"Yes [the new convective heaters are] working and much more efficient. We have also put in two thirds of the windows in there as well."

The principal interests of the school staff were to become more energy efficient and reduce energy use within the school. The interests were highlighted by the school head teacher, who encouraged the adoption of EEM within the school, as mentioned:

"It was something we were interested in doing, becoming more energy efficient…energy efficiency is part of our school improvement plan…we, every year, have an energy certificate, display energy certificate and if you compare ours against a lot of the local cluster schools, we are more efficient."

(2) Key negotiation issues

Two negotiation issues were raised. First, the negotiation surrounding the justification of EEM and raising awareness within the school highlighted the requirement of communication skills for both actor groups.

The school head teacher (HT21) emphasised the negotiation and communication between the school and LA energy team through the process of EEM adoption, by stating:

"So we [the school staff] went to the governors and said there is this grant, is this possible. So a group of governors and us met the energy officer and he came did a presentation to the governors…

Second, the negotiation issue relating to the selection of suitable EEM emphasised the requirement of project management skills. The LA energy team (more specifically the energy officer) appeared to require a higher level of project management skills and greater involvement in the choice of EEM, however, the school staff still had a significant contribution to the assessment and choice of EEM. As explained by the school head teacher, who stated:

"We [the school staff] spoke to the energy officer about it, and we had problems with our heating so it's part of the whole package. So they [LA energy team] are looking at upgrading the heating. The classrooms were really cold so they have put in heaters, convective heaters…we have gone with the [double glazing window] design that actually is most suitable for the outside as that is an outside area. We need restrictors on them as we don't want people climbing in."

2. Interactions between the LA energy team [1] and the institution funding provider [3]

See chapter 4 section 4.4.2

3. Interactions between the LA energy team [1] and the LA building management team [4]

See chapter 4 section 4.4.2

4. Interactions between the school staff [2] and the LA building management team [4]

(1) Principal interests

The principal interest of the school staff was the use of a reliable energy supply for the building. The principal interest for the LA building management team was to ensure the local authority owned buildings have an appropriate energy supply.

A meeting with the energy officer (OB10 and OB11) and observation of the energy audits (OB2, OB6, OB7) supported the above interests. The LA building management team are most concerned with the heating and electricity supply for LA owned buildings, more so than saving energy within the school.

The school head teacher (HT21) further expressed the concern with the heating system, primarily the whole heating system of the building, in addition to the convective heaters, as mentioned:

"…we [school staff] have had all sorts of issues with the gas boilers. But part of the problem with the heating around the school is that parts have been upgraded separately…"

(2) Key negotiation issues

One negotiation issue was raised in regards to the adoption of EEM and the available budget by the school and LA building management team, highlighting project management skills. The negotiation is similar to that between the school staff / LA energy team and school staff / EEM surveyor, however, the negotiation is more focussed on the school heating system and supply.

This negotiation highlights the requirement of the ability to budget and prioritise the spending within the school. As explained by the school head teacher (HT21), as stated:

"We would love to [have more EEM] if they [LA] will help us, but we have such limited budget now… It is about priority, I mean will we look to save a few hundred pound when we have toilets that are in desperate need of replacing. It is about prioritising where our needs are."

5. Interactions between the school staff [2] and the EEM surveyor [6]

(1) Principal interests

The principal interest of the school staff was to gain the most suitable EEM for the building and end-users, i.e. fellow school staff and pupils. As indicated by the head teacher (HT21), in connection to the choice of double glazing window styles, frames and fittings, it was stated:

"They [double glazed windows] have made a brilliant difference, the only difference is that you don't get...as they have a hinge on there because we don't want people climbing out or in. You've got to be mindful of the air circulating. We have replaced 3 opening windows, where there were only 2 opening windows before. So we have created more openings and replaced the fixed window but I am conscious it's about the air circulating."

The principal interest of the EEM surveyor was to conduct a survey for the required EEM to win the work. This interest, and EEM process, was explained by the EEM estimator (ES21), as expressed:

“Then he [the energy officer] sent the project 2 school through for us to go and survey and we won the work and then fitted it…It was just loft. I have a copy of the quotation letter. Before we won the job to carry out the survey.”

(2) Key negotiation issues

One negotiation was raised that presented the decisions surrounding the suitability of the EEM (i.e. type, cost, appropriateness of EEM). The negotiation emphasised the requirement of two key skills sets by the school staff. First, project management skills to assess the required EEM, and school budget. The project management skill and need to weigh up the costings of the EEM was highlighted by the school business manager (BM12), who stated:

“If it’s not broke you are not going to fix it are you. It is only when things start to change and you start to look at it, you realise how out dated they are, like the insulation, and they can make a difference. So we have the energy efficiency thing and you look at where your arrow is and how we can get better. But you know it is all about money, and schools don’t have a huge amounts of money coming in anymore…the biggest budget restraints. If I could of had the same windows it would be great, but they are so expensive. The ones that we have had have proved to be not great quality, so I wouldn’t want to go down the route of those sash windows there.”

The second skill set required was connected the previous experience gained by the school staff and an element of common sense when deciding the EEM. When choosing the type of windows most suitable the school head teacher (HT21) explained the reasoning behind the type chosen, and stated:

“My main concern is the need to open the windows and getting the air circulating…We need restrictors on them as we don’t want people climbing in.”

6. Interactions between the LA energy team [1] and the EEM estimator [5]

(1) Principal interests

The principal interests of the LA energy team were to gain a low cost EEM option and an estimation of the work (see figure 5.5 below of the socio-technical network (STN) showing the principal interests of the LA energy team). This interest was evidenced by the EEM estimator (ES21), as expressed:

“We looked for loft and cavity…before we won the job to carry out the survey they [the local authority] asked for budget prices. So we sent them a letter out explaining some of our rates.”

The key interest of the EEM estimator was to price the job to produce an estimate for the EEM (see figure 5.5 below for the interest of the EEM estimator).
The role and interest of was stated by the EEM estimator (ES21), as mentioned:

"…it's our job to price them for each project – so for the cavity wall and loft…he [surveyor] just brought me in a basic measurement and I input the tools like this. A very basic job to price."

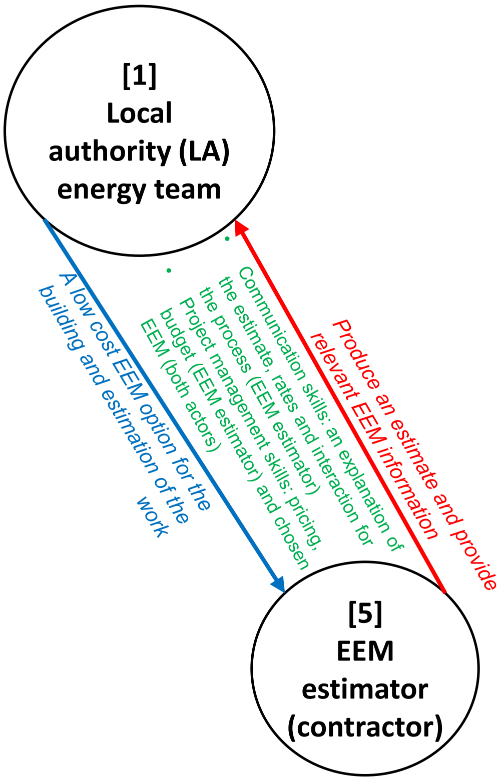

Figure 5.5: the STN showing principal interests, negotiation issues and required skills for the LA energy team and EEM estimator

(2) Key negotiation issues

Two negotiation issues were raised (see figure 5.5 for evidence of negotiation issues and required skills for the LA energy team and EEM estimator). First, there was a negotiation over the pricing and type of the EEM (insulation) for adoption. This interaction between the actor groups, the use of a pricing tool for the EEM (insulation) and the requirement of a project management skill, was explained by the EEM estimator (ES21), who stated:

"…now we have got a pricing tool that generates it all…this is the loft, so say the building 68m^2, nothing in the loft, they require 300. It [spreadsheet] simply fires the price like that in this way."

Furthermore, the EEM estimator mentions the decision of material for the EEM can be part of the process, as stated:

"With the cavity there are two main sort of products we use, which is polly pearl and IS21 sue as well. With the polly pearl if the cavity is narrow we use the polly pearl which is like a bead, which is also used if the building is close to the coast as its a better material for not getting damp."

The second negotiation raised was concerned with the winning of the work, through interaction of explaining the price of the work and the overall budget of the LA energy team. The EEM estimator (ES21), for example, explained the communication skills required by both actors for the adoption of the EEM (insulation), by mentioning:

"Then our job to put together a written letter explaining this. We tend not to break the rates down for them. It [letter and EEM pricing] would get signed off by my seniors here to check. I would send it out and if he [LA energy officer] wants the order, I would put the file together myself."

7. Interactions between the EEM estimator [5] and the EEM surveyor [6]

(1) Principal interests

The principal interest of the EEM estimator was to gain information of the EEM. The principal interest of the EEM surveyor was to conduct a survey to provide information for the EEM estimate. The interests were supported by the EEM estimator (ES21), who stated the required details of the EEM survey requested:

"…what happens is we will receive surveys from the surveyor with measurements on for cavity wall and loft…as all surveyors are trained, so level 4 trained are able to go out and look for everything. But we do have surveyors who can perhaps just look for loft and cavity at the moment."

(2) Key negotiation issues

Two negotiation issues were raised. First, there was the negotiation surrounding the exchange of information and type of detail that was required from both actors. This issue highlighted the need for communication skills. The requirement of communication skills set by both actors was highlighted by the EEM estimator, who stated:

"If ever we notice something on the surveys, it's a company where we are comfortable of ringing the staff and saying could you talk me through this. So yeah the different teams are sort of in touch with each other."

The quotation emphasises the conversations and interactions required not just by the EEM estimator and EEM surveyor, but the also the possibility of communication with other employees within the company. The EEM estimator (ES21) further extends the skill set to include a social skill for the role, by mentioning:

"Obviously working within a team, we have to make sure we all get on, have a lot of social skills and listen to each other. I work very closely with a colleague next to you and obviously need to know what each other is doing on a daily basic and as a team. So I would say it is very important to have social skills in the job."

Furthermore, an observation (OB13) (below) of the EEM installers, who were unable to install the EEM (insulation), highlighted the significance of communication between actors (or absence of communication in this case):

The insulation could not be fitted due to the suspended ceiling within the school. The ceiling for the insulation had a number of pipes and no plasterboard for stability. The correct joists were required for the fitting of the insulation to rest on (to take the weight from the suspended ceiling). The installers were unaware of this and did not have the correct tools for the job. There was a lack of communication by the surveyor and possibly insufficient knowledge for the requirements surrounding the install.

The second negotiation issued raised surrounded the level of detail of the EEM survey in order for the EEM estimator to produce an accurate quote, which highlighted the need for attention to detail from both actors.

The EEM estimator (ES21) evidenced the requirement for attention to detail, by explaining:

"…when you are looking at surveys, looking for damp and everything. I'd say an eye for detail, as it can be quote easy to miss one number and it can change the whole price so yeah… they [surveyor] will send in the information and highlight. There are occasions where we look at it and think well to be honest I disagree, I would have used this or that product. It is always getting a second and thorough check when it comes to the estimating department...if we don't highlight it [the insulation job] as a suspended ceiling and we turn up with normal loft roll, it wouldn't be weight bearing, so the ceiling would fall through."

Furthermore, in connection to the negotiation surrounding the survey and details required, a form of construction knowledge needed for both actors was evident. The knowledge required for the EEM estimator (ES21) appeared to be basic construction knowledge, as stated:

"…it's about knowing what you are looking for on the photos and basic construction knowledge… [when asked for an example] just looking at the walls, the brick type and knowing whether it would need insulation just by looking, keeping an eye out for things like damp problems, damage to buildings and whether we could insulate them. Even looking for things as basic as the height of the loft, so knowing what things we need to send on site for kit wise, such as tower scaffold for a high one, or high up and we just need ladders."

In contrast to the EEM estimator, the EEM surveyor required more in-depth construction knowledge, as explained by the EEM estimator (ES21):

"…a surveyor ideally really needs an in depth knowledge of construction and what they are looking for on a building. In an ideal world the surveyor would highlight everything on a building like damp or if there was any damage on the motor or anything like that before it comes into us."

8. Interactions between the EEM surveyor [6] and the EEM installer [7]

(1) Principal interests

The principal interest of the EEM surveyor was to provide a survey for the EEM install. The principal interests of the EEM installer were to gain information and install the EEM.

The interests from both actors were highlighted during an observation (OB13) of the school EEM install (insulation). The observation highlighted a problem with the install (see above), and the following notes were taken:

- *The installers have documents from the surveyor that give instructions for the fitting of the loft insulation. This document was highlighted as key by the installers.*
- *As the installers did not have the correct tools they were unable to fit the insulation on a suspended ceiling. Lack of communication/ information between the surveyor and installers.*

Furthermore, when speaking to the EEM installer (II21) (in reference to what is needed for the survey), it was mentioned:

"The install is not viable, we need it in black and white on the survey."

(2) Key negotiation issues

One negotiation issue was raised in connection to the problem of the install being unable to go ahead. The problem highlighted the need for two skill sets by both actors. First, the need for communication skills, and second, the need for in-depth construction knowledge. The absence of communication, and the type / level of detail of the communication were the basis as to why the EEM could not be fitted (the incorrect materials / tools and knowledge for the install). Furthermore, in-depth construction knowledge was required by the EEM surveyor to understand to type of tools needed for the install (and state on the survey). In addition to in-depth construction knowledge by the EEM installer to understand the documents and survey produced.

9. Interactions between the EEM installer [7] and the school staff [2]

(1) Principal interests

The principal interest of the EEM installer was to install the adopted EEM. The principal interests of the school staff were to ensure the EEM was fitted systematically and is reliable.

The interest of the EEM installers was evidenced in the install observation (OB13), where the installers' main objective was to fit the EEM (insulation).

The interests of the school staff were supported by the school head teacher (HT21), by stating:

"…we have had all sorts of issues with the gas boilers. But part of the problem with the heating around the school is that parts have been upgraded separately, nothing has been done systematically."

(2) Key negotiation issues

Two negotiation issues were raised. First, there was interaction between the school staff and the EEM installers. During an observation (OB13) (insulation installers), for example, there were indications of confusion surrounding the date / time and whether the school had been informed of the details of the install. The negotiation emphasized the need for communication skills by both actor groups.

Second, during and post implementation of the EEM, it was evident the end-users required information surrounding the EEM, where a research skill was required by the school staff.

Both negotiations surrounding the installation of the EEM were observed during the install (OB13). The school staff were aware of the EEM install, but unaware of specific details, such as where the insulation was to fitted and further details of the job.

Furthermore, it was indicated research skills were required by the school staff. Particularly in relation the solar PV system, the school emphasised their knowledge of the system (how much electricity it was generating, carbon emissions it was saving and an understanding around the display panel (see figure 5.3 above).

In support of required research skills, the school head teacher (HT21) mentioned:

"I think the challenge is keeping on top of it [learning about EEM] and keep refreshing it because the children move on so we need to keep that level of understanding."

10. Interactions between the EEM installer [7] and EEM supplier [8]

(1) Principal interests

The principal interest of the EEM installer was to gain the correct materials for the install. The principal interest of the EEM supplier is to supply the appropriate materials for the EEM.

The EEM estimator (ES21) confirmed the interests, as mentioned:

"…they [EEM contractor / installers] order it off, I know they [suppliers] order the super fill from and the loft rolls. The polly pearl not too sure where they order that from. I think the same company as I see the delivery vans coming in."

(2) Key negotiation issues

One negotiation issue was highlighted during the observation. Due to the issue with the EEM installation, the depth of construction knowledge required by the EEM installer (i.e. the knowledge surrounding why the install could not go ahead, and tools and materials to use) was evident.

11. Interactions between the school staff [2] and the pupils and parents [9]

(1) Principal interests

The principal interests of the school staff were to raise parental awareness of environmental policies within the school, and pass the Green Flag assessment. The principal interest of the pupils and parents was to contribute to school activities (see figure 5.6 below of the STN for principal interests of the school staff, pupils and parents)

These interests were explained during conversations surrounding the Green Flag assessment, environmental awareness within the school and Eco-week. The school head teacher for example, mentioned activities within the school associated with the environment and energy saving, where the children and their parents become involved. In support of the interests, the school head teacher (HT21), stated:

"So in the honey bee one they had hexagons, and the parents did some drawings on them and then joined them all together like a piece of honeycomb…it is about parental awareness aswell…I just think there are loads within the media anyway and its stuff that you pick up. And say actually that would be really good for the school. Raising awareness for children and parents by raising awareness."

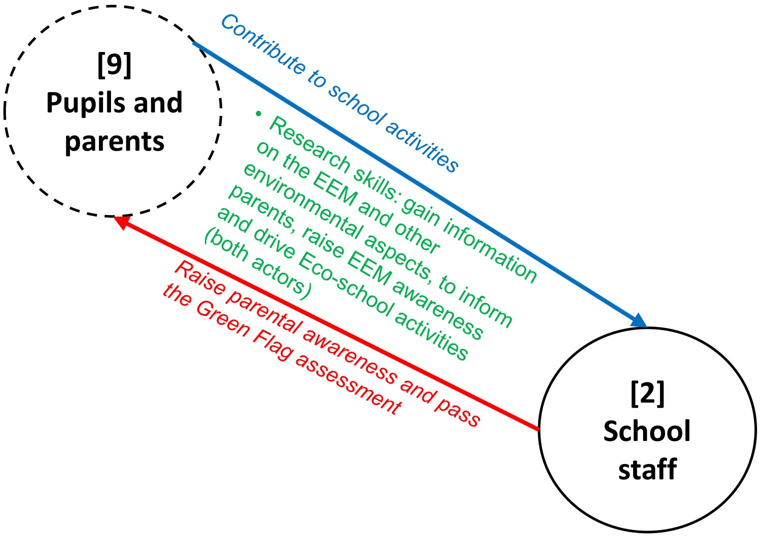

Figure 5.6: the STN showing principal interests, negotiation issues and required skills for the school staff, pupils and parents.

(2) Key negotiation issues

Two key negotiation issues were raised. First, the negotiation around the parents being involved in the school activities and how to raise awareness. Second, the Green flag assessment in regards to the type of actions the school staff, and pupils and parents required to carry out in order to pass the procedure. The negotiations highlighted the requirement of research skills, for both actor groups (see figure 5.6 showing evidence of negotiation issues and required skills for the school staff, pupils and parents).

The need for research skills was emphasised by the school head teacher (HT21), who explained;

"…to keep refreshing it [knowledge surround environmental issues and EEM] but we have started the Eco-clubs so we have got our Eco focus in the school. We have just got our Green Flag award so that has been a big part of that as well. Not only looking at the solar panels but energy saving around the school… they [pupils] spent a week researching all of this [for Eco-week]. The brief was that we were going to take the parents on a walk through different areas of ecological significance."

Summary of the skills required

In relation to skills required for the principal actor groups involved in project 2, the key skill sets required for the LA energy team were communication skills, energy management skills and project management skills. For the EEM contractors, a level of construction knowledge was required and a level of communication skills. The school staff required communication skills, project management skills and research skills. Communication skills were common to all three actor groups and core skills required within the network surrounding project 2. Furthermore, the project indicates the potential challenges for key actors, more specifically, the delivery of the project where communication links were weak or not present at all.

Knowledge production

The interactions and interactive learning associated with the identification of the required skills to deliver project 2 highlight knowledge production within the network. Both tacit and explicit knowledge were identified. First, explicit knowledge was primarily identified between the LA energy team and the school staff through meetings and a presentation. The LA energy team explained the process of gaining the EEM, and the benefits of EEM adoption. Furthermore, there were also conversations between the EEM surveyor (solar PV) and school staff, where a solar PV handbook was also provided. Second, tacit knowledge, which was much more dominant, was evidenced within the network. Many of the EEM contractors, for example, demonstrated tacit knowledge of construction, an understanding surrounding the EEM and required skills, during the EEM development and installation process. Little explanation was provided to the school staff (e.g. how to use the EEM / system) and other EEM contractors (e.g. required tools for EEM installation). The interactions and type of knowledge produced, by EEM contractors was shown to be essential to highlight the issues with the delivery of project 2. The type of knowledge produced between the EEM surveyor and EEM installer, for example, could have potentially minimised the disruption and challenge of the EEM implementation, had the knowledge have been of an explicit nature. Project 2 captured the need for explicit knowledge, but also the challenges associated with the management of knowledge where primarily, knowledge was of a tacit nature, i.e. the management of knowledge was a greater issue and of further disruption to the delivery of the school retrofit project.

Proximity

Physical proximity is highlighted within the network, where EEM contractors are located outside of the region. It is interesting that one of the firms involved in an EEM measure (i.e. insulation) have designated EEM contractors for specific UK areas. However, as the firm is based at a national level, the EEM contractors are still located outside of the project 2 region. The different relationships between these EEM contractors emphasises the contrast in spatial proximity within the network. The EEM surveyor and EEM estimator have strong links are communication and exchanges (e.g. exchanges of documents, emails and more conversations). However, the EEM installer and surveyor appear to have very little communication, solely the exchange of a survey. It is worth noting that all EEM contractors have a wide ranging physical proximity, indicating there is little connection to their spatial proximity.

Embeddedness

The LA energy team and school staff show embeddedness within the network through exchanges of knowledge and information, and greater social interactions associated with the required skills. The LA energy team were willing and able to offer advice, visual presentations and opportunities of learning to school staff, for example, which assisted the adoption and understanding of EEM within the building.

Chapter 6 School retrofit project 3

6.1 Introduction

This chapter will introduce project 3 of the research. A description of the project and the school under investigation will be given. The required skills identified for the delivery of the project will also be outlined. Furthermore, an explanation of the mechanisms evident within project 3 will be stated.

6.1.1 Description of school 3

Project 3 (figure 6.1) is both a nursery and primary school (five-hundred and ninety-two pupils), located in a village within the south of the region. The school was first built during 1971, with the majority of the original building being what is now known as the ground floor. Certain sections of the building were redeveloped during the 1980s (nursery) and 1990s (reception area and infant school). The school consists of two permanent buildings (nursery and primary school), and two temporary rollalongs (teaching classrooms). A swimming pool is located within the grounds of the school (south-east of the building), and is primarily used by the pupils every morning during (spring and summer) term time.

Figure 6.1: school retrofit project 3 site photos

6.1.2 Description of existing energy efficient measures / technologies

The school uses gas for its main heating supply, although, there are (fixed) electric heaters within a number of classrooms, and (mobile) air conditioning units in classrooms where overheating occurs. The swimming pool is heated by electricity. The school building also has a PV array and solar thermal system (figure 6.2), installed during 2011. A reading of the PV meter (i.e. the electricity generated) is taken once a month by the school governor and pupils.

Figure 6.2: EEM (solar thermal system) adopted

6.1.3 Areas for improvement identified by the energy audit

The energy audit by the LA energy team identified a number of improvements and EEM implementation for the school. Changes to the current building heating system, for example, were suggested, along with a lighting upgrade and insulation survey as priority actions. Furthermore, the adoption of an air source heat pump (ASHP) as a cheaper option of heating the swimming pool (currently being heated by electricity) was recommend for the school. Energy education was also mentioned as a method of raising the awareness of energy use and EEM within the school.

6.1.4 The implementation, or in the process of adoption, of EEM

Recently (September 2014), due to electricity billing complications, the school had its electric meter replaced with a smart meter. The school boilers were replaced (Summer 2014), and the heating system in the process of being updated (October / November 2014) for the school to have more control over the heating settings, i.e. the implementation of a building management system (BMS). The school has also undergone a loft and cavity wall insulation survey (November 2014) and estimation provided for the LA energy officer.

6.2 The regional innovation system (RIS) and socio-technical network analysis (STNA) for project 3

The RIS and socio-technical network (STN) that surrounds school project 3 is shown in figure 6.3 (below).

6.2.1 RIS elements

The research findings indicate there are eight key actors / actor groups within the network, and each can be distinguished by their role within the RIS as follows:

Institutions

- Local authority (LA) energy team: respond to energy supply issues and concerns of local authority owned buildings, and monitor energy consumption within the buildings.
- Institution funding provider: provide finance for LA energy team projects (e.g. project 3)
- Local authority (LA) building management team: provide funding and EEM support for local authority owned buildings.
- School community (school head teacher, school caretaker, maintenance manager, school governor): monitor building energy consumption, co-operate for the implementation of EEM and ensure maintenance of adopted measure(s).

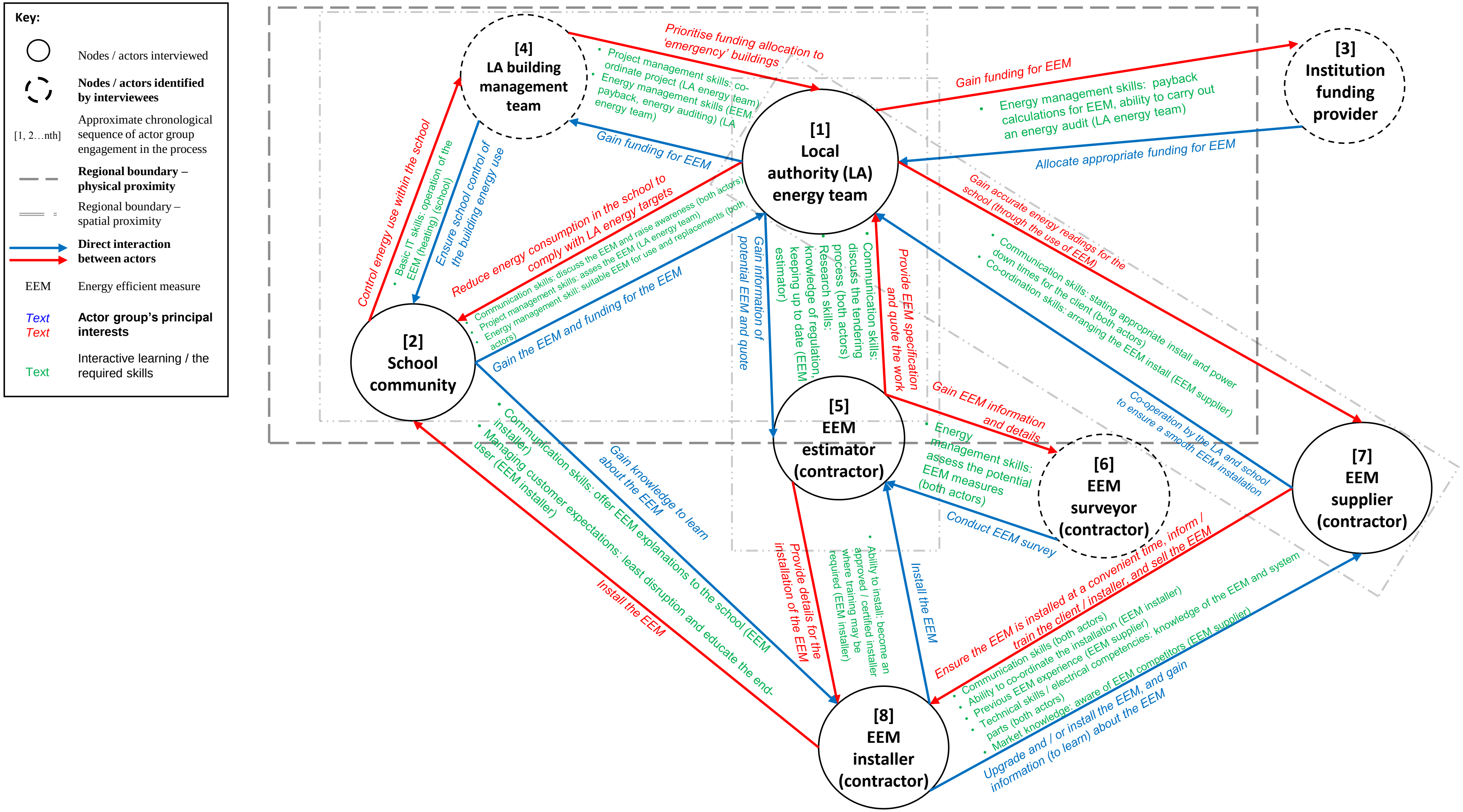

Figure 6.3: school retrofit project 3 - adoption of EEM and surrounding RIS / STN

Firms (EEM contractors)

- EEM estimator (loft / cavity wall insulation): provide an estimate for the EEM.
- EEM surveyor (loft / cavity wall, ASHP): carry out an initial survey to assess the potential for EEM installation.
- EEM installer (loft / cavity wall, smart meter, ASHP): install the adopted EEM and (on occasions) provide information of measure(s) during the handover.
- EEM supplier (insulation, ASHP, smart meter): co-ordinate the implementation the EEM (smart meter), and provide EEM products / information for the installation of the adopted EEM.

Knowledge infrastructure

- LA energy team: provide training (e.g. energy auditing) and EEM knowledge (e.g. decisions around the EEM) to departments within the local authority, and information / awareness for the EEM to the school staff.
- EEM supplier (insulation, ASHP, smart meter): Provide training and information to EEM contractors.

Policy orientated regional innovation

- LA: implement energy reduction targets for the local authority, such as the carbon emissions reduction target of 15% by 2015 and 40% by 2020. As stated in the Carbon Management Plan and the local authority Sustainable Environment Strategy, energy and sustainability targets are required to be met by the LA energy team.

6.2.2 RIS mechanisms

Definition of key skills required

Skills

The definition of a skill was associated with learning and the requirement of interaction with another individual (who possesses the skill). This was indicated by the heating engineer (HE31), as stated: *"A skill is something that you have to learn, by definition it is something that requires application and being shown how to do it by someone else. You are learning a skill from another person. It is very difficult to learn a skill by yourself…a skill is something that you have been taught in the correct way."* A skill can also be termed as a personal characteristic, or individual asset, as indicated by the school site controller (SC31), who expressed: *"…it [a skill] is something you can do that no-one else can do."*

Furthermore, the definition of a skill extends to an individual having previous experience of a task or within role, and further knowledge of carrying out the task. This meaning was supported by the school maintenance manager (MM31), as explained: *"A skill for me is that you have done something before and you know how to do it."*

Technical skills

Technical skills are associated with a particular piece of technology, and can be connected to the ability to analyse, use knowledge (new or existing technical knowledge) to further understand the function of the technology. As captured by the air source heat pump manufacturer (AM31), who stated: *"For me a technical skill is nothing else but a means of analysing a situation. If someone can analyse about a product in any situation that is technical…for me technical is directly proportional to analysis…I got trained on all the technical products and the system…it is very important at our end, in this role, to understand where it [technical knowledge] is used, for the application."* In support of a technical skill being defined as the need for knowledge of the technology, the components and how it operates, the smart meter project manager (SPM31), mentioned: *"They have to have that technical skill as they are dealing with a large technical supply…I would pass that [issue with the smart meter] onto the technical guy, as he used to be a meter engineer."* Furthermore, the dominance of the technology in the context of the technical skill definition was highlighted by the heating engineer (HE31), as expressed: *"[a technical skill is] "not really a new skill, your skills change with the product demands and because the products are more technical you have to be trained and more familiar with the product…this boiler 30 years ago didn't have any of that going on [points to the wires and compartments towards the centre of the boiler]. Now it has demisters, electrical components, so whenever it goes wrong you have to be able to apply the skills you have learnt."*

Interactive learning: evidence of skills required through negotiations

Through the identification of the principal interests of key actors / actor groups and the key skills required for project 3 (see Figure 6.3), interactive learning, a RIS mechanism, and negotiations between actor groups within the network were highlighted. The negotiations gave further insight into the meanings and definitions of the skills required for the project. There are ten key interactions surrounding the delivery of project 3:

Interactions between the key actor groups

1. Interactions between the LA energy team [1] and school community [2]

(1) Principal interests

The principal interest of the LA energy team was to reduce energy consumption in the school to comply with LA energy reduction targets (15% reduction from current building emissions by 2015).

See chapter 4 section 4.4.2 for the evidence of interests.

The school caretaker (SC31) further evidenced the interest to reduce energy consumption of the school, and the local authority influence regarding the choice of EEM, as stated:

"We have 3 different sources of heating. It really up to the council what they think it more efficient…."

The key interest of the school community was to gain the funding for the installation of the EEMs. This was evident in the school caretaker (SC31) who explained:

"We are trying to get the council to … provide the money for double glazing, insulation, maintenance of the solar panels."

(2) Key negotiation issues

Three key negotiation issues were raised. The first negotiation surrounded the choice of the EEM and decisions by the LA energy team. This issue highlighted the requirement of project management skills for both the energy officer and energy assistant (see section 4.4.2 for evidence).

Second, the raising awareness, use and negotiations of the EEM required communication skills by both the LA energy team and school end-users. The EEM project manager (SPM31), for example, mentioned the communication process between the LA energy team and the school end-users during the implementation of an EEM (smart meter), by stating:

"I then contacted the energy assistant to get in contact with the sites [project 3]. She was happy to manage that, there were so few, so the energy assistant just got back to us with the dates."

Furthermore, the negotiation issue surrounding problems with the EEM highlighted the requirement for communication skills between the actor groups. The school maintenance manager (MM31), for example, mentioned:

"Basically we allowed to change all the tubes, all the bulbs but if there are any electrical problems we basically call the council and they send someone out for the problem."

The final negotiation issue involved the different types of EEM and the choice of replacement for measures within the school, highlighting a further requirement of EEM knowledge and the need for energy management skills.

The maintenance manager (MM31), for example, explained the variation in types of EEM (lighting in this case) within the school, by stating:

"…we are only allowed to change the simple tubes or change the starters. That is all we can do. In parts of the school we are using 18 to 35 watts then 35 to 65 watts, so really depends you know…we need these low wattage ones."

2. Interactions between the LA energy team [1] and the institution funding provider [3]

The discussion of the interactions between the LA energy team [1] and the institution funding provider [3] can be found in section 4.4.2.

3. Interactions between the LA energy team [1] and the LA building management team [4]

The discussion of the interactions between the LA energy team [1] and the LA building management team [4] can be found in section 4.4.2.

4. Interactions between the school community [2] and the LA building management team [4]

(1) Principal interests

The principal interest of the school community was the ability to control energy use within the school. In regards to the new heating system, for example, the school head teacher confirmed their role and interaction with the EEM, by stating:

"A whole new control system is being set-up [via a building management system] as we couldn't control any of the heating. The system will soon be connected to my laptop so I will be able to control the heating system."

The key interest of the LA building management team was to ensure the school had control over the energy use within the building. This was confirmed by the school caretaker (SC31), who expressed:

"It [new computer system] is for the schools to have more control over the heating system. Because you know in the olden days you know the council would have a gel system. Linked up to their console somewhere in Place A and they would be aware of, or say they would be aware of, the temperatures in the school to try to get the boiler to come on and adjust it. They are trying to get where we are all at and for the school to say look we have complete control of the system."

(2) Key negotiation issues

One negotiation issue was raised. Specific to the new heating system, problems arose that indicated the requirement of basic IT skills by the school community.

This was evident as during an observation (OB16) of changes to the heating control system and interview with the school maintenance manager (MM31), who was not sure the correct settings for the new computer controlled heating system.

The school maintenance manager (MM31) supported the observation by stating:

"I don't even know how to get into the option if anything happens [to the heating], to change anything…at the moment yes, it [heating system] is a concern."

Furthermore, the school caretaker (SC31) expressed a concern regarding the controls for the heating system, as stated:

"IT skills, I don't know. I presume it is going to be quite easy to access the computer, just have one temperature read out system. I have not really talked to the IT bloke…anything that happens in the future that includes technology, obviously we need to be aware of it to deal with the problem." Obviously we need to know how this is going to be controlled. Who is going to have the link to the computer to control it."

5. Interactions between the LA energy team [1] and the EEM estimator [5]

(1) Principal interests

The principal interests for the LA energy team were to gain information and a quote for the EEM. The key interests for the EEM estimator were to provide an EEM specification and quote the work.

The interests were highlighted by the EEM estimator (ES31), who stated:

"The energy officer sent a list across to us of the schools within the area and asked us to go and have a look if the project 3's loft needed any insulation, turned out we could do a small part...we [main contractor company] have done quite a lot of work with local councils and schools with PV…if they came to us and said we want 50kW in that field there, we would have a look, come up with a suitable [PV] design then go through the necessary stages we have to go through to put in an order for that. With that we use an A framed system and we had to get trained up from a suitable supplier/installer. So we could install our system."

(2) Key negotiation issues

One negotiation issue was raised surrounding the tendering process in terms of which EEM to be adopted, i.e. the appropriateness and, more specifically the costing (by means of a quote) for the EEM. This negotiation highlighted the requirement of two skill sets. First, the need for communication skills was evidenced by the EEM estimator (ES31), who stated:

"The energy officer had a list of schools he wanted to look at. He probably sent them to a number of companies and I expect certain companies would have been cheaper than us on certain projects…I receive an order or an email confirmation [from the energy officer] saying please proceed."

Second, research skills for the EEM estimator, linked to the required knowledge and keeping up to date with regulations was highlighted by the EEM estimator (ES31), who mentioned:

"We keep in sync with insulation; loft insulation is 300 [ml] at the moment. That could be revised when the new regulations come out…it's the same with building regulations are revised, building regulations are like the bible so anything changes in that then we have to change according with what we are doing. That's the main one then we have separate bits off that that we have to abide by."

In addition to the need to revise regulations, the EEM estimator (ES31) further emphasised the challenge of constantly learning about government schemes, as stated:

"…everyone in the office has had to keep up with it [Green Deal scheme]. Always teaching each other. We had some basic in house training for the GD (Green Deal) and this was filtered out though our network."

6. Interactions between the EEM estimator [5] and the EEM surveyor [6]

(1) Principal interests

The principal interest of the EEM estimator was to gain information and details of the adopted EEM. The key interest of the EEM surveyor was to conduct a survey of the EEM.

"The surveyor went there [the loft] to measure up for any loft space we could do. There were a lot of suspended ceilings there and service cables, air conditioning unit and things like that are not really suitable for loft insulation installed. Only a small area there so the surveyor went up the loft to see what insulation thickness was required there [above the kitchen]."

(2) Key negotiation issues

One negotiation issue was raised, which was linked to the details and decisions surrounding the EEM to advise the EEM estimator and LA energy team. This negotiation highlighted the need for energy management skills that entailed knowledge of the most suitable EEM for the project.

The EEM estimator (ES31) indicated the requirement for energy management skills for both actors, by stating:

"…you can produce an EPC [energy performance certificate] for properties and give them a list of measures to save the customer money."

Furthermore, in relation to domestic properties the EEM estimator (ES31) described in greater detail the assessment by the surveyor to highlight the required energy management skills:

"…with domestic properties normally exist 100mil so we would top up to 270 300 depends on thickness. Some we go into may have nothing so we would do 300 for the customer."

7. Interactions between the LA energy team [1] and the EEM supplier [7]

(1) Principal interests

The key interest for the LA energy team was to gain accurate energy readings for the school (through the use of the EEM) (see figure 6.4 below of the socio-technical network (STN) showing the key interest of the LA energy team). The school head teacher (HT31) indicated this interest by stating the reason for adopting the EEM, as stated:

"…it [smart meter] was just fitted because our electricity bill was wrong – either too much or not enough. One of them."

The principal interest for the EEM supplier was to co-operate with the LA energy team to ensure a smooth EEM installation process for the school community (see figure 6.4 below for this interest of the EEM supplier). This interest was highlighted by the EEM project manager (SPM31) who noted:

"Yes I think we did [turn the power off for the school]…the challenge with that one is that the meter is in the classroom, and the children…then [during holidays] you have the issue of no one being there. Even if you organise someone to be there, there may be problems with is that person going to diarise it? It is really simple stuff that often is a bit of a challenge, which is out of our control."

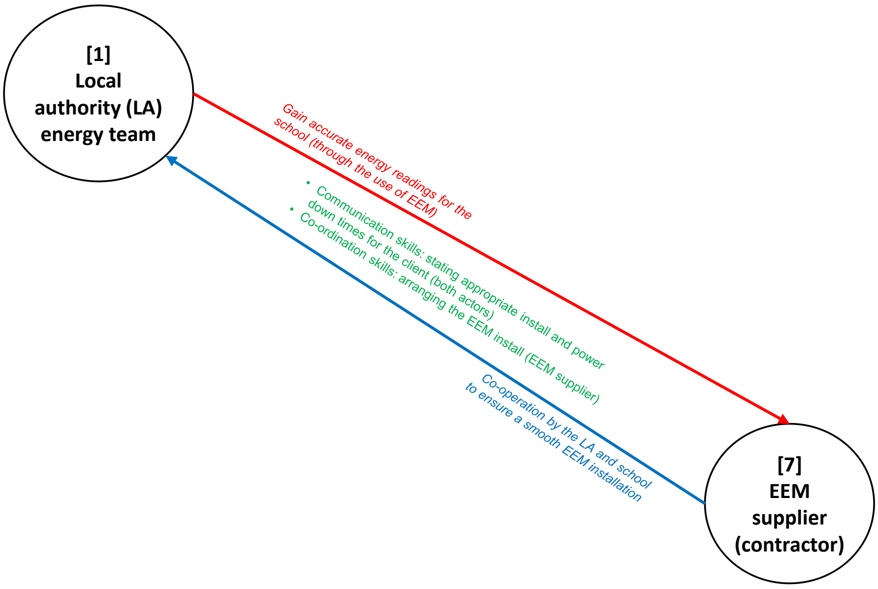

Figure 6.4: the STN showing the principal interests, negotiation issues and the required skills for the LA energy team and EEM supplier

(2) Key negotiation issues

One negotiation issue was raised that surrounded the arrangement of the EEM installation (see figure 6.4 of the STN for evidence of the negotiation issue and required skills). The negotiation highlighted the requirement of two key skills. First, the need for communication skills by both actors. The communication between the LA energy team and the EEM supplier was continuous throughout the adoption of the EEM, and was evidenced by the EEM project manager (SPM31), who stated:

"We contacted the LA energy officer because we are under a lot of pressure from the government…So we contacted the LA energy officer to say look, the government want you to put smart in these sites, you don't have to, we are not going to force you. But it would be great…eventually after speaking to the LA energy officer, he didn't want smart for all of the schools, it's just too difficult to mobilise, so we only targeted the mandatory ones."

Second, the negotiations surrounding the adoption of the EEM indicated the need for the ability of the EEM supplier to co-ordinate the project. This was captured by the EEM project manager (SPM31), who mentioned:

"…its co-ordination…It is basically the delivery of the roll out. Which is quite simple as long as you can get everybody on board, engaged in the process, understanding their responsibilities, that is really the most important thing…I think for the most part one of our biggest challenges is co-ordination."

8. Interactions between the EEM estimator [5] and the EEM installer [8]

(1) Principal interests

The principal interest of the EEM estimator was to provide details for the installation of the EEM. The principal interest of the EEM installer was to install the EEM.

The EEM estimator (ES31) highlights these interests by indicating the different EEM options, by stating:

"The same thing it may take a bit longer, normally cross layered. Only difference is that it would take a bit longer and more labour intensive…quilt thickness comes in at 100 / 150 mil, and 200 mil thicknesses so we have to lay it cross layered, not an issue but a bit more labour intensive for our guys."

The heating engineer (HE31) further elaborated to explain the importance and perhaps urgency regarding the installation of the EEM, by stating:

"If there is anything outside of my skill range then we get someone in, we get a subcontractor in. Otherwise it may mean going on a month course to get whatever that new skills maybe so we subcontract out."

(2) Key negotiation issues

One negotiation issue was raised. The EEM installer's ability to fit the measure, having specific qualifications and certifications relating to the adopted EEM. The certifications discussed (below) were provided by a construction association, set up by the government during 1966 to inspect and further give approval to suppliers and installers.

The level of skill required (i.e. certifications) for EEM installers (insulation installers) was explained by the EEM estimator (ES31), who stated:

*"Cavity wall insulation we have to have certificates [provided by a construction association] for cavity wall. They are certifications stating we are qualified to install cavity wall insulation…*we then had to train everyone up for the new system [solid wall]…*we would be informed by the governing body of any changes [to regulations], and if there are any we would have to go to gain the necessary qualification to gain cert for that product or system. Recently doing a lot of solid cavity wall insulation so we had to be audited on that to be qualified."*

The view by the smart meter installer (SMI31) is consistent with that of the EEM estimator, which indicates the requirement of training and the need to hold a specific certificate in relation to the EEM, as stated:

"You need to be qualified and certified to do it [install the smart meter]… you have to be trained. You can't just rock up and do it. You need to know what you are doing."

9. Interactions between the EEM supplier [7] and EEM installer [8]

(1) Principal interests

The principal interests of the EEM supplier were to ensure the EEM was installed at a convenient time for the school, provide information and on occasions train for the installer / client, and sell the EEM.

The need to ensure a convenient time for the install was captured by the EEM supplier (project manager) (SPM31) who stated:

"…for me it's like right get a meter on the wall…Schools are actually quite easy as you have so many people that are responsible for certain areas of the building. You got caretakers, maintenance, the head teacher who may even have keys to the meter."

The interests to inform the client, and try to sell the EEM were explained by the EEM (ASHP) manufacturer (AM31), who stated:

"The skills of having a conversation, especially with the customer in terms of financial situations, when we are selling a product we have different ways to have conversations with them…when you are explaining to someone, say an end-user, it is very important for you to tell them how much money they will save."

To support the key interests of the EEM supplier, the heating engineer (HE31) explains the reasoning behind the training by the manufacturer:

"What manufacturers do when they bring our a new product they always train us…because the manufacturer knows that [my] company heating, and their installers, have been trained on how to commission and install the boiler correctly."

The principal interests of the EEM installer were to upgrade and / or install the EEM, and gain information about the EEM. The general procedure for an EEM installer is to upgrade the smart meter if there is currently an old smart meter in place, or install a new one if the school does not own an existing meter (usually a half hourly meter). The interest was highlighted by the smart meter (EEM) installer (SMI31) who mentioned:

"…I am upgrading old fashioned dumb meters to smart meters."

The EEM project manager (SPM31) further supported this principal interest of the EEM installer, as expressed:

"…it's the smart meter installer's responsibility as they install it [smart meter]."

Furthermore, the interest of the EEM installer to learn about the EEM, such as those the EEM installer had not fitted previously, was highlighted by the EEM (ASHP) installer, who stated:

"If ever I am installing a new product I always refer to the manufacturer. So yes, there is always going to be some sort of different feature as all the products are different…the manufacturers have a factory and take us around…So and then you do the training [with the manufacturer], it's not that great, but you are talking to the guys who have some inside knowledge…You are learning all the time, I like to think I am getting better all the time."

(2) Key negotiation issues

Two negotiation issues were raised. The first negotiation was related to the EEM installation process. This issue highlighted the need for communication skills for both actors, and the ability to co-ordinate the EEM installation for the EEM installer. Communication skills and the co-ordination of the project were required to confirm the correct date and time of the install.

The negotiation issue and the required skills were evident by the smart meter installer (SMI31), who mentioned:

"Communication more and more, to organise the job. Sometimes when appointments are made they [customers] don't speak to the right people. So I turn up when they are not expecting me or today when I turn up I have been sent to the wrong job you know."

Similarly, communication skills required for the EEM supplier and the need to build a relationship with the customer / installer were highlighted by the ASHP manufacturer (AM31), who stated:

"Communication is foremost as we are dealing with the customer day in day out…Relationship building. One thing with the team is that we have to be very patient when dealing with the customer on perhaps difficult conversations. The skills of having a conversation, especially with the customer in terms of financial situations, when we are selling a product we have different ways to have conversations with them…in the sales I would say communication. In a big company like ours it is very important for us to communicate with the customer about new updates, the product happenings, and what is happening in the market. Communication is key…On the skills that are more customer relationship skills."

This negotiation issue surrounding the EEM also evidenced the need for previous experience by the EEM supplier. The requirement for experience to gain knowledge of the EEM project and potential problems was highlighted by the EEM supplier (PM) (SPM31), as expressed:

"The reason why I am in this role and why my colleagues are is because of our experience within the business…we have to have that level of knowledge with years of experience in the business."

Furthermore, for the correct installation of the EEM, a technical knowledge was required for both actors. The EEM project manager (SPM31) expressed the need for a technical knowledge for the role, along with interactive learning from colleagues to gain technical information, as stated:

"[I] then moved into smart metering, so my level of skill is different to an account manager as they need to know everything. My role is slightly more technical…We are actually restructuring our team to incorporate a large technical presence…we have a technical expert in our team…We are actually restructuring our team to incorporate a large technical presence. For our technical guys, it's all in here [head] for them. And I think in our technical guy he is overworked in that respect as it's always [to technical guy] 'why didn't this go ahead...' So we are trying to restructure our team so he has some more support."

The EEM supplier (PM) (SPM31) went on to argue the need for technical knowledge for the installer by stating:

"…technically you need to have a lot of knowledge, as there are so many reasons why a smart meter cannot be installed…They [smart meter installers] have to have that technical skill as they are dealing with a large technical supply."

To support the above view and explain a 'technical skill', the EEM supplier (ASHP manufacturer) (AM31), explains:

"On the technical side, I would say its skills that we need to know on our system, which unit is what, what parts go with them...I got trained on all the technical products and the system, but the role as such does not need you to know the system inside and out, the ASHP system…We do have an end-user warranty, but we come back to the issues and this is where I need my technical knowledge of the system."

This view was consistent with the smart meter installer (SM31), who illustrated the need technical knowledge, along with a competency similar to that of an electrician, as expressed:

"Not an electrician, you need what they call a competency, I'm not a trained electrician but I am trained to do this…you get something like this, a competency form [see appendix F] that says I am authorised to work on different kinds of installations…3 week training course then after that you go out and get mentored. You go out with someone who is qualified then they watch you do it for 3 or 4 weeks to make sure you know what you are doing. If you got any problems, they [mentor] sort it out for you.

After that you get an assessment by the district technical assessor and he will say whether you are actually competent enough to do it on your own or not."

The second negotiation was related to the supply and sale of the EEM by the EEM supplier. This issue highlighted the need for the EEM supplier to have an understanding of the market related to EEM and further knowledge of current competitors. The ASHP manufacturer (AM31) explained the significance of recognising the demand of EEM and the market for the EEM supplier, as stated:

"The skill of understanding the market is important to us [supplier] because it is important for us to advise the customer of the best. So we need to understand what is best. Understanding the market and knowledge is very important…understanding the regulation in the market and the incentives. The heat pump market or renewable market there are lots of incentives by the government and the regulations changes, and this is very important for us to make everyone aware…always learning about the product, learning about the market…competition as well! When you are learning about other manufacturers that is very important as well, to learn about the competition."

10. Interactions between the EEM installer [7] and the school end-users [2]

(1) Principal interests

The principal interest of the EEM installer was to install the EEM. This interest was stated by the EEM project manager (SPM31), who expressed:

"…they [installers] just want to get the meter on the wall."

The interest of the school end-users was to gain knowledge to learn about the adopted EEM. This was evidenced by the maintenance manager (MM31), who stated:

"They fitted a new system and we don't know nothing about it to be honest. I think it is really important for people like me and SC31 to know about it."

(2) Key negotiation issues

One negotiation issue was raised surrounding the EEM installation. This issue captured the need for communication skills. The EEM estimator (ES31) expressed the importance of communication skills by the installer (and a number of other contractors, such as assessors and surveyors), by stating:

"Even our assessors' as well [as installers]. They will be able to talk about things like this with the customers as well instead of things coming back to the office."

Furthermore, the negotiation highlighted the need to manage customer expectations by the EEM installer. Ensuring the least disruption for the end-user, checking correct dates / times and possibly educating the school. This issue was raised by the EEM project manager (SPM31), who mentioned:

"Even though they [installers] have the knowledge they don't have that kind of customer service skill. Its topic of contention for us because the engineers should have that level of you know good customer service, but a lot of them don't…"

Summary of the key skills required

The key skills required for the delivery of project 3 can be grouped in relation to the principal actor groups: the LA energy team, the EEM contractors and the schools end-users. The LA energy team require communication skills, project management skills and energy management skills. The EEM contractors required a number of technical skills; connected to the electrical components of the technology, knowledge of the EEM and understanding of how to carry out an installation, and previous experience of the EEM. The requirement of communication skills were also needed by EEM contractors linked the ability to provide a high standard of customer service, and co-ordination skills for the organisation and delivery of the project. The school end-users required communication skills, and degree of knowledge surrounding the technology in terms of basic IT skills to operate the EEM and energy management skills.

Knowledge production

The interactive learning between actors / actor groups through different interests, and further negotiation, illustrate knowledge production within the network. The majority of knowledge produced to deliver the low carbon building tends to illuminate tacit knowledge within the network. The issues related to the delivery of project 3 are resolved through much of the actors / actor groups existing knowledge and understanding of the EEM and problems. The challenges experienced by the new heating and building management system, for example, were dealt with by the local authority with little explanation to the maintenance manager (i.e. the maintenance manager did not understand how to change the heating system settings). The general procedure for the occurring issue with the heating system, similar to the solar systems, was to contact the local authority. The analysis of project 3 highlights very few interactions where explicit knowledge was generated. A large part of explicit knowledge surrounding the delivery of project 3 appeared to be within the firms and institutions of the network. The EEM supplier (project manager), for example, mentioned much of their technical knowledge was a result of internal learning (i.e. the 'technical' employee was on hand to explain the EEM (smart meter) and advise recurring issues). Project 3 emphasised the essential need for explicit knowledge, and further highlighted the contrast in outcomes where explicit knowledge was evidenced (e.g. during the smart meter instructions) as opposed to tacit knowledge (e.g. the EEM information provided within the school). There was, however, insight into the management of knowledge, where the school end-users recognised the need to understand the information provided to them (i.e. how to apply the knowledge provided to the school end-users in order to control the EEM).

Proximity: physical and spatial

The physical proximity of the network emphasises the geographical distance between actors / actor groups, particularly the location for many EEM contractors (i.e. outside of the region). It is interesting to highlight the location of the EEM estimator, within and close to the regional boundary, and the interaction of the LA energy team. Whether it was the case where the EEM (insulation) adoption did not require the LA energy team to be in contact with the EEM surveyor and EEM installer, or, due to the absence of decisions of EEM contractors by the LA energy team, the EEM estimator chose EEM contractors outside of the region.

Project 3 highlights two distinct references to spatial proximity between actors / actor groups within the network. First, LA energy team and EEM supplier indicate strong levels of spatial proximity through continuous contact and communication throughout the project, despite a great physical distance between the actor groups. Second, there is evidence of spatial proximity between the LA energy team and the EEM estimator. Again, the strong communication may be due to the EEM estimator being the only contact for the cavity wall and loft insulation assessment and installation. The EEM estimator is also located within the region, which may play a part.

Embeddedness

Embeddedness and its occurrence within the network is better explained by the relationships within the firms and institutions. The school end-users, for example, have strong links of embeddedness, where many of the individual actors within the school are informed about the EEM and potential problems. The EEM contractor, more specifically the contractors involved in the adoption of the smart meter (e.g. the EEM project manager and department / working team) illustrate greater relationship links and interactions, which indicate greater rates of embeddedness between the local authority (LA energy team and LA building management tea) is small, emphasising the interactions and how issues for the delivery of project 3 are quickly resolved, if possible.

Chapter 7 School retrofit project 4

7.1 Introduction

This chapter will introduce project 4 of the research. A description of the project and the school under investigation will be given. The required skills identified for the delivery of the project will also be outlined. Furthermore, an explanation of the mechanisms evident within project 4 will be stated.

7.1.1 Description of school 4

Project 4 is a medium sized primary school (figure 7.1) (three hundred and two pupils), located towards the outskirts of a small town within the centre of the region. The school was originally built in 1855, but the majority of the building was redeveloped during 1989 (entrance, classrooms and staff rooms). The school has implemented an Eco-Schools programme, appointed an energy officer and was in the process of trying to achieve the Green Flag award (October 2014). The Green Flag award is a certification that can be gained by the school through the assessment of certain Eco-School's criteria, such as the appointment of an eco-committee and school action plans.

Figure 7.1: school retrofit project 4

7.1.2 Description of existing energy efficient measures / technologies

The main building has existing loft insulation, which was implemented during the building development (1989). However, the loft insulation was below the recommended depth / thickness requirement (2014 recommendation of 270mm). The main building also has a south facing solar PV array (Figure 7.1), supplied and fitted during 2012 by a local energy supplier.

7.1.3 Areas for improvement identified by the energy audit

The energy audit identified the need to improve the building fabric through an assessment of loft insulation, and potential changes to the single glazed windows to reduce draft problems. Lighting within the school was also highlighted as a priority project as many of the rooms were using T12 and T8 bulbs (low efficiency light bulbs), which can be improved through the adoption of T5 bulbs (more efficient light bulbs). Furthermore, the heating system and boilers were also looked at in regards to a potential upgrade, due to their age and uncertainty surrounding their efficiency. Finally, the energy audit identified the energy behaviour of the school could be improved through the development of energy education (for both school pupils and school staff).

7.1.4 The implementation, or in the process of adoption, of EEM

Following the energy audit, project 4 has had a smart meter installed (figure 7.2) to monitor energy through the production of electricity readings for the building, and sun pipes integrated within one classroom (figures 7.3 and 7.4). A loft and cavity wall insulation and lighting survey has also been carried out, but further discussions between the school and the LA energy team are on-going (October 2014) in relation to funding for the EEM and possible installation. Furthermore, the school site controller implemented energy saving measures within and around the school grounds, such as a grey water and water butt system (figure 7.5), made from old council bins. The implementation of double glazing within the school building was rejected due to the lack of funding available to the school by the LA energy team and LA building management team. The current single glazing area within the school was not classified as in ‘poor condition’ and payback periods for double glazing would have be considerably longer (i.e. twenty years or more) in comparison to other EEM (those adopted above).

Figure 7.2: EEM (smart mater) adopted

Figure 7.3: EEM (sun pipes) adopted

Figure 7.4: EEM (sun pipes) adopted

Figure 7.5: grey water and water butt system adopted

7.2 The regional innovation system (RIS) and socio-technical network analysis (STNA) for project 4

The RIS and socio-technical network (STN) that surrounds school project 4 is shown in figure 7.6 (below).

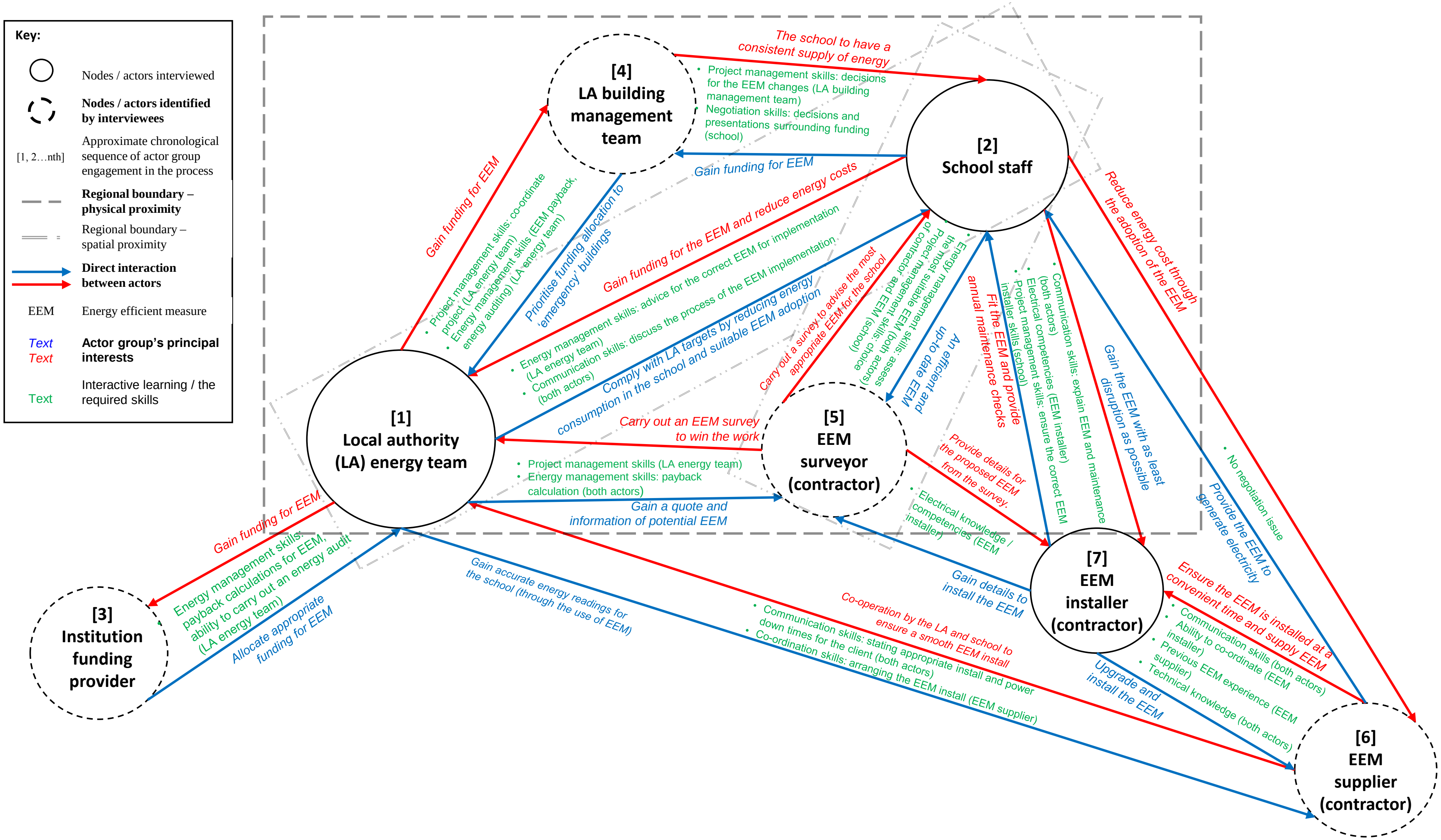

Figure 7.6: school retrofit project 4 - adoption of EEM and surrounding RIS / STN

7.2.1 RIS elements

The research findings indicate there are seven key actors / actor groups within the network, and each can be distinguished by their role within the RIS as follows:

Institutions

- Local authority (LA) energy team: respond to energy supply issues and concerns of local authority owned buildings, and monitor energy consumption within the buildings.
- Local authority (LA) building management team: provide funding for local authority owned buildings.
- Institution funding provider: provide finance for LA energy team projects (e.g. EEM adopted for project 4).
- School staff (school finance manager, site controller): monitor building energy consumption and energy costs, co-operate for the implementation of EEM and ensure maintenance of adopted measure(s).

Firms (EEM contractors)

- EEM surveyor (loft insulation, lighting, sun pipes): carry out an initial survey to assess the potential for EEM installation.
- EEM installer (smart meter, sun pipes, PV): install the adopted EEM and (on occasions) provide information of measure(s) during the handover.
- EEM supplier (smart meter, sun pipes, PV): provide materials / information for the installation of the adopted EEM.

Knowledge infrastructure

- LA energy team: provide training and information on energy auditing for the local authority departments, and information for the EEM to the school staff.

Policy orientated regional innovation

- LA: implement energy reduction targets for the local authority, such as the carbon emissions reduction target of 15% by 2015 and 40% by 2020. As stated in the Carbon Management Plan and the local authority Sustainable Environment Strategy, energy and sustainability targets are required to be met by the LA energy team.

7.2.2 RIS mechanisms

Definition of key skills required

Skills

The term skills were viewed as a combination of existing and new, where there is an element of an individual possessing particular skills, but this individual also has to ability to further build on existing skills. As mentioned by the school site controller (SC41), by stating: "*More building upon, yeah. And some of the skills I've had to learn since I've been here, but you obviously bring a bag of skills with you that help you learn and embed the new ones."*

Project management skills

Project management skills were defined as the ability to oversee a number of projects (various EEM) at one time, closely connected to the planning stages of the project to make decisions regarding EEM contractors and the appropriate EEM for the building. This was indicated by the school finance manager (FM41), by explaining: *"Then there was the planning stages, as quite often when we do these projects it is tide in at a time when there is other projects going on so you have that project management element going on…I had to speak to the different companies to find out what they offered, the difference between each product, know about all the electrics going in…"*

Communication Skills

Communication skills were associated with the ability to interact and exchange information with other actors / actor groups involved in the delivery of the project. This was highlighted by the school finance manager (FM41), by stating: *"Communication that is key as well, as I was in touch with both the energy officer and energy assistant. I think the energy assistant was there, she might have been very new. I also met with the contractors so I showed them the room [for the EEM] and everything."*

Project 4 findings provided detailed insight on the definitions of skills required from the view of the school end-users, and roles of the school staff for the project. Due to the involvement of the finance manager and school site controller, project management skills were not only required during the planning stages of the project, but also the installation and post implementation of the EEM. The school staff were heavily involved in the decisions of the EEM, and had the ability and knowledge of how to drive and further aid the delivery of the project (e.g. the funding process, choice of EEM and EEM contractors).

Interactive learning: evidence of skills required through negotiations

Through the identification of the principal interests of key actors / actor groups and the key skills required for project 4 (see Figure 7.6), interactive learning, a RIS mechanism, and negotiations between actor groups within the network were highlighted. There are ten key interactions surrounding the delivery of project 4:

Interactions between the key actor groups

1. Interactions between the LA energy team [1] and the school staff [2]

(1) Principal interests

The principal interests of the LA energy team were to comply with LA targets by reducing energy consumption in the school and ensuring the suitable EEM were adopted (see figure 7.7 below of the socio-technical network (STN) for the principal interests). The discussion to support these interests can be found in section 4.3.2. The interests were further evidenced by the school finance manager (FM41), who stated:

"Place A [of the LA energy team] were checking all of the schools [insulation] and because our depth was below the standard…" [270mm is the standard depth / thickness for loft insulation]

This was expanded by the school site controller (SC41), who added:

"Yes it [the insulation] shrunk, collapsed over age. They [installers] put an extra 200 [ml of insulation] over the top."

The key interests of the school staff were to reduce energy costs within the school and gain funding for the EEM (through the LA energy team from the institution funding provider) (see figure 7.7 below of the STN for the principal interests of the school staff). This was evidenced by the school finance manager (FM41), who expressed:

"I think originally I think it was going to be 90% funding [from the institution funding body], 10% funding from the school. So they had £15,000 to spend and we would contribute £1500…[in reference to the sun pipes] originally I would of had them [the sun pipes] everywhere, you know because they are free, not free to buy but once they are in it's free…"

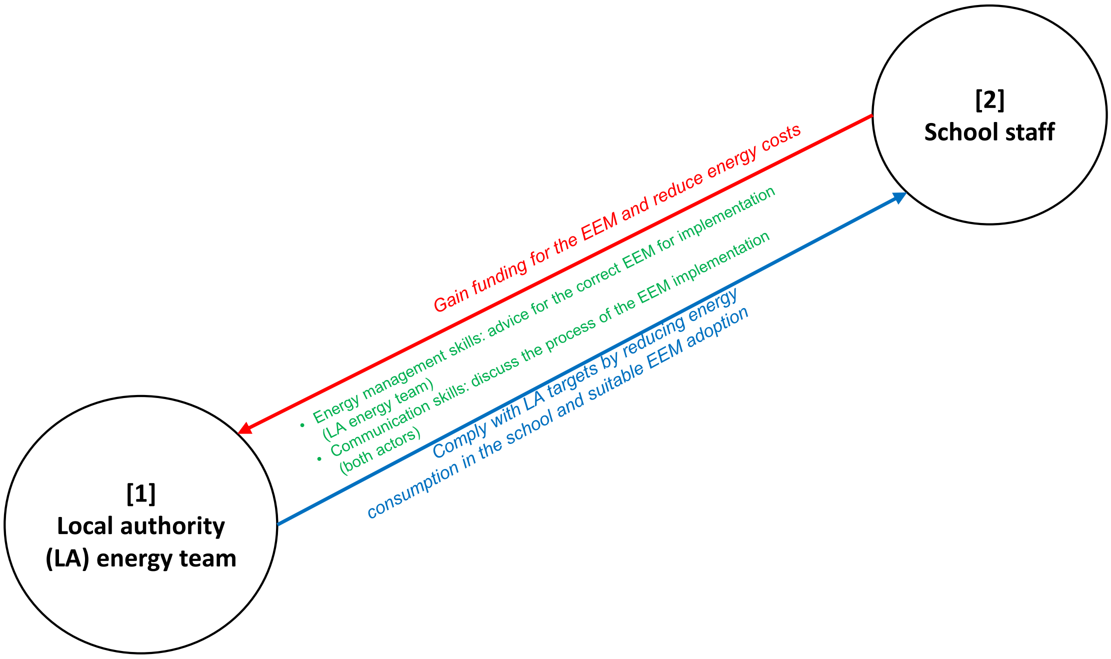

Figure 7.7: the STN showing the principal interests, negotiation issues and required skills for the LA energy team and school staff

(2) Key negotiation issues

Two negotiation issues were raised (see figure 7.7 of the STN for evidence of the key negotiation issues and required skills). First, there was a negotiation over the type of EEM to be installed. Typically, the process of EEM adoption by the school is through the LA energy team offering advice on the correct EEM and funding, for which energy management skills are required. This negotiation was highlighted by the school finance manager (FM41), who mentioned:

"I have emailed EA11 [the energy assistant] and EO11 [the energy officer] over the summer and said these are the things we want to do: lighting, placement windows, boilers, doors…And some of them [lights and fittings] or quite a lot of them will be original, so that's 25 years old. So that project is going up the priority list."

Second, negotiations surrounded the adoption process in terms of EEM contractors visiting the school (i.e. EEM surveyors, EEM installers), which highlighted the need to be in communication with the LA energy team (in addition to the EEM contractors). This was captured by the school finance manager (FM41), who noted:

"Communication that is key as well, as I was in touch with both EO11 [the energy officer] and EA11 [the energy assistant]…through LA11 [the local authority], in that we have a contact and some kind of email correspondence that says we are going to come out and see you."

2. Interactions between the LA energy team [1] and the institution funding provider [3]

The discussion of the interactions between the LA energy team [1] and the institution funding provider [3] can be found in section 4.4.2.

3. Interactions between the LA energy team [1] and the LA building management team [4]

The discussion of the interactions between the LA energy team [1] and the LA building management team [4] can be found in section 4.4.2.

4. Interactions between the school staff [2] and the LA building management team [4]

(1) Principal interests

The principal interest of the school staff was to gain funding for the EEM. Funding for the EEM was provided by either the LA building management team or the institution funding provider, via the LA energy team. This was captured by the finance manager (FM41), who stated:

"The lighting project, I've been on about this lighting project for 3 years now, and we have had a couple of people out to measure up…so funding by LA11 [the local authority], and it's all gone very quiet. I keep chipping away at it to try."

The principal interest of the LA building management team was for the school the school to have a consistent supply of energy. In relation to the heating system and current boilers being twenty-five years old within the school, the site contractor (SC41), stated:

"We haven't done anything on it yet as we just keep being told they [the heating boilers] work."

Furthermore, the school finance manager (FM41) noted:

"They [the local authority] knowing we are banging on about it so it's in their view, just nothing is being done about it. I don't want to get to stage where they [the heating boilers] stop working. The last thing we want is that snowy January day and the boilers fail. I mean we would have to close."

(2) Key negotiation issues

One negotiation issue was raised surrounding the adoption of the EEM. As highlighted above, the LA building management team have an influence over the changes to the building and control a large part of the finance, and hence decisions, for the EEM. The issue highlighted the requirement of both negotiation skills and presentation skills, which were used by the school finance manager to gain funding and justify to the school governor the adoption of the EEM. As supported by the school finance manager (FM41), by stating:

"…negotiations for the grant, then I had to talk to the governors so there is an element of presentation skills. Although I didn't have to stand up or anything."

5. Interactions between the LA energy team [1] and the EEM surveyor [5]

(1) Principal interests

The principal interest of the LA energy team was to gain a quote and information of the potential EEM. The principal interest of the EEM surveyor was to carry out an EEM survey to win the work.

The interests and interactions between these two actors are supported in section 4.4.2.

(2) Key negotiation issues

The discussion for the key negotiation issues and skills required by both actor groups can be found in section 4.4.2.

6. Interactions between the school staff [2] and the EEM surveyor [5]

(1) Principal interests

The key interest of the school staff was to gain the most efficient and up-to date EEM as possible. This was evident by the school finance manager (FM41), who stated:

"As efficient as they [EEM / lighting] could be, the up-to-date models. They said to us they are running as efficiently as they possibly."

The principal interest of the EEM surveyor was to carry out a survey to advise the most appropriate EEM for the school. This was supported by the school finance manager (FM41), who noted:

"So somebody came out and did the survey for the whole building…"

Furthermore, the site controller (SC41), added:

"I know they [the surveyor] were just talking about changing the insides, weren't they. But all our fitting are going so they might be doing complete new fittings all the way through."

(2) Key negotiation issues

Two negotiation issues were raised. The first issue was related to the most suitable EEM for the school building. The negotiation highlighted the need for energy management skills for the EEM surveyor. This was supported by the school finance manager (FM41) who stated:

"They [lighting surveyor] went around every room in the school to see which lights needed to be replaced and how much they would cost, based on the return over 5-6 years. The idea was I would look down the list of buildings and say well I don't want you to replace the lights in that cupboard because that's not worth spending the money on, can you focus on the class rooms or here."

The second negotiation surrounded the choice of EEM contractor and most appropriate EEM for the school. This negotiation emphasised the school end-user requirement of project management skills, as noted by the school finance manager (SC41), who mentioned:

*"I had to speak to the different companies to find out what they offered, the difference between each product, know about all the electrics going in…*quite often when we do these projects it is tide in at a time when there is other projects going on so you have that project management element going on."

7. Interactions between the EEM surveyor [5] and EEM installer [7]

(1) Principal interests

The principal interest of the EEM surveyor was to provide details for the proposed EEM from the survey previously conducted. The discussion surrounding the interests of the EEM surveyor can be found in section 4.4.2.

The interest of the EEM installer was to gain details to install the EEM. The discussion surrounding the interests of the EEM installer can be found in sections 4.4.2 and 6.2.2.

(2) Key negotiation issues

The discussion surrounding the negotiations can be found in section 4.4.2.

8. Interactions between the school staff [2] and the EEM installer [7]

(1) Principal interests

The principal interest of the school staff was to gain the EEM with the least disruption possible. The principal interests of the EEM installer were to fit the EEM and provide annual maintenance checks. This was highlighted by the site controller (SC41), as stated:

"They [installers] put it all in for us. They done it as a complete job. They fitted it on the roof for us, put all the cables in and boards across, ran the cobles from the boards to the meter…they [installers] do come in and check them once a year. We should be due one soon."

To further support the interest of the EEM installer, the school finance manager (FM41) added:

"Well I hope so as I've been trying to get in touch with them about this checking them out to make sure they are working properly…"

(2) Key negotiation issues

Two negotiation issues were raised. First, the negotiation surrounding the level of skills required for the installer to fit the proposed EEM. This issue highlighted the need for electrical knowledge and an understanding of how to actually install the EEM by the EEM installer, and project management skills required for the school staff. This was evidenced by the school finance manager (SC41), who expressed:

"They [EEM contractor] didn't provide us with the electrician so I had to go to one of my other contacts and ask if we could use their electrician for the day to connect it up. So they put it all there, but didn't connect it up as they don't have an electrician. Then I had to bring somebody else in. So it wasn't a whole complete service."

Furthermore, to support the need for electrical skills by the EEM installer, which gives indication of a form of technical skills required, the school finance manager (FM41) added:

"I think for the job they are doing [installing sun pipes] on a daily basis that is a feature that is missing. If you are installing electrics you need an electrician."

Second, a negotiation surrounded the EEM in relation to the installation and further explanations linked to the use and EEM maintenance (or lack of information / contact provided). This issue highlighted the requirement of communication skills by both actor groups. The school finance manager (FM41) highlighted the need for communication with the EEM installer / EEM contractor, as stated:

"I also met with the contractors so I showed them the room and everything…we have through LA11 [local authority], in that we have a contact and some kind of email correspondence that says we are going to come out and see you, can we book you in…we may not see them from one year to the next, but I can pull up an email so we know who to go to… for us to have an annual check that it is working alright would be reassuring."

Furthermore, the site controller (SC41) supported the requirement of communication skills by the EEM installer and the end-users in relation to an explanation of the EEM, as mentioned:

"I think at the time they [installers] explained as much as they could. They were telling us how it comes down the line, gets converted, how it comes to the board.

9. Interactions between the EEM installer [7] and EEM supplier [6]

(1) Principal interests

The principal interest of the EEM installer was to upgrade and install the EEM. The principal interests of the EEM supplier was to ensure the EEM was installed at a convenient time, and supply the EEM.

The discussions supporting these interests of the EEM installer and EEM supplier can be found in section 6.2.2.

(2) Key negotiation issues

The negotiations issues and further skills required for the EEM installer and EEM supplier can be found in section 6.2.2.

10. Interactions between the school staff [2] and the EEM supplier [6]

(1) Principal interests

The principal interest of the school staff was to reduce energy costs for the school through the adoption of the EEM. This interest was evidenced by the school finance manager (FM41), who expressed:

"We don't get all the return of the project, I think we get a minimal of about £600 a year that offsets our electricity bill."

The principal interest of the EEM supplier was to provide the EEM to generate electricity.

(2) Key negotiation issues

No negotiation issues.

Summary of the skills required

Project 4 captured a number of dominant skill sets required by the key actor groups involved in the delivery of the retrofit project. The LA energy team required project management and energy management skill sets, and a degree of communication skills. The EEM contractors needed technical skills that involved a level of electrical knowledge, experience and understanding surrounding the

EEM. Furthermore, energy management skills were required my EEM contractors during the development and implementation of the EEM, and communication skills to interact with the majority of actors / actor groups to deliver the project. The key skills required for the school staff, as they were very much involved in the early stages of the project and key decisions, were project management skills to evaluate and organise the EEM and its contractors, and communication skills (before, during and after EEM implementation). It is interesting to note, in addition to these skills required by the school staff, a range of other required skills were evident for the site controller to develop the school and become more eco-friendly, and possibly gain the Green Flag award. There was little interaction with the EEM contractors or the local authority, however, evidence suggests practical skills and problem solving skills, in relation to building the water butts, were required by the school site controller.

Knowledge production

The knowledge produced through interactions between the different actors / actor groups was predominantly tacit knowledge. The information for EEM decisions (e.g. the various types of EEM, EEM contractors chosen) by the local authority was existing knowledge by the actor groups involved. As noted by the school staff, for example, the communication surrounding the EEM (its use and maintenance), was insufficient, which highlights the lack of explicit knowledge by EEM contractors. The dominance of tacit knowledge within the network further emphasises the need for additional skill sets, such as research skills, by actors / actor groups for the delivery of the project. This finding also indicates the greater challenge associated with the management of knowledge, specifically where tacit knowledge is produced. The school staff required additional learning to understand how to manage the knowledge. Furthermore, during the adoption of the solar PV, tacit knowledge was captured by the EEM supplier, as the school finance manager was a little unsure of the system, i.e. how to work the solar system and solar PV maintenance. In contrast, explicit knowledge was present by the site controller as a source of information for the finance manager, offering knowledge on the EEM. Similarly, explicit knowledge was present within the network in connection to the school presentations to governors, where the finance manager explained the choice and use of the EEM.

Proximity: physical and spatial

In relation to the physical proximity, many of the EEM contractors were located outside of the network, or in close proximity to the regional boundary. This finding indicates a possible connection to the level of involvement of the school staff, their enthusiasm and drive for the EEM, and further input at the early planning stages, i.e. contractors, choice of EEM. The use of sun pipes and solar PV, for example, was dominantly driven by the school finance manager, who located the EEM contractors that were outside of the region.

In terms of spatial proximity, the school staff are in close communication to the LA energy team via meetings, emails to discuss energy auditing, EEM funding and EEM contractors. Similarly, spatial proximity is evident between the school staff and the EEM contractors, particularly the EEM surveyor, where communication and relationships are evident to discuss the EEM. It is interesting to note the spatial proximity between the school staff and EEM contractors highlight skills or lack of required skills by the EEM contractors (e.g. electrical skills).

Embeddedness

Greater levels of embeddedness is evident within the LA, particularly the LA energy team, in terms of using resources, exchanges of any EEM information and communication surrounding the delivery of the project. Embeddedness was also captured within the school, where school staff required close communication and interactions for EEM, and school pupils were part of a learning programme with the school staff to drive and help deliver project 4.

Chapter 8 School retrofit project 5

8.1 Introduction

This chapter will introduce project 5 of the research. A description of the project and the school under investigation will be given. The required skills identified for the delivery of the project will also be outlined. Furthermore, an explanation of the mechanisms evident within project 5 will be stated.

8.1.1 Description of school 5

Project 5 is a small primary school (figure 8.1) (ninety eight pupils), located within a village north of the region, in close proximity to the region boundary. The school consists of one main permanent structure, which is surrounded by a large playing field, and houses and facilities used by the local community. The display energy certificate (DEC) (figure 8.2) for the building is 'C' rated, i.e. a score of sixty-seven, which is above the 'typical' building energy rating of one hundred. The project has been ongoing by the local authority (LA) since February 2011, with a number of energy efficient measures (EEM) completed or in the process of being completed prior to the research.

Figure 8.1: school retrofit project 5

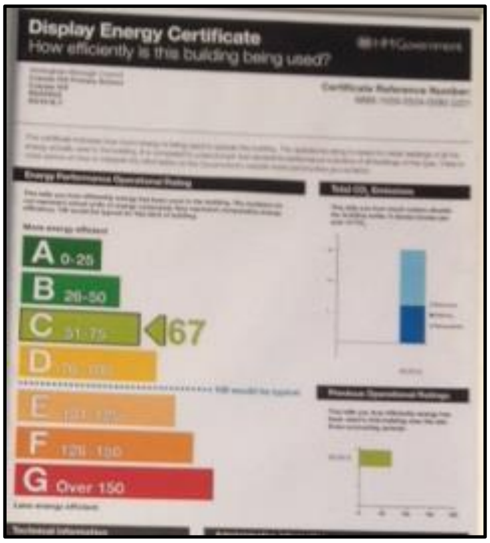

Figure 8.2: display energy certificate (DEC) for project 5

8.1.2 Description of existing energy efficient measures / technologies

The school building has an existing PV array (figures 8.3 and 8.4), which was fitted during the summer of 2012. Certain sections of the building, the 'new' parts that were redeveloped during 2012, have loft and cavity wall insulation. There are also parts of the building that have double glazing and energy efficient lighting.

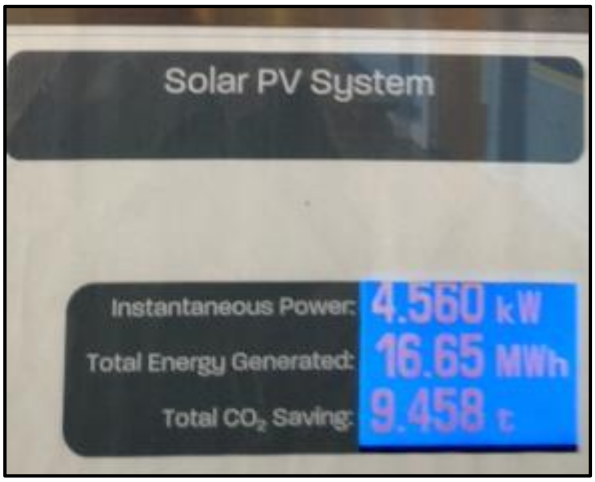

Figure 8.3: solar PV display monitor

Figure 8.4: solar PV inverter and controls

8.1.3 Areas for improvement identified by the energy audit

Following the energy audit conducted by the LA energy assistant, three primary areas of improvement and proposed EEM adoption were identified for the school building. First, the EEM of priority were changes to the lighting system (T12s and T8s to be replaced with T5s) and single glazing areas (windows and doors) upgraded to double glazing for the remainder of the school, i.e. approximately half of the building. Second, improvements to the heating system were mentioned in terms of updating the heating controls for school staff, more specifically, controls for sections of the building and individual classrooms. Finally, in relation to actions by the school staff, changes to energy behaviour were also advised. Turning off electrical equipment and shutting doors, for example, were highlighted throughout the energy audit.

8.1.4 The implementation, or in the process of adoption, of EEM

Improvements were made to the lighting of the building in terms of an upgrade from T12s and T8s, to T5s. Sections of the building that were single glazed were replaced with double glazing, both doors and windows. The heating system was also upgraded, which included a more energy efficient boiler, radiators and changes to the controls and location of heating components (figure 8.5). Furthermore, the school has been fitted with a smart meter for the LA energy team and end-users to gain an accurate account of the electricity readings.

Figure 8.5: energy efficient heating system adopted for project 5

8.2 The regional innovation system (RIS) and socio-technical network analysis (STNA) for project 5

The RIS and socio-technical network (STN) that surrounds school project 5 is shown in figure 8.6 (below).

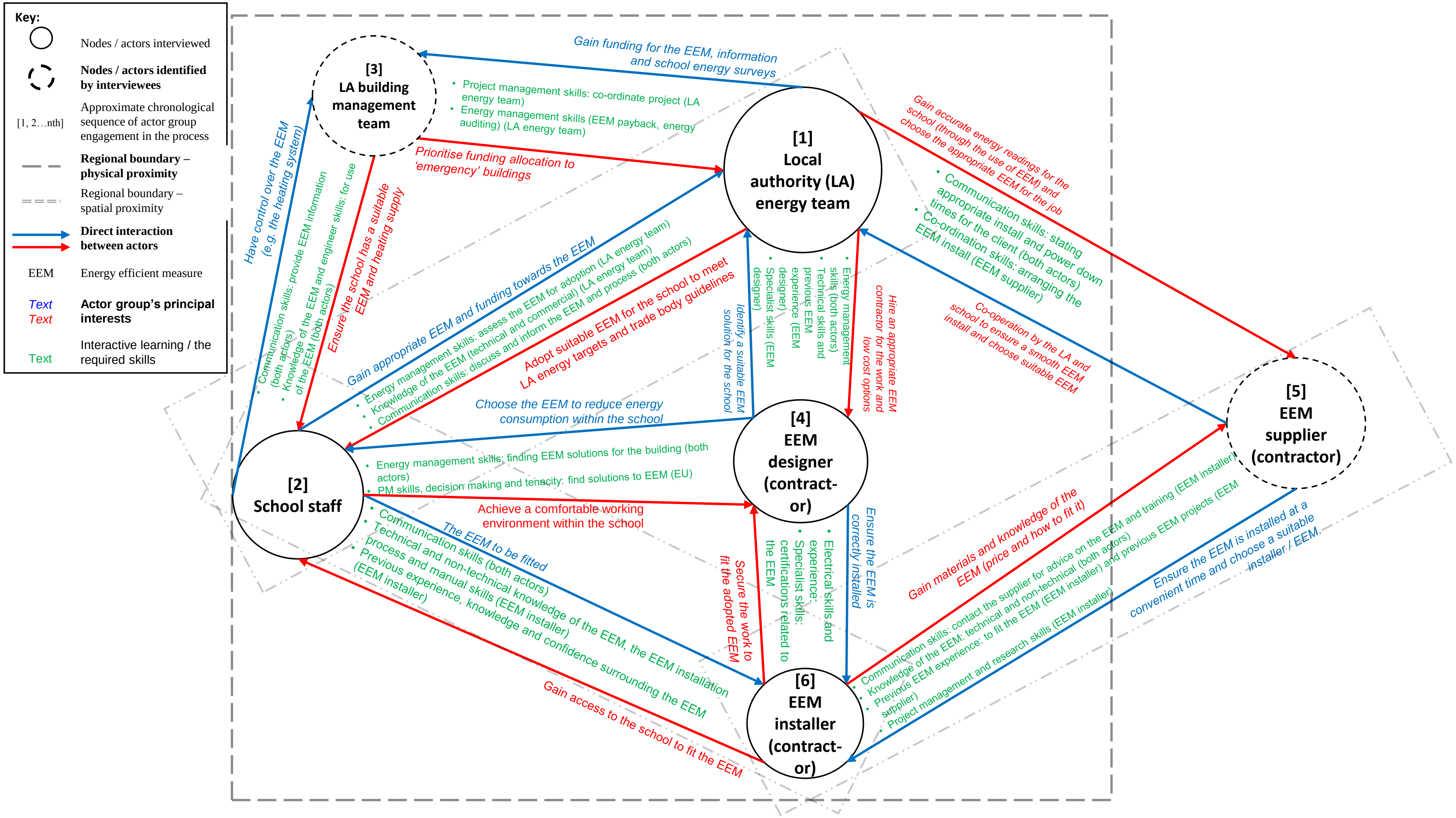

Figure 8.6: school retrofit project 5 - adoption of EEM and surrounding RIS / STN

8.2.1 RIS elements

The research findings indicate there are six key actors / actor groups within the network, and each can be distinguished by their role within the RIS as follows:

Institutions

- Local authority (LA) energy team: respond to energy supply issues and concerns of local authority owned buildings, and monitor energy consumption within the buildings.
- Local authority (LA) building management team: provide funding and EEM support for local authority owned buildings. Provide an in-house project manager for the EEM (solar PV).
- School staff (school finance manager, school head teacher): monitor building energy consumption and energy costs, co-operate for the implementation of EEMs and ensure maintenance of adopted measures. As the school size is small (under 100 pupils), the school finance manager also fulfils a school facilities manager role.

Firms (EEM contractors)

- EEM designer (lighting, PV, heating): carry out an initial survey to assess the potential for EEM installation, and further recommends the EEM for adoption.
- EEM installer (smart meter, heating system, lighting, PV): install the adopted EEM and (on occasions) provide information of measure(s) during the handover.
- EEM supplier (lighting, smart meter, heating system, PV): provide materials / information for the installation of the adopted EEM. Respond to LA energy team and EEM installer through EEM project manager (smart meter adoption).

Knowledge infrastructure

- LA energy team: provide training (e.g. energy auditing) and information (e.g. decisions around the EEM) to departments within the local authority, and information / awareness for the EEM to the school staff and (on occasions) to school pupils.
- EEM supplier (heating): provide training to EEM contractors.

Policy orientated regional innovation

- LA: implement energy reduction targets for the local authority, such as the carbon emissions reduction target of 15% by 2015 and 40% by 2020. As stated in the Carbon Management Plan and the local authority Sustainable Environment Strategy, energy and sustainability targets are required to be met by the LA energy team.

8.2.2 RIS mechanisms

Definition of key skills required

Skills

The notion of a skill was defined as the ability to learn and closely associated with training, but also the view that an element of a skill, the ability to learn and further carry out a task can be an individual characteristic, or already exist within the individual. As evidenced by the smart meter installer (SMI51), who expressed: *"A skill is something you have been trained for or some people have a natural skill. For some people you can teach and teach them and they will never get it. It all depends on whether, not an empathy for it, but you know what I mean. Even as a kid I was into electronics and stuff."*

Furthermore, a skill can be viewed as a more physical attribute through the ability to finish a job and further compared to knowledge, which is associated with memory and possibly long-term characteristic. This was indicated by the energy manager (EM51) who explained: *"Less skills and more knowledge…I find that it is knowledge now rather than a skill… a skill is the ability to complete a task, whereas knowledge is something you can hold in your memory."*

Technical skills

The definition of a technical skill varied by the different EEM contractors involved in the delivery of project 5. Technical skills were associated with knowledge of the EEM, electrical competencies and previous experience with the EEM. Technical skills were viewed as the ability to retain knowledge of the technology, and have a further understanding of the technology specifics. As mentioned by the energy manager (EM51), who stated: *"I think all of them [technical specialists] in that role have a masters degree, so quite well educated to start with so that gives them a broad knowledge base. But then also specifically trained for the technologies that we were working with."* In support of this definition of technical skills, the energy officer (EO12) associates a technical skill with a broad knowledge of the technology (e.g. ease of accessibility, integration within the building, commercial knowledge, and short-term and long-term challenges, both technical and non-technical.), as expressed: *"[A technical skill] basically knowing the costs and benefits of PV, also the risks, knowing how they work, how they are installed in practice and reality. Things to avoid when installed in terms of what products to use, how they are installed and how they are designed fit together. The consequences and complications surrounding energy production for example, and also the risks down the line to the building owner, to users of the building. So to do with everything from electrics to the grid connection, to the cabling itself, to the inverter, the solar panels, the accessories, and then the* *actual fixing of the panel to the roof. So not just technically, but planning and building structure."* Furthermore, the definition of technical skills was extended with regards to post implementation of the technology by the ability to use to EEM (i.e. understand, operate and control the system). As explained by the school finance manager (FM51) (who acted as a school site controller), when asked if they possessed a technical skill, in response stated: *"I'm not an engineer, building surveying was my background, in construction…I wouldn't be able to walk in and fix the boiler, I can change a light bulb."*

Specialist skills

Specialist skills were viewed as distinct and separate to technical skills by the EEM contractors involved in project 5, and connected to a specific EEM (e.g. solar PV), a trade (e.g. plumbing) or a qualification (e.g. MSc degree).

Interactive learning: evidence of skills required through negotiations

Through the identification of the principal interests of key actors / actor groups and the key skills required for project 5 (see Figure 8.6), interactive learning, a RIS mechanism, and negotiations between actor groups within the network were highlighted. Negotiations identified within the network gave further explanation and insight to the different meanings associated with the required skills. There are nine key interactions surrounding the delivery of project 5:

Interactions between the key actor groups

1. Interactions between the LA energy team [1] and the school staff [2]

(1) Principal interests

The principal interest of the LA energy team was to adopt suitable EEM for the school to meet LA energy targets and trade body guidelines (i.e. the need for a suitable working environment within the school, e.g. heating and lighting). This interest was supported by the LA energy officer (EO12), who expressed:

"…basically the remit was solar PV investment…great detail was in all of the options. I think it [school project 3] was one of the best sort of roofs in terms of carbon savings…You also have to ensure you are meeting the guidelines… The guidelines are there for a reason, to ensure a decent environment for the staff, children and visitors. For example, you could just take out all of the lights and say work during day light hours only, which would save a lot of energy and be ideal for environmental purposes. However, not ideal for learning and usual business…So we just use the guidelines and standards where possible, and you just have to accept the compromise.

The principal interests of the school staff were to gain appropriate EEM for a suitable working environment and funding for the EEM. The interest of the school in adopting the EEM was illustrated by the energy officer (EO12), as stated:

"…we didn't need to sell it to any of the schools. They were all extremely leaping as they have all heard of it and interested. Project 5 was no exception."

To evidence the interest of gaining an appropriate EEM for the school, and the challenges associated with adopted and possibly unsuitable measures, the school finance manager (FM51) stated:

"…we have had low energy bulbs installed. With varying success. I only know this as we have had problems with them recently. In one area we have, because energy efficient compact fluorescent tubes are shorter so we have had transformers at the end, which it is not a terribly good system…I'm not sure if we will continue with those."

Furthermore, the interest of funding for the EEM was captured by the school finance manager (FM51), who expressed:

"We wanted the double glazing done and it's a lot of money for a school of this size, or any size really. So we approached LA11 and told there was a pot of funding available, and that enabled the project to go ahead really… I think it's good that the local authority is keeping up with legislation and there are grants and things available, and then it feeds back down to the school."

(2) Key negotiation issues

One negotiation issue was raised surrounding the selection of a more suitable EEM for the school. This issue highlighted the requirement for energy management skills for the LA energy team in terms of financial calculations for the EEM, and the need to gain knowledge of the EEM. In the case of the solar PV the required knowledge for the EEM was related to technical knowledge (i.e. the wires and components of the system), and commercial knowledge (i.e. EEM costings and market knowledge). The need for energy management skills and EEM knowledge were evidenced by the energy officer (EO12), who stated:

"A complete change of lighting, you have to think about your economical means, that's one aspect for the council…I am learning about certain areas more and more. The breadth of low carbon technologies, but also as I go along and do projects, then the depth as well. Getting more familiar with the technical as well as commercial aspects…the project team or individual need an appreciation of the wider variety of areas (for the solar PV technology), which is not all to common to have in an individual. That covers, the commercial side, the regulation side, the technical side, I mean

the electrics even down to the building structural issues. Not on a detailed level but they have to be commissioned."

Furthermore, this negotiation captured the need for communication skills for the LA energy team as noted by the energy officer (EO12):

"A lot of it was on the job sort of pooling people for resources and knowledge as you go."

Similarly, there was a need for communication skills by both the school and LA energy team, as stated by the energy officer (EO12):

"…we wrote to all of the schools being potentially looked at, and said we were after their interest to have the school surveys undertaken… I did need to have a lot of interaction with the school as they become more of the project."

2. Interactions between the LA energy team [1] and the LA building management team [3]

The discussion of the interactions between the LA energy team [1] and the LA building management team [3] can be found in section 4.4.2.

Furthermore, as well as the interactions above, the LA energy team of project 5 hires an in-house project manager for the EEM (solar PV) through the LA building management team. The role of the in-house PM relates to a survey of the school to establish its energy performance, the priority for an EEM and to co-ordinate the solar PV project. The LA energy team and LA building management interaction highlighted the LA energy team interest to gain information on the school energy performance and potential for solar PV, as stated by the energy officer (EO21):

"I got in a PM from the in-house council from buildings management team. I was the project owner but the PM acted in terms of getting surveys done, I directed them to happen, but they carried them out. The surveys were energy performance certificates...this was before a get out claw for schools, so we had to get EPC for every building and structural surveys done. Because the person being PM was embedded in the council building management team, he assured me it would all be done e.g. reports would be made available."

One further negotiation issue was raised between the LA energy team and LA building management team (project manager) that surrounded the job requirements and ability of the in-house project manager to carry out tasks. This was supported by the LA energy officer (EO12) who explained what skills were required of the in-house project manager, by stating:

"…[the PM was required to] stick to the timescale or the basic instructions for what was asked from them [the PM]… ability to get the basics done."

3. Interactions between the school staff [2] and the LA building management team [3]

(1) Principal interests

The principal interest of the school staff was to have control over the EEM, i.e. the heating system, as the LA building management team are primarily concerned with the heating systems within the schools. This interest was supported by the school finance manager (FM51), who expressed:

"You could have a meeting or something when you first come into the school, the hall or maybe an evening, but as soon as the children get in there for assembly, it's far too hot isn't it… So it is to have the ability to immediately control the heaters, it's very good… we can now control its [heating and boilers] operation via an internet site."

The interests of the LA building management team were to ensure the school had a suitable EEM and heating supply. These interests were captured by the school finance manager (FM51), who expressed the need for the LA operations assistant (OA51) (of the LA building management team) to fit the new heating system due the previous being very old and inefficient.

(2) Key negotiation issues

Two negotiation issues were raised. First, a negotiation surrounded the explanation to the school staff of the EEM, the heating system. This issue required communication skills by both actors, as when asked about training, the school head teacher stated:

"Yes they [the local authority] came to you [the school finance manager] and then cascaded it to us!"

The second negotiation issue was related to a lack of understanding of the EEM by school staff, or periods where end-users were unable to use and operate the system (EEM). This negotiation captured the need for a knowledge surrounding the EEM and the possibility of an engineering background or skill required. The school finance manager (FM51) evidenced these required skills as expressed:

"As soon as something goes wrong in the boiler room, my knowledge is obviously increasing as times goes on… But I am not an engineer so once I start pressing a couple of buttons then that it, it has to be a telephone call."

4. Interactions between the LA energy team [1] and the EEM designer [5]

(1) Principal interests

The key interests of the LA energy team were to hire an appropriate EEM designer for the work and low cost options (see figure 8.7 below of the socio-technical network (STN) for the key interests of the

LA energy team). The process of hiring an EEM contractor and need to look for specific traits and characteristics (e.g. skills) was evidenced by the energy officer (EO12), who stated:

"Yes, we did a tendering exercise ourselves and from that shortlist available. It was quite a demanding invitation for tender that we put together…"

Furthermore, the interest of the LA energy team for the EEM costing and indication of preferred cheapest option was captured by the heating contractor (HC51), who stated:

"Often we work to a specification, we put that all down on paper I price it and send them the price. They [LA11] either go with it or don't go with it, depending on what they can afford."

The key interest of the EEM designer was to select EEM options for the LA energy and further EEM contractors for them to further decide the adopted EEM (see figure 8.7 below for the principal interest of the EEM designer). This was noted by the energy manager (EM51), as expressed:

"…identifying the solution is that came down to myself, people in the energy team, energy managers and similar people who would identify the best technology to use was, and we have quite a rigid process."

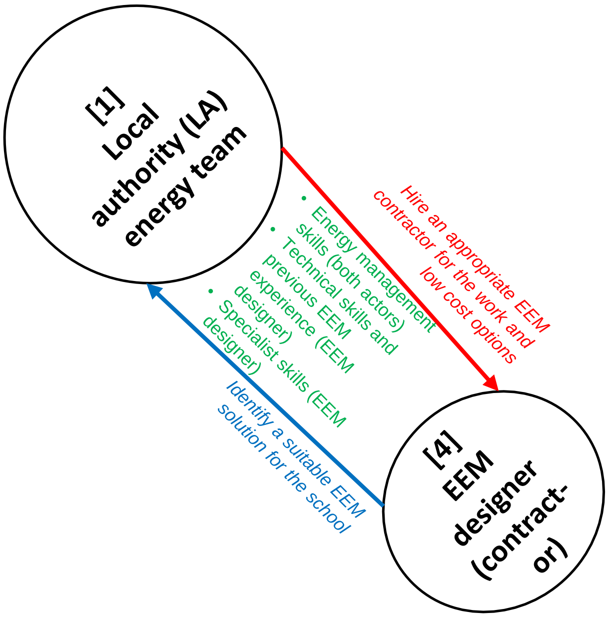

Figure 8.7: the STN showing principal interests, negotiation issues and the required skills for the LA energy team and EEM designer

(2) Key negotiation issues

One negotiation issue was raised that involved the design of the EEM (see figure 8.7 of the STN for evidence of the negotiation issues and required skills for the LA energy team and EEM designer). During the evaluation and choice of EEM by the EEM designers (lighting), it was highlighted energy management skills (e.g. EEM calculations) and technical skills were required. This was captured by the energy manager (EM51), who mentioned:

"…skills that aren't specifically energy skills, on the financial side maybe. So the other that goes hand in hand with energy management that help identify solutions…all of our people working to fulfil that function [technical specialists] would have a degree in engineering or science. I think all of them [specialists] in that role have a masters degree, so quite well educated to start with so that gives them a broad knowledge base. But then also specifically trained for the technologies that we we're working with… They would then ask them [energy specialist] to make a technical recommendation and appraisal of the opportunity."

To further support the requirement of technical skills required for the EEM designer, the energy officer (EO21) expresses:

"They had to have specialist skills…from the designer who was an MSc level educated engineering who specialised in solar…he [designer] was an engineer so by definition had technical skills and experience designing solar installations."

5. Interactions between the school staff [2] and the EEM designer [5]

(1) Principal interests

The key interest of the school staff was to gain a comfortable environment within the school (see figure 8.8 below of the STN for the principal interest of the school staff). This was evidenced by the school finance manager (FM51), who stated:

"The radiator in there [the cloakroom] didn't work, so by introducing a ceiling mounted heater and the double glazing that solved the problem in there…the worst thing was the windows, we had those old metal brittle framed windows, so some of them you couldn't open."

The principal interest of the EEM designer was to choose the EEM to reduce energy consumption within the school (see figure 8.8. below of the STN showing the key interest of the EEM designer). This interest was supported by the energy manager (EM51), who expressed:

"…we did lighting replacement and lighting controls… working with our customers to help them identify ways to reduce energy consumption and hopefully they take on the measures we identify."

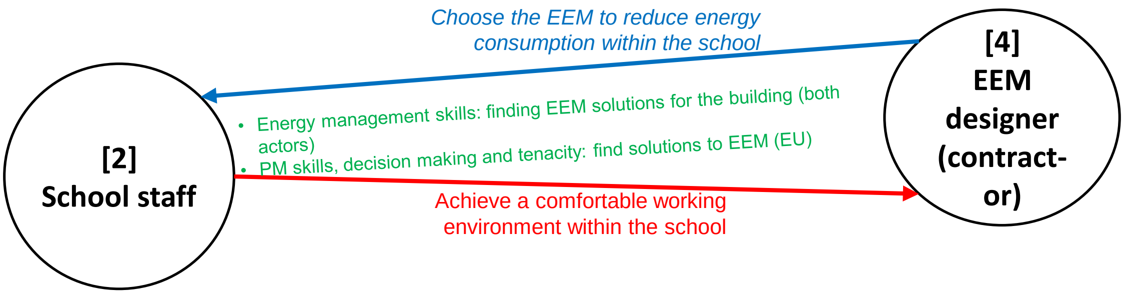

Figure 8.8: the STN showing the principal interests, negotiation issues and required skills for the school staff and EEM designer

(2) Key negotiation issues

One negotiation issue was raised in relation to the more suitable EEM to adopt for the school (see figure 8.8 of the STN for evidence of the negotiation issue and required skills for the school staff and EEM designer). This issue highlighted the need for energy management skills for the designer of the EEM (lighting). These skills were captured by the energy manager (EM51), who mentioned:

"I provide energy management to our customers, not a one off basis but an on-going one as well. I employ energy conservation measures for them [customers]. I then have the challenge that is it worth them having the energy conservation measures and it is worth them investing their money in it…I am a chartered energy manager with the chartered institute so I have a fairly high level of energy management skills."

Similarly, energy management skills and project management skills were required for the school staff. The school finance manager, for example, had a view and opinion regarding the choice of suitable EEM for classrooms (e.g. wall mounted heater) and the EEM locations. As stated by the school finance manager (FM51):

"…while that was going on we were also able to put heaters in the cloakroom area of Lindon because that was a very damp area. The radiator in there didn't work, so by introducing a ceiling mounted

heater and the double glazing that solved the problem in there…It is about managing the project in a proactive way…"

Furthermore, in connection to the requirement of project management skills and to extend the role of the school finance manager, the need for tenacity was mentioned as an important trait during the adoption of the EEM. The school head teacher (HT51) evidenced this need as expresses:

"The finance manager is doing herself down, she is extremely capable and well, tenacity is a big thing, but also having a go. And partly needs must but also you have the inclination to do it."

In support, the finance manager (FM51) states:

"Yes, I'm a big solution finder, fix a problem."

6. Interactions between the EEM designer [5] and EEM installer [6]

(1) Principal interests

The key interest of the EEM designer was to ensure the EEM is correctly installed. The key interest of the EEM installer was to secure the work to for the installation of the adopted EEM. This interest was evidenced by the energy manager (EM51), as stated:

"…the electrician's job is to take the light fitting from the back of the van and put it on the light fitting."

(2) Key negotiation issues

One negotiation issue was raised that was connected to the installation of the EEM and the appropriate installers for the work. This issue highlighted the requirement of two key skills for the EEM installers. First, the need for electrical skills and experience, i.e. the knowledge of the electrical components of the EEM. The energy manager (EM51) supported the requirement of these skills, by stating:

"The installers are part of a third group. They are electricians. When it comes to lighting the electricians have experience in the technologies they are working with…obviously they [electrical installers] have additional qualifications, something like additional light regulations for example…the electricians are given very simple instructions to follow so they don't need specific training. It might be one thing above that where they do need to have that understanding."

Furthermore, the energy manager (EM51) also noted that this electrical skills set is not a new skill that needs to be learnt by the EEM installer, as they should already have an electrical knowledge.

Second, the requirement of specialist skills (e.g. plumbing and heating certification) by the EEM installer were evident. As captured by the heating contractor (HC51), who expressed:

"Well our engineers fit the heaters for me. They are all apprentice trained plumbing and heating engineers...in our industry you get lots of pipe fitters who are or ordinary, then you have ones with specialist skills…one of my engineers is trained to do large diameter pipework, which is quite a specialist thing. You know you have to have a certificate to be able to even do that. I have another one who does domestic boilers and he has to have a special certificate to do domestic boilers. We do pressurised vessels and they have all got to have certificates for that. So they have all got specialist skills."

This view was further reinforced by the heating assistant (HA51), who stated:

"They [installers] have specialist skills as well… but individually, like the specialist skills of a gas man."

7. Interactions between the LA energy team [1] and EEM supplier [7]

(1) Principal interests

The key interests for the LA energy team were to gain accurate energy readings for the school (through the use of the EEM), and choose the appropriate EEM (products) for the work. The discussion surrounding the interest to gain accurate energy readings can be found in chapter 6.2.2. Furthermore, the heating contractor (HC51) evidenced the interest of choosing the EEM and gaining advice from the manufacturer, as stated:

"The local authority picked it [heating products]. They spoke to the manufacturer, gave them an idea of what they were trying to do."

The interests of the EEM supplier were the co-operation by the local authority and school to ensure a smooth installation process, and choose suitable EEM for the work. The discussion surrounding the interests for the EEM process are evidenced in chapter 6.2.2. Furthermore, in this instance it was the option and choice of parts for the new heating system. The heating contractor (HC51), for example, briefly mentioned the role of choosing a suitable EEM, as stated:

"…the manufacturer came up with the product."

(2) Key negotiation issues

The discussions of the interaction between the LA energy team [1] and EEM supplier [5] can be found in section 6.2.2.

8. Interactions between the EEM installer [6] and EEM supplier [7]

(1) Principal interests

The key interests of the EEM installer were to gain the appropriate material for the installation and learn about the EEM in terms of the fitting, potential challenges ad price. The heating contractor (HC51) supports the interests by stating:

"We go to the manufacturer, he gives us a price, if there I anything we don't know how to install he [manufacturer] instructs us on it…at school 5, there was a different type of heater than we have fitted before so there, I think on one of those it has an air inlet from one side. This is a totally new heater that we have never fitted before. Via the manufacturer…whoever the manufacturer was he gave us the training if you like to know how to fit the heaters…only a day, they came to site and went through it all with us."

The key interests of the EEM supplier were to ensure the EEM was installed at the convenience of the school and LA energy team (time and date), and choose a suitable installer. The evidence for these interests can be found in section 6.2.2.

(2) Key negotiation issues

Three negotiation issues were raised. The first negotiation was connected to the challenges of fitting the EEM, where it was essential the suppliers provided training for the EEM installers (as noted above). This issue highlighted the requirement of communication skills, as evidenced by the heating contractor (HC51), as mentioned:

"Yes, you do get things wrong. For instance a boiler, we fits lots and lots of boilers. Sometimes you fit a boiler and through no fault of our own it packs up after 6 weeks because there is a fault on it. Or you have to get the manufacturer back to look at it."

Furthermore, the need for the EEM installers to gain knowledge and skills in terms of understanding the EEM (both technical and non-technical knowledge), and experience in fitting the EEM was captured by the negotiation. As supported by the heating contractor (HC51), who evidenced:

"Most clients now ask us to fit condensing because, without getting too technical, the flue gases go back through the combustion chamber so everything going back to the atmosphere, the temperature is lower so you are not doing too much harm to the atmosphere and plus you are reheating the flue gases so the boiler is running a lot less time. But that is a condensing boiler, we do a lot of those. I would say they are pretty carbon efficient… I think they [installers] had to top up their existing skills

with new skills, they weren't particularly technical, but there were things they hadn't done before which they had to learn to do."

Second, a negotiation issue was raised surrounding the costings of the EEM and EEM contractors for the project. As evidenced by the heating contractor (HC51), the requirement of project management skills and research skills were captured, as mentioned:

"As there is more work involved in fitting them than there was a conventional boiler, then I have to balance that up as I put a labour cost against every job. So I have to increase the labour costs, and that is something you have to learn to do."

Finally, an issue related to the process of the EEM installation was raised, which highlighted the requirement of communication skills, previous experience of similar EEM products (in this case the smart meter project manager) and co-ordination for the project. Discussions that captured these skills were discussed in section 6.2.2.

9. Interactions between the school staff [2] and the EEM installer [6]

(1) Principal interests

The principal interest for the EEM installer was to gain access to the school to fit the EEM. As highlighted by the energy officer (EO12), who stated:

"More importantly access for the contractors, and they didn't have a school keeper or on site officer. So I think access was made by a governor, who lived over the road, to make the keys available."

The principal interest of the school staff was for the EEM to be fitted.

(2) Key negotiation issues

Two negotiation issues were raised. The first negotiation was linked to the concern for the process and fitting of the EEM within the school. The requirement of communication skills by both the school staff and EEM installers was noted during this negotiation. This required skills set was evidenced by the school head teacher (HT51), who stated:

"I think you [the school finance manager] have had a lot of communication [with the EEM contractors], and think you have got an understanding, I think that really helps."

To further support the need for communication skills, the heating contractor (HC51), stated:

"…they [installers] all get on with my customers. They need to liaise with customers, clients, myself."

Additionally, the fitting of the EEM further highlighted the requirement of manual skills, knowledge of the EEM and installation procedure, and confidence for the EEM installer. As noted by the heating controller (HC51), by stating:

"They [installer skills] are more manual skills than technical skills. We have technical skills within the office because that's the sort of thing we have to do but their [the engineers] are more manual skills."

To support the requirement of knowledge surrounding the EEM, the smart meter installer (SMI51) mentioned:

"To change these meters is a skill I didn't have. I knew about it but I hadn't been trained, I had a knowledge of it… different companies have different procedures so you have to learn your companies' procedures…you have to follow that procedure as it is laid down to you… basically you had to put the theory into practice…the more knowledge and experience you have, the more confidence you have…if you are confident, and confidence does come into it, the more you know the more confident you are."

Summary of the skills required

The delivery of project 5 evidenced a number of required skills for the key actors / actors groups involved to deliver the project. The local authority (LA) required energy management skills, closely linked to these skills were the need for both technical and non-technical knowledge of the EEM, project management skills and a degree of communication skills. The EEM contractors required technical skills associated with the experience of the EEM, technical competencies and knowledge of the EEM, predominantly the installation of the measure(s). Furthermore, EEM contractors required specialist skills within their specific trade and communication skills for interactions and exchanges with actors / actor groups involved in the project. The school end-users required communication skills as interactions with both the EEM contractors and the local authority were essential throughout the delivery of the project. Furthermore, the school staff had a high level of involvement in the project and initial EEM selection / location, which required both project management skills and a form of technical and non-technical knowledge of the EEM.

Knowledge production

A great deal of knowledge within the network of project 5 was tacit knowledge. There was very little explanation and learning within or between actor groups, and the skills being used were existing of those actors involved in the EEM adoption. There was, however, explicit knowledge generated between the EEM installers and EEM suppliers, where new EEM adopted within the firm required demonstrations and information exchange by the EEM supplier. Linked to the management of knowledge, there were issues associated with the knowledge produced between the EEM installers and the EEM suppliers. This finding questions whether both actor groups had a greater understanding of how to use the knowledge generated or, due to the type of knowledge produced (e.g. explicit knowledge) there were fewer challenges in terms of understanding the EEM and its use. Moreover, learning by doing was key to the EEM installers in this case, e.g. learning how to fit the heating systems. Experience in the EEM was highlighted throughout the other EEM contractors, however, there was little evidence of explicit knowledge produced.

Proximity: physical and spatial

As shown in figure 8.6, many of the actors / actor groups involved in the project were located within or close to the regional boundary, capturing the physical proximity between those involved in the project. In terms of spatial proximity, the LA energy team had close communication and relationships with the school staff, offering advice on funding and EEM adoption throughout the retrofit process. The EEM contractors, particularly the EEM installers, also had close communication with the school. The school finance manager was heavily involved in the EEM adoption and post implementation process, being described as the school site controller at one stage, due the school not having a care taker or site controller. There was evidence this role of the finance manager enhanced the spatial proximity between the school staff and EEM contractors. Spatial proximity was also captured by the EEM installer and EEM supplier, more specifically the heating contractors and suppliers, where communication and interactions occurred for training and exchange of knowledge.

Embeddedness

A high level of embeddedness was recognised within the LA, more specifically the LA energy team and LA building management team through the use of an in-house PM for the solar PV project. Embeddedness was also captured within the EEM contractors, where the majority were small firms located within the region, and many contractors were sourced from within the firm or within close proximity to the region.

Chapter 9 Discussion

9.1 Introduction

This chapter will present the key findings from all five school low and zero carbon (LZC) building / retrofit projects (chapters 4-8). The section will also discuss the results within the context of the literature on the subject of the type of required skills and the prevailing regional innovation systems (RIS) knowledge. The discussion will state the RIS elements for the projects, followed by the RIS mechanisms where the skills required for the key actors will be identified and explained, and finally reference will be given to the existing literature.

9.2 RIS elements

The five case studies highlighted the range of different actors / actor groups involved in the delivery of the LZC building projects, and each were classified as one of the following key actor groups:

The local authority (LA) consisted of two actor groups (i.e. two local authority departments) who were identified for the delivery of the projects. First, the LA energy team were the main drivers of the LZC building projects. The requirement was to comply with the local authority energy targets to reduce the energy consumption of local authority owned buildings. The standard procedure for the LA energy team was to contact the schools (first those schools with high energy consumption or deemed priority schools) to investigate the potential to reduce energy use within the buildings. Second, the LA building management team consisted of a number of actors who primarily helped fund local authority owned buildings, particularly those schools that required emergency funds for building retrofit and the implementation of the energy efficient measure (EEM). The LA building management team also liaised with both the school staff and the LA energy team to exchange EEM information and further advice. Project 5 also captured the provision of an in-house project manager to the LA energy team by the LA building management team, for the adoption of the EEM (solar PV).

The EEM contractors consisted of five separate actors / actor groups who were involved in the delivery of the projects. First, the 'EEM estimator' of the projects provided an initial estimate for the EEM work and, on occasions, continued to further manage the EEM adoption process for the EEM surveyor and EEM installer. Second, the 'EEM surveyor' carried out an initial survey to assess the potential EEM, or those EEM highlighted as potential by the EEM estimator, the LA energy team or the school end-users. Third, the 'EEM designer' carried out an initial survey to assess the potential and different types of EEM for adoption, and in the case of project 5, the lighting designer offered further EEM detail and had a greater involvement in the EEM implementation process. Fourth, the 'EEM installer' fulfilled the role of installing the EEM adopted and, on occasions, provided a handover to the school end-users (e.g. how to use the system, a handbook and further maintenance). Finally, the 'EEM supplier' for the projects had the role of providing materials and information for the installation of the adopted EEM.

The school end-users consisted of four actors / actor groups during the delivery of the projects. First, the 'school staff' comprised of the school head teacher, finance manager, business manager, site controller and maintenance manager. In all five projects the school staff had a dominant role in terms of monitoring the energy consumption of the school, and for the majority of projects, had input into key decisions surrounding the EEM for adoption (e.g. type of EEM). Second, the 'school community' actor group had a key role in project 3, being involved in the school's environmental activities and close communication with the school staff. Third, the school parents and pupils' actor group was identified where engagement with the EEM and environmental awareness were encouraged by either the school staff or the LA energy team (the case for projects 1 and 2). The LA energy team (i.e. the energy assistant), for example, provided energy education to the school pupils. Finally, the school governor had key roles during a number of projects, such as being involved in reading the smart meter (project 3) and consulted on key decisions surrounding the justification of school funding availability for the EEM (project 4).

In relation to the RIS, each of the above key actor groups had a role in the RIS and are classified as a RIS element(s).

9.2.1 Institutions

Two key actor groups were classified as 'institutions' within the RIS network for the delivery of the projects: the local authority and the school end-users. First, the local authority, both LA energy team and LA building management team had primary roles in the RIS, which involved a response to local authority owned buildings within the region in regards to energy use and energy issues. Second, the school end-users were primarily interested in monitoring building energy consumption, the potential of gaining the EEM and a percentage of funding toward the EEM. The local authority was key to the projects to drive and raise awareness of the EEM, and encourage frequent communication with the majority of actors involved in the projects. The LA energy team were primarily involved in driving the projects, whereas the LA building management team became more involved in those emergency projects, such as those buildings that required funding and work as soon as possible. It was the case where the school end-users acted differently depending on their budget for funding, further resources and enthusiasm for the project. In the majority of projects the roles of the school staff were the actors' key to the learning process (either providing information or learning from actors / actor groups) and knowledge exchange.

In connection to the RIS literature, a number of similarities were found within the case study findings and how the literature describes the role of institutions. First, literature stated the role of an institution in terms of the transfer of knowledge and information, but indicated information was more dominant. There was evidence of both knowledge and information being produced and transferred within the project, but it is understandable why institutions were referred to as 'informational devices.' The local authority was the dominant actor group for the transfer of information within the network. Both the LA energy team and LA building management team provided information regarding the most appropriate EEM to adopt, funding options, the use of EEM within the schools and reports for school energy use. The transfer of information was indicated by more tangible efforts by the local authority, such as email exchanges, reports and leaflets. However, there was also a significant amount of knowledge transferred, where both the LA energy team and LA building management team demonstrated their knowledge of how to use the EEM adopted. The empirical results indicated the school end-users also had a role for the transfer of information and knowledge, again more so the transfer of information to the LA energy team (e.g. energy readings). The school as an institution within the RIS, however, did not show as a significant role as the local authority for the transfer of knowledge and information. Second, the institutions did focus on learning, particularly the LA energy team that highlighted the need for energy education within the projects. The literature further stated institutions took different paths for learning, which indicated the possibility of the connection to a wider range of actors within the system. This was most certainly the case for the local authority, who acted as the project manager for the projects, interacting with schools, EEM contractors and funding bodies. It was also the case, particularly projects 2, 4 and 5 where the schools were drivers of learning and highlighted the importance of interactions with actors within the projects. Finally, the literature suggested, in comparison to firms within a RIS, institutions were associated with more formal roles. There was evidence of more formal procedures within the local authority (e.g. the energy reduction targets and the methods of funding), noted through paperwork and emails issued within the local authority and to the school. Informal roles by the LA energy team and further interactions with the school, however, were also captured and significant to the projects.

9.2.2 Firms

The EEM contractors were classified as 'firms' within the RIS network, where five actors / actor groups were identified as being key to the delivery of the projects. Each project consisted of different EEM contractors, and each EEM contractor had different roles (estimator, surveyor, designer, installer and supplier). The projects highlighted the importance of information exchange and communication between the EEM contractors with each other, but also the local authority and school end-users. The communication between the EEM installer and supplier, for instance, was vital to learning and further exchange of knowledge surrounding the adopted EEM.

In connection to the RIS literature, the firms (EEM contractors) within the projects were key to knowledge transfer within the network, perhaps more so than knowledge production. The EEM estimators, for example, held the knowledge for the process to drive the insulation install, where knowledge (e.g. EEM materials and installation instructions) needed to be transferred to the EEM surveyor and installers. Similarly, for other types of EEM in the projects, EEM contractors held the knowledge in terms of which EEM was more appropriate for the building, how to use various tools and programmes for the EEM, and aided the evaluations for the EEM delivery. Although, it must be noted that in many cases the EEM contractors did not appear to be the only elements to produce the knowledge required. The institutions, such as the school staff and more so the LA energy team, produced knowledge for the EEM evaluation and adoption. The literature, however, was unclear on whether the significant interactions by the firms were by the entre firm or individuals within the firm. The research highlights that the individuals within the firm have a significant knowledge transfer role within the RIS, as evident during activities where knowledge was needed to be transferred by certain individuals within the firm (the insulation surveyor / installer relationship). The entire firm also appeared vital to the RIS, where interactions took place to help support colleagues and other firms within the projects. The EEM supplier (project manager), for example, relied on a colleague's technical knowledge of the EEM to support the adopted and delivery of the project.

9.2.3 Knowledge infrastructure

Both the LA energy team and EEM suppliers were classified as 'knowledge infrastructure' within the RIS, capturing both physical and non-physical knowledge infrastructure within the network. First, the LA energy team, primarily the energy officer, acted as knowledge infrastructure by the diffusion of knowledge within the LA energy team (i.e. for the energy assistant) through training (e.g. energy auditing). Similarly, the diffusion and further transfer of knowledge was also evident by the LA energy team to other departments in the local authority (i.e. the LA building management team) and to the school staff and pupils. Knowledge infrastructure captured was of a physical nature through energy education to the schools and procedures put in place within the local authority. Informal interactions and relationships between colleagues were also present, where the local authority contributed to the diffusion of knowledge, representing non-physical knowledge infrastructure within the network. Second, the EEM suppliers, through the use of workshops and the provision of documentation to other

EEM contractors (i.e. EEM installers and EEM designers), highlighted their roles for the transfer and exchange of knowledge within the network. Knowledge infrastructure was primarily of a physical nature by EEM suppliers (e.g. workshops). Interactions between EEM suppliers and EEM installers, however, were captured in connection to the EEM adoption, emphasising the importance of informal communications for the transfer of knowledge.

Similar to the ideas in the RIS literature, the significance of knowledge infrastructure within the RIS as a support mechanism was evident in all projects. Both the LA energy team and the EEM suppliers aided the production, diffusion and transfer of knowledge within the network. The EEM suppliers emphasised their role in terms of physical knowledge infrastructure, such as the transfer of knowledge by the EEM project manager (smart meter) to EEM contractors, which offered support for innovative activity to firms and institutions. There was further evidence of knowledge production within the network, as oppose to the diffusion of knowledge, where the majority of the knowledge appeared to be of a tacit nature. Non-physical knowledge infrastructure was evidenced by relationships and informal interactions between actors that contributed to the transfer of EEM and project information. The physical knowledge infrastructure, however, played more of a significant role towards the delivery of the projects. It was common for EEM contractors to attend EEM supplier workshops and training facilities, for example, to gain and enhance knowledge and skills of the EEM and appropriate methods of implementation.

9.2.4 Policy orientated regional innovation

The Carbon Management Plan, produced by the local authority, was classified as 'policy orientated regional innovation' within the network. This element created individual formal and informal policies for the region to fulfil targets, such as energy reduction and wider environmental policy initiatives. The LA energy team, for example, were required to reduce energy consumption within the local authority owned schools through carbon emission reduction targets of 15% by 2015 and 40% by 2020. As suggested by the RIS literature, the policy orientated regional innovation element encouraged the bringing together of actors within the RIS, which was indicated by the need for local authority departments to collaborate for the majority of projects, i.e. the learning of the EEM and maintenance. Similarly, literature suggests the policy orientated regional innovation element also encourages learning and interactions from the remaining three elements (firms, institutions and knowledge infrastructure). Findings indicated this was the case within this investigation, however, policy orientated regional innovation appeared to have a dominant effect on institutions, in comparison to firms and knowledge infrastructure elements. Furthermore, the literature gave indications of the policies created within the RIS being advantageous, which was captured within all the projects, e.g.

beneficial to energy reduction, energy saving for the school and the enhancement of the environment for the region.

The identification of RIS mechanisms was also necessary to evidence the required skills for the delivery of LZC buildings within the region, and further investigate the less tangible activities between key actor groups, as discussed in the next section.

9.3 RIS mechanism: the required skills

9.3.1 The definitions of key skills required

The investigation captured various ideas associated with the meaning of a skill, and definitions of each of the required skills that were evident within the projects. Each key skill and its definition is discussed in turn:

Skills

A skill can be associated with the ability to carry out a task to fulfil a particular role, or the achievement of a task / job that can be specific to an individual. This definition resonates with the prevailing literature that links a skill to tasks associated with a specific job role (CBI 2013) and activities to be carried out by an individual (Clarke and Winch 2006, OECD 2011). The findings further emphasise the idea that a skill can be unique to an individual (i.e. no-one else can do it). Similar to ideas within the skills literature (Clarke and Winch 2006, OECD 2011) a skill can further be defined as the ability to learn, provided by either formal training through the attendance of training events, informal training from another individual, or previous experience of a task (i.e. the idea of retaining knowledge).

Energy management skills

The ability to carry out an energy audit (i.e. evaluate building energy consumption and the feasibility of the building / building users to reduce energy use), and further understand the EEM following the energy audit to assess the more appropriate EEM for adoption. The financial element of the EEM and ability to perform payback calculations, for example, is an energy management skill that is required to evaluate the costs and benefits of the EEM adoption. This definition resonates with the literature that emphasises the need for a form of understanding the technology, such as the EEM or what is referred to as 'renewable technology' or 'advanced technology' (Aldersgate Group 2009, Xu et al. 2015). In contrast to the literature, however, the definition of energy management skills from the findings focuses on knowledge and processes of technology adoption prior to installation, possibly the development stage and design stage of the LZC building project. There is literature that states the importance of energy assessment skills (Energy UK 2014) and further technological knowledge at the design stage (RIBA 2008), but there primarily appears to be ideas around skills for LZC buildings associated more so with the physical technology and its implementation. The skills and greater association with the implementation of the technology was noted within this investigation, but greater reference of this skill as a 'technical skill' (see below) was evident.

Project management (PM) skills

The ability to organise and co-ordinate the project in terms of planning the project (i.e. evaluating the proposed EEM), through to the design and the implementation of the EEM (i.e. decisions surrounding contractors and materials), and post implementation of the EEM (i.e. ensuring the end-users have a working EEM and are able to understand / use the system). The PM skills evident within the projects appear to have a much narrower definition than the prevailing literature, capturing more of an association to the project undertaken, rather than encompassing a number of 'generic' skills as described within the literature. Similar to the existing literature, however, PM skills can relate to both hard skills (e.g. association with the EEM technology) and 'soft skills,' (e.g. knowledge of project budgets and schedules, and the ability to build relationships) (Winch et al. 1998, Thamhain 2016).A number of PM skills are also of an existing nature, i.e. not a new skill. Furthermore, there is an element of experience required for the PM skill, also noted in the literature. An idea that is unclear in the literature, however, is the link of experience to the provision of new skills. The investigation provided insight to the need for experience to build upon existing skills, not necessarily the creation of new skills for the construction sector and its clients.

Social skills

The ability to work within or part of a team, interact, listen, co-operate and work together with others involved in the project, particularly colleagues, in order to keep up-to-date and gain information and knowledge of the EEM process and project as a whole. Social skills are much broader than communication skills (see below) as they relate to more than an interaction, and can be closely linked to interpersonal skills. To expand the literature that connects communication skills to interpersonal skills (Benson 2014), it is valuable to also consider the link, and possibly closer connection, of interpersonal skills to social skills. Interpersonal skills extends communication skills beyond that 'effective communication' to develop a relationship with an individual (Duffy et al. 2004). The literature also connected social skills to the management of knowledge, where the sharing and transfer of knowledge was linked to a social setting, networks or relationships (Bresnen et al. 2003, Fernie et al. 2003). Similarly, the investigation and the above definition agrees with the literature to suggest the idea of a social skill being much more than communication (i.e. communication skills are a small strand of social skills), and further verifies the importance of building relationships, connectedness and being personable (all elements of social skills) for the successful / effective management of knowledge.

Communication skills (connected to the broader social skills)

An element of the wider 'social skills' that centres specifically on the interaction and ability to convey information (i.e. communicate effectively) to other actors / actor groups involved within the project. Similar to the prevailing literature (Siriwardane et al. 2015), emphasis was given to the need for 'effective communication' (i.e. acknowledging the audience or listener during the exchange of information and, in the case of the investigation, learning and exchanging knowledge during the communication. This finding was highlighted by the ability of the LA energy team to provide information of the EEM and educate actors / actor groups. There was a need for the LA energy team to consider the type of EEM information to convey to the school end-users regarding the EEM, and possibly the language and terms used (i.e. the complexity of the EEM explanation). Furthermore, in agreement with the skills literature, there was the requirement of both actors / actor groups interacting to possess communication skills, and the importance of an 'active listener' (Fisher 2011). Building on the literature (Dainty et al. 2005a), the communication skills required and emphasis on effective communication were embedded within project management skills, but also applied to other roles within the project (i.e. not solely for those actors / actor groups who required project management skills), and further a communication skill is skill within its own right.

Research skills

The ability of an actor / actor groups to independently investigate the potential EEM and range of EEM options for adoption, and further explore and understand how to operate the adopted EEM components and EEM systems within the school. Examples of research skills used within the projects, primarily by the school staff, included the use media and the internet to gain information for different EEM options.

Technical skills

Skills linked specifically to the EEM (usually a renewable / advanced technology EEM solar PV, air source heat pumps, energy efficient boiler), the ability to understand and install the EEM, and further knowledge of how to use the appropriate tools (including specialist software) for the EEM survey, design and installation. This definition is closely connected to the idea of 'green skills' and 'low carbon skills' within the literature (Aldersgate Group 2009, Construction skills 2011), which focuses on understanding the technology (e.g. how the EEM works in practice and challenges), tools and methods of implementation. There is also literature that emphasises the need for ‘technical skills’ associated with the technology, but does not refer to these skills as green skills, new skills or low carbon skills (Xu et al. 2015).

Technical skills (electrical competencies)

The knowledge and understanding of the EEM in terms of the individual electrical components and the system associated with the EEM, for the EEM adoption process, for instance, the knowledge and application of the correct electrical wiring of the EEM within the building.

Technical skills (technical knowledge of the EEM)

A wide knowledge, understanding and ability to explain the advantages, disadvantages, short term and long term challenges of the EEM in terms of its technical attributes, such as the technical challenges and process at the EEM installation procedure, operation, and any maintenance required for the EEM post implementation.

Non-technical knowledge of the EEM

A wide knowledge and understanding of the EEM that is not of a technical nature, primarily knowledge of EEM paperwork prior to installation and an understanding of commercial benefits of the EEM. For many actor groups it was the case where both a technical and non-technical knowledge of the EEM was required.

Technical skills (previous technical experience of the EEM)

The ability to understand the EEM delivery process, the procedure of EEM adoption and recognise potential problems that can be encountered during the planning, design and implementation stages. The EEM supplier, for example, required previous EEM experience to have an awareness of the EEM problems that can be encountered, and the ability to provide the correct handover process. Previous experience of the EEM also encouraged confidence during the implementation of the system.

Specialist skills specific to a trade

The skills, knowledge and experience connected to a particular trade that require a certain level of education or qualification, in order to perform a particular task. A gas safe certification was an example of a specific requirement for the heating system installer, a specialist skill to their trade, in order to fit an energy efficient boiler.

Co-ordination skills

The ability to organise and arrange an appropriate date / time to carry out EEM estimations, surveys and installations. The need for the EEM installer / supplier to understand and co-ordinate the most convenient date / time with the school community for the EEM installation, for instance, was emphasised as essential to the delivery of the project.

Building structure and construction skills (basic and in-depth)

The understanding of building fabric and challenges connected to elements of the buildings, and further knowledge of construction and tools required for the successful EEM adoption. The identification and ability to use the correct tools required for the installation of loft insulation, for example, was essential to the delivery of the project.

Basic IT skills to operate the EEM adopted

The ability to operate the EEM, and understand the installed (computer) components required to make changes and maintain the EEM and system in place. The ability and understanding of how to change the heating control components through the use of a computer, for example, were essential during the adoption of the EEM.

9.3.2 The required skills for each actor group

Each actor group was found to have a number of required skills that were key to the delivery of the projects, as shown in table 9.1.

1. Local authority (LA)

It was found that four dominant skill sets were required for the local authority for the delivery of the projects (see table 9.1): project management skills, energy management skills and communication skills (all five projects), and technical and non-technical knowledge of the EEM (project 5). First, 'project management skills' were related to the ability to organise the project from start to finish, i.e. successfully complete a retrofit project through the design, implementation and post completion stages. The local authority required project management skills to co-ordinate EEM contractors, liaise with the other actors involved and make key decisions and choices surrounding the project (finance, sourcing of contractors and local authority resources). Project management skills appeared to be linked to an individual's role and the tasks required to carry out that role. The LA energy officer, for example, needed project management skills to manage and assess the school retrofit projects. These skills, however, were not specifically related to the project managing of LZC buildings. The energy assistant further supports this statement by their involvement and ability to carry out specific tasks for the projects. Due to the lack of project management skills, however, the energy assistant was not able to manage certain tasks within the project, and further required support from the energy officer to oversee the whole project. The link of project management skills and a specific role correlates with the prevailing construction literature, which appears to associate the project management role with a range of closely connected skills, rather than one definitive skill (APM 2012, APM 2014). Furthermore, the energy assistant mentioned the possibility of a project management course to provide key training and learning opportunities, which resonates with the literature that links the need for learning and development to gain project management skills (Crawford et al. 2006). Project management skills were essential to the LA energy team for the development and implementation of the LZC building projects. The skills, however, were not described as new by the energy officer, but had been gained from many years of experience managing projects. The essential experience needed by the energy team (i.e. experience required to gain knowledge of project processes and budgeting), can relate to the literature that suggests the requirement of knowledge associated with project management skills (Dogbegah et al. 2011). Knowledge appeared to be connected to an understanding of the tasks carried out to fulfil the project manager role. The need for the LA energy assistant to gain insight from the LA energy officer, as opposed to a training course (there were indications this would be the training received by the LA energy assistant), can relate to specific knowledge from experience required, but further indicates the development of both existing and new skills.

Second, 'energy management skills' were linked to the building in terms of energy auditing, evaluating the proposed EEM and its suitability, the ability to assess and compare EEM payback periods / calculations (economics of the EEM) and the need to consider the more appropriate EEM solutions for the school end-users. Examples of these skills included the need to perform calculations, and the understanding and justification of the short and long term costs / benefits of EEM adoption. Energy management skills were related to LZC buildings, and learning was required by the LA energy team to gain these skills for the development and implementation of the EEM within the buildings. The energy assistant, for example, required new skills, such as the ability to perform an energy audit. Existing energy management skills, however, were also prevalent, such as carbon management and environmental knowledge. In connection to the literature, an element of new skills and the requirement of learning new knowledge, primarily by the energy assistant, was evident to gain energy management skills, but there was no mention of them being green skills or low carbon skills by the local authority.

Third, 'communication skills' required by the local authority were captured through the need for the LA energy team to interact with the EEM contractors during the process of the EEM adoption. The EEM decisions and negotiations required the use of communication skills, which were evident between the LA energy team and EEM estimator / surveyor. Communication skills were also needed by the local authority to build a relationship with school end-users, to drive the adoption of the EEM, explain the EEM implementation process and on an occasion (project 1), provide energy education to school pupils. More specifically, an interview captured how the LA energy officer required communication skills to help the school staff buy into the EEM, e.g. effective communication to convey the benefits and discuss information of interest to the school end-users. The relationship between the LA energy team and school end-users echoes the existing literature that emphasises the need for effective communication (Benson 2014, Janthon et al. 2015, Siriwardane et al. 2015), and also demonstrates the meaning given to appropriate communication (i.e. having an awareness of whom you are communicating to). This evidence connects to the need for communication skills to build a foundation for relationships within the projects. Constant communication, EEM advice and reassurance by the LA energy team to the school end-users built strong relationships and trust to drive the projects. Furthermore, the LA energy team communicated with the LA building management team to discuss and offer further information on the EEM, EEM contractors and on occasions exchange advice in regards to building energy use. A reason for the requirement of communication skills for the local authority can be linked to the existing knowledge and enthusiasm of the school end-users, surrounding the adoption of the EEM. The school staff in project 2 and project 3, for instance, did not appear to have that initial awareness or information towards the specifics of the EEM. Project 3 in particular did not understand the EEM use and controls, and a confusion regarding the type of EEM technology (solar PV / thermal) adopted was noted during observations. As a result, there were indications the LA energy team needed to further explain the EEM, and justify EEM advantages / use to the school staff. These situations highlight the need for skills associated with how to communicate, due to challenges evidenced for the exchange of information. Similar to the literature, the findings further evidence the need for active listening (Fisher 2011), where the effectiveness of the communication is a two-way process. In contrast to those actors / actor groups who had little awareness of the EEM adopted, particularly evident within project 4 and project 5, interviews and observations (e.g. meetings with the LA energy team and school finance manager) captured actors / actor groups who had a desire to adopt the EEM and existing knowledge surrounding the measures. Communication skills were not connected to a new skill required by the LA energy team. The skills were part of LA energy assistant's day-to-day activities during emails and conversations with the school staff, and skills that were developed by the LA energy officer throughout their career, and constant interactions and dealings with various individuals. Finally, in regards to the LA energy officer, who required project management skills for the delivery of the project, the need for communication skills was also demonstrated. As noted within the construction skills literature (Loo 2002, Dainty et al.

2005b, Fisher 2011), effective communication was essential to project management skills. The LA energy officer, for example, required knowledge and empathy of what concerns to discuss with school end-users, in contrast to with the type of information needed to be discussed with the EEM contractors.

Finally, ‘technical and non-technical knowledge of the EEM’ was required by the local authority (project 5). This was captured by the need for the LA energy officer to offer advice and information for the solar PV project. Technical knowledge in terms of the details of the EEM were required by the LA energy officer in order to evaluate the adoption of solar PV within the school, but further non-technical knowledge was required to discuss and explain the appropriate EEM adoption with the school staff, e.g. commercial knowledge of the EEM. This finding echoes the literature in regards to ideas surrounding project management skills (i.e. the notion of project management skills being of a technical nature), and technical knowledge being connected to ‘green skills’ and ‘low carbon skills.’ The evidence for a combination of technical knowledge and project management skills for the LA energy officer (i.e. for the evaluation, organisation and adoption of the solar PV for the project), agrees with the literature that suggests the ‘technical skills’ classification (Dainty et al. 2005b), and further ‘hard skills’ element (Ingason and Jónasson 2009) of project management skills. Both classifications having a link to a form of advanced technology (Thamhain 2016). In connection to the literature on the required skills for LZC buildings, there are indications that the ‘technical knowledge of the EEM’ may relate to the accounts provided on green skills and low carbon skills. The knowledge needed on the use of the technology (e.g. how the solar PV works, its implementation and operational unit / interface) for successful adoption, is similar to the (broad) definition provided by Construction Skills (2011). Furthermore, the use of solar PV and the requirement of understanding and explaining up-to date government schemes (e.g. the feed-in tariff), support the idea for the need for knowledge on policies surrounding the EEM, for the delivery of LZC buildings (Gooding and Gul 2016). Further technical skills insights are given below where these skills are not only linked to project management skills, but required for other actors / actor groups involved in the projects (e.g. required for EEM contractors; a technical skill in its own right).

2. EEM contractors

It was found that six dominant skill sets were required by the EEM contractors for the delivery of the projects (see table 9.1): technical skills, communication skills (all five projects), co-ordination skills, specialist skills, energy management skills, and construction skills and building knowledge (one project). First, a ‘technical skill’ can be linked to different stages of the EEM adoption, applied to the various types of EEM contractors (estimator, designer, surveyor and installer) and further be classified as four separate key skills: technical skills (related to the EEM and knowledge of the tools used for the EEM delivery), electrical competencies (an understanding of the electrical components of the EEM and electrical background of the EEM contractor e.g. wiring), technical knowledge of the EEM (broad range of EEM information, its advantages, disadvantages, potential challenges to develop, implement and further explain the EEM) and technical experience of the EEM (previous experience of the EEM implementation and aware of the potential challenges). In relation to the broad term of technical skills, and the majority of the discussions relating to the meaning and definition of these skills, many actors involved in the projects related these technical skills to a technology or piece of equipment or tools associated with technology. This finding relates to the prevailing literature that states the need for knowledge of the technology adopted (‘renewable technology’ and ‘advanced technology’), construction methods or tools required for technology implementation during the delivery of LZC buildings (Aldersgate Group 2009, Xu et al. 2015). The connection to the understanding around technology can be known as ‘technical skills’ (Xu et al. 2015), or have an association with ‘green skills’ (Energy UK 2014) and ‘low carbon skills’ (Construction skills 2011). As technical skills are linked to a specific technology or the tools required to develop and implement the technology, there was an element of these skills being new to EEM contractors. The technical skills, however, required for the delivery of the projects also included existing skills, further highlighting the need for a combination of both existing and new skills for the EEM contractors. The new skills were connected to knowledge required on how to fit the EEM, which supports and adds to the vague account of new skills within the current construction skills literature. New skills do not only appear to be linked to new construction methods and equipment (Home Building Skills 2013a), but knowledge, and more importantly, an understanding of the technology. The understanding of the technology is linked to the EEM contractors’ ability to apply the new knowledge, which also indicates the use of existing skills in order to carry out the work. The skills required for the installation of an air source heat pump, for instance, were similar to those needed for a boiler (existing skills), but further understanding of the components of the EEM were required to be able to apply these components. Furthermore, even though evidence indicated technical skills were part of new skills and similarities to green skills and low carbon skills, there were no expressions or views of these new skills being known as green skills or low carbon skills throughout the observations and interviews.

Table 9.1: cross case analysis of the required skills for the school retrofit projects 1-5

School retrofit project / School feature / actor groups	Project 1 (WK)	Project 2 (RS)	Project 3 (C)	Project 4 (W)	Project 5 (CH)
Display energy certificate (DEC)	Performance rating of 'E' (109 points)	Performance rating of 'D' (87 points)	Unavailable	Performance rating of 'D' (99 points)	Performance rating of 'C' (67 points)
Number of pupils	394 pupils (2015)	471 pupils (2015)	592 pupils (2014)	302 pupils (2015)	98 pupils (2014)
Energy efficient measure (EEM) adopted	• Double glazing • Lighting upgrade • Half hourly meter installation • Solar PV • Cavity wall and loft insulation survey • Energy education	• Double glazing • Half hourly meter installation • Solar PV • Cavity wall and loft insulation survey	• Smart meter installation • Heating system and heating controls (BMS) updated • Solar PV • Solar Thermal • Cavity wall and loft insulation survey	• Smart meter installation • Sun / solar pipes • External grey water system • Solar PV • Loft insulation • Lighting survey	• Double glazing • Lighting upgrade • Smart meter installation • Heating system and heating controls (BMS) updated • Solar PV
Local authority (LA)	• Energy management skills • Project management skills • Communication skills	• Energy management skills • Project management skills • Communication skills	• Energy management skills • Project management skills • Communication skills	• Energy management skills • Project management skills • Communication skills	• Energy management skills • Project management skills • Communication skills • Technical and non-technical knowledge of the EEM
EEM contractors	• Technical skills • Communication skills	• Building structure and construction skills (in-depth and basic) • Communication skills (part of a wider social skill)	• Technical skills (electrical) • Technical skills (knowledge of EEM / ability to install) • Communication skills • Co-ordination skills • Technical skills (previous EEM experience)	• Technical skills • Technical skills (electrical) • Communication skills • Energy management skills • Co-ordination skills • Technical skills (previous EEM experience)	• Technical skills (electrical) • Technical skills (knowledge of the EEM) • Technical skills (previous EEM experience) • Communication skills • Specialist skills (specific to trade)
School end-users	• Communication skills • Research skills • Project management skills • Basic IT skills to operate the EEM adopted	• Communication skills • Research skills • Project management skills	• Communication skills • Energy management skills • Basic IT skills to operate the EEM adopted	• Communication skills • Project management skills	• Communication skills • Project management skills • Technical and non-technical knowledge of the EEM

Second, 'communication skills' were captured, for which the definition and meaning were similar to the communication skills needed by the local authority. EEM contractors were required to interact with the LA energy team (during initial stages) and fellow EEM contractors within the project (during all stages) for the EEM selection, and exchange additional information correctly regarding the EEM and project. Communication was also required with the school end-users primarily during the EEM implementation and post implementation to arrange EEM installation and inform the school end-users of EEM use and maintenance. Again, communication skills did not appear new for the EEM contractors. Furthermore, weakly linked to the ability to effectively communicate, one project (project 2) noted the requirement of a broader social skill to work within a team and engage with fellow colleagues. This evidence ties in the communication skills, social skills and interpersonal skills overlap of definitions and meanings of each skill (Benson 2014).

Third, 'co-ordination skills' were primarily linked to the EEM supplier and installer in many cases (projects 3, 4 and 5), and further connected to the need to co-ordinate and manage the implementation of the smart meter. The EEM installer, for example, described one of challenges of the smart meter install was connected to a suitable time / date to visit the school, where organisation with the EEM supplier was essential.

Fourth, the requirement of 'specialist skills' were referenced by a number of EEM contractors in one project (project 5). Specialist skills were linked the EEM, such as the requirement for a gas safe registration / certificate for the heating engineer to carry out work and perform daily tasks, or discussed in relevance to a specific trade held by the EEM contractor. A job role and activities to fulfil that job role were connected to a specialist skill. These skills were not described as new, nor related to LZC buildings.

Fifth, 'energy management skills' were a key requirement for EEM contractors (project 4). In contrast to the findings from the LA energy team, the EEM contractors gave indications the required energy management skills were related to LZC buildings. Not all of these required skills, however, were new. The EEM surveyor, for example, had previous experience in performing calculations and the use of spreadsheets, which we required to evaluate the finance associated with the EEM. There were indications the new energy management skills were related to the knowledge of the procedure of carrying out the assessment.

Finally, 'construction skills and building knowledge', both basic and depth, were required for the EEM contractors (predominantly for loft and cavity wall insulation). These skills were essential to be aware of possible challenges and required for the EEM contractors to have knowledge of the correct information and tools to locate to site. The findings indicated these skills were existing and not solely specific to LZC buildings, but related to the EEM contractors' job role and activities.

3. School end-users

It was found that six key skill sets were required by the school end-users (community / parents) (see table 9.1): communication skills (evident for all five projects), project management (projects 1, 2 4 and 5), research skills (two projects), energy management skills, basic IT skills and knowledge of the EEM (one project). First, 'communication skills' were key, particularly to the school end-users, to receive knowledge from the local authority, and further discuss the EEM with EEM contractors. The close relationship between the local authority and school staff, i.e. the local authority being the primary contact for the EEM adoption, challenges and upgrades, was highlighted throughout all five projects. The relationship between the school staff and EEM contractors was further supported by evidence of interactions and negotiations in all five projects. There was a need, for example, for convenient scheduled times for the EEM installations, handover processes and detailed explanations by the EEM contractors, which encouraged the school staff to build relationships with the EEM contractors. Communication skills did not appear to be new for the school end-users. Communication was used in day-to-day situations by the school staff, and impressions were given that the ability to interact and hold conversations were not considered a 'skill.' This finding is similar to the literature that indicates the capability to interact and communicate effectively is not an easy task (Butt et al. 2016), and very much a skill that requires a form of effort by both the communicator and respondent (Fisher 2011, Siriwardane et al. 2015). Furthermore, communication skills tended to be related to the roles of those actor groups involved, and school staff that had communication with the LA energy team, contractors and visitors involved in the school.

Second, the requirement of 'project management skills' for the school end-users were evident within the majority of projects. More specific to project 4 and project 5, the school staff was active in driving the adoption of different EEM for the school. Evidence suggests, due to an active interest primarily by the school finance manager, there was the need for a knowledge of how to co-ordinate the EEM, justification of the funding, and further evaluation of the costs and benefits for the school. The project management skills for the school community (school staff and on occasions the school governor) was linked to the early decisions surrounding the EEM. The school finance managers were primarily active in finding EEM solutions for the school, on occasions the location for the EEM (project 5), negotiate the EEM funding and organise EEM contractors. More specifically to project 2, project management skills were linked to experience in this role and, and the need to integrate an element of common sense to the tasks to carry them out. In connection to the previous literature, elements of 'soft skills'

(APM 2012, APM 2014) or 'human skills' (El-Sabaa 2001) were evidenced within project management skills for the school end-users. A desire by the school end-users to build relationships for further understanding of the EEM, and EEM adoption processes, was evident in a number of projects. This findings highlighted the need for soft project management skills by actors / actor groups, and further indications of why the prevailing literature closely associates communication skills to project management skills. To add to the current understanding of project management skills, it may be valuable to associate the classification with the broader social skills, as oppose to solely communication skills, which would highlight the incorporation of a range of skills, such as interpersonal skills. Furthermore, the findings indicate the required project management skills were linked to the actors' role within the school and the various activities that were assigned to actors, or during projects where the school end-users were motivated to achieve a reduction in energy use. There were no indications within the key findings that linked project management skills to a new skill for school end-users

Third, 'research skills' were key to the school end-users to deliver the projects (projects 1 and 2). Research skills were linked to the need to use media, such as the internet, to gain knowledge and information during the selection process of the EEM and, more importantly, use of the EEM post installation. These skills did not appear to be related to low carbon buildings, however, the knowledge gained by using research skills was related to the specific EEM adopted. In project 1, for instance, the research appeared to be around the knowledge of EEM contractors and an understanding of how a solar PV system would be of benefit to the school. Similarly, there were indications research skills for project 2 were related to the solar PV system, but also the need for information and advice as to how the school community can become more environmentally friendly. The ability to carry out research was not new, but an existing skill. Much of the knowledge gained from the research, however, was new knowledge / information, and specific to LZC buildings.

Fourth, the required 'energy management skills,' for school staff were only found in one project (project 3). The findings indicate these skills contributed towards the decisions connected to the EEM and the management of the project. Even though the ability to manage the project was not specific or new for the delivery of LZC buildings, there were indications that the knowledge surrounding the EEM in order to make the decisions, was new (see above for how EEM knowledge was gained through research skills).

Fifth, 'basic IT skills,' which were required to operate the adopted EEM, were key to school end-users in one project (project 3). These skills were connected to the EEM adopted (the new heating components), and the operation system, i.e. the building management system (BMS). Previously the heating controls were managed manually by the school staff, whereas the new BMS was managed by a computer (controls on the head teacher's laptop and in the boiler room). The findings evidence mixed views surrounding the requirement of basic IT skills. The school maintenance manager, for example, had previous experience in using a computer and fairly confident that following a demonstration of the new controls, they would be able to use the EEM (the school end-users had not been shown how to control the system). As a result, basic IT skills did not appear a new skill, but the need for new knowledge surrounding the EEM. The school site controller, however, was less confident in their IT skills, and, possibly more sceptical of using the new EEM system correctly. There were indications the use of basic IT skills were a combination of existing and new skills, and possibly linked to LZC buildings due to the need for understanding the EEM involved.

Finally, 'technical and non-technical knowledge of the EEM', was key to the school staff, primarily the school finance manager, for one project (project 5). The need for a knowledge of the EEM was evident within this specific project due to the role of the school finance manager who was heavily involved in the EEM adoption, maintenance and further challenges, similar to the role of a school site controller. Knowledge of the EEM was essential to the use, control and to inform the school of the adopted EEM. The requirement of these skills being classified as new for the school end-users, more specifically the school staff, were related to who lead the project, i.e. the initiative for the EEM either from the school or the local authority. If lead by the local authority, the LA energy team had the task of explaining the EEM to the school end-users. In contrast, if the EEM adoption was led by the school, the school finance manager indicated there were more challenges associated with the learning of new EEM information, training and possibly new skills required.

Summary: the different skill sets required

Each of the key actor groups evidenced a number of skill sets required for the delivery of each project. It was found that the dominant skills for the local authority were energy management skills, project management skills, communication skills, and technical and non-technical knowledge of the EEM; the EEM contractors required technical skills (electrical competencies, technical knowledge of the EEM and previous technical experience of the EEM), communication skills, co-ordination skills, energy management skills, building structure and construction skills, and specialist skills; and, the school end-users needed communication skills, research skills, project management skills, energy management skills and basic IT skills to operate the adopted EEM.

The findings highlighted 'communication skills' and 'energy management skills' were common to all three actor groups, and 'project management skills' common to both the local authority and end-user actor groups. The requirement of 'technical skills,' however, emphasised the need for specific skills for a particular actor group, where these skills were primarily required by the EEM contractors (with the exception of project 5). Furthermore, the investigation captured the different roles of key actors of the projects, which highlighted the broad range of tasks, various skills and different meanings attached to the required skills. The LA energy team, for instance, required project management skills to support and contend with a number of challenges throughout all stages of the project. The school staff on the other hand, required project management skills for tasks surrounding the initial planning stages of the EEM adoption (e.g. the ability to organise and evaluate funding for the EEM). In contrast to skills that involved different activities for the range actors / actor groups, 'communication skills,' had similar meanings and associated tasks / roles for all three actor groups.

The skills required present the interactions and, in reference to the RIS literature, the mechanism of interactive learning between actors / actor groups within the network. In agreement with the literature, the presence of interactive learning was key to the delivery of the LZC buildings within the region (i.e. the retrofitting of the schools), to exchange knowledge in regards to the project details, the appropriate EEM and the retrofitting process before and after EEM implementation. Furthermore, the literature suggested the importance of 'firms' as 'knowledge providers' through interactive learning (section 2.5.2). This was the case of the EEM contractors, more specifically the EEM suppliers. The institutions, primarily the LA energy team, however, were also vital to knowledge exchange within the network and key to learning (localised learning) for those involved in the project. Finally, the awareness of how to actually use the knowledge required from interactive learning was mentioned within the literature. The end-users, particularly the school staff, stressed this issue during the use and potential adjustments within the schools to the EEM following implementation. It must be further noted, a lack of understanding for the EEM may have also been the result of ineffective communication (i.e. insufficient information provided or lack of explicit knowledge), rather than the school being unaware of how to apply the knowledge to use the EEM.

In connection to the skills literature, the principal skills required by the key actor groups were a combination of both 'new skills' and 'existing skills,' similar to the ideas suggested within the literature in terms of what 'green skills' and 'low carbon skills' can be associated with (HM Government 2010, Energy UK 2014). The primary new skills were associated with 'energy management skills' and 'technical skills,' where both were linked to the EEM being adopted and training for the actors / actor groups to obtain these skills. The need for training associated with the technology (e.g. information provided for the EEM implementation for EEM contractors, or understanding of the use of the EEM for school end-users) resonates with the existing literature, in particular the training to gain the required technical skills (Aldersgate Group 2009, SDC 2010, Energy UK 2014). Furthermore, an association of knowledge required of current policies, principally evident in relation to EEM funding, for the development and the implementation of LZC buildings, was emphasised within the investigation, and supports the existing literature (Caputo and Pasetti 2015, Gooding and Gul 2016). The investigation can also extend the vague ideas around the need for knowledge on government policies to deliver LZC buildings, which lacks information on the type actors for which policy understanding is necessary. The findings evidenced all three key actor groups required some form of understanding around funding and impacts of government intervention, for the adoption of the EEM. Both the LA energy team and the school end-users, however, required a greater level of knowledge of funding opportunities and energy regulations, due to specific tasks carried out within the school retrofit projects.

A knowledge surrounding the EEM and policy pressures can further correlate with the required energy management skills for the projects, where the LA energy team required specific knowledge of local authority policies, targets and policy pressures within the region. It is also important to highlight the emphasis placed on new knowledge in relation to both energy management skills and technical skills. In many projects, the skill itself was identifying how to apply existing skills, being able and willing to learn about the EEM and the procedure(s) surrounding EEM adoption. This finding correlates to the literature where investigations highlighted a successful role (i.e. carrying out specific tasks), was connected to the ability to understand and further apply skills to the role, the situation or the technology in question. This investigation emphasised this fundamental need to understand the application of skills for the delivery of all five school retrofit projects. Both energy management skills and technical skills were related to the development and implementation of the EEM and its adoption process, but there was no / little indication of these new skills being known or referred to as green skills or low carbon skills. It was, however, the case where certain actors connected specific required skills and skill development to the delivery of LZC buildings. Similar understandings were portrayed in the prevailing literature in terms of required skills for LZC buildings, more specifically green skills and low carbon skills, having a connection to the adoption, use and management of renewable technology (Killip 2008, Xu et al. 2015). It is important to notice, however, that this skill set, particularly technical skills, were a mixture of new and existing skills (depending on the actor in some cases), which indicated not all the skills or tasks within the skill set were associated with the delivery of LZC buildings. This observation of the findings supports the literature that also suggests the need for existing skills for LZC buildings (Aldersgate Group 2009), i.e. existing skills that have been developed prior to the LZC building projects, and further training may not be essential.

9.4 RIS mechanism: knowledge production

It was found that both tacit and explicit types of knowledge (see table 9.2) were produced within the RIS network. A large proportion of knowledge produced, however, was that of a tacit nature by those involved in the projects. The tacit knowledge involving the decisions regarding the choice of EEM, particularly during the initial planning stages of the project, and the chosen EEM contractors, stemmed from the LA energy team. Similarly, the knowledge and instructions for the use of the EEM (e.g. how to control the systems), directed by the LA building management team, were primarily tacit in nature. Furthermore, findings indicated the majority of conversations between the EEM contractors and the school end-users, mainly the school staff, were that of tacit knowledge. Similar to ideas within the prevailing management of knowledge literature (Fernie et al. 2003, Koskinen et al. 2003), this type of tacit knowledge production within the network evidenced various challenges for the delivery of the projects, and hence LZC buildings within the region.

Two issues associated with tacit knowledge production were evidenced in Project 2. First, due to a lack of explicit knowledge from the EEM surveyor to the EEM installers (insufficient information on the survey report regarding the tools required for the installation), the EEM installation could not take place. Second, the school had not been informed that the EEM installers were attending to fit the EEM, i.e. lack of explicit knowledge meant the school staff were unprepared for the installation. These findings resonate with the current literature that highlights the challenges of sharing and transferring knowledge (Fernie et al. 2003), but more so, the difficulty regarding the management of knowledge that is of a tacit nature (Morgan 2001, Koskinen et al. 2003). Tacit knowledge, for instance, was the most exercised by actors / actor groups and widespread within the RIS, but difficult to identify due to its embedded nature, and therefore difficult to transfer between actors / actor groups involved in the school retrofit projects. Furthermore, as stated in previous investigations (Fernie et al. 2003, Koskinen et al. 2003), the requirement and potential impact of the social setting (i.e. the occurrence of interactions and relationships) to enhance the management of knowledge, was indicated within the research. The use of tacit knowledge, for example, evidenced fewer communication links, or issues with communication, between actors / actor groups surrounding the delivery of the LZC building projects. The local authority and EEM contractors, often used tacit knowledge associated with the fitting and further maintenance of the EEM. This resulted in many end-users being unaware of certain aspects of the implemented EEM, e.g. how to change the settings and what procedures to take in the event of a breakdown. This was of particular relevance to the heating system in project 4. In order to enhance the sharing of tacit knowledge, evidence suggested the need for a more personable approach to interactions. The findings indicate a greater explanation to the end-user, particularly those dealing with the EEM on a daily basis, could have resulted in a better understanding of the EEM. The need for a more personable approach and social network to drive the transfer of knowledge following knowledge production, supports the existing management of knowledge literature (Bresnen et al. 2003). Furthermore, to add to the current understanding on the management of knowledge, findings indicate the required 'personal skills' stated by Bresnen (2003) were closely related to the need for 'communication skills' by actors / actor groups involved in the LZC building projects (see section 10.2 and table 10.2 for the definition of communication skills).

In contrast to solely explicit knowledge being evident within the investigation, the production of both explicit and tacit knowledge was captured through different activities during the delivery of the projects, such as the process of energy auditing by the LA energy assistant. Tacit knowledge was provided to the school staff through the advice of the most appropriate EEM, and also the use and explanation of documentation referring to the energy auditing process and EEM recommendations. Explicit knowledge, which appeared the most beneficial to actors / actor groups, occurred within the network where EEM contractors provided EEM manuals / instructions, and offered further EEM guidance to the school end-users.

The RIS literature stresses the complexity of the knowledge production mechanism, i.e. different forms of knowledge and their identification, with the RIS, which was evident within the findings. What was also emphasised within the findings were the challenges of sharing knowledge and the transfer of knowledge within the network surrounding the project. As supported by the literature, the research investigation emphasised the essential need to pay attention to the management of knowledge, as oppose to solely knowledge production, during the delivery of the school retrofit projects (i.e. innovation with a region). The management of knowledge plays as an important role as the type of knowledge produced within the RIS. The explicit knowledge produced from an EEM manual, for example, was of little significance to the school due to the end-users lack of awareness surrounding the application of the knowledge. There was further evidence that suggested the type of knowledge produced may have posed greater challenges for the management of knowledge. Tacit knowledge produced by the LA building management team, for instance, appeared to be more difficult to understand in terms of how to manage it by the school end-users, than had it been that of explicit knowledge. Furthermore, what was evident by the creation of both tacit and explicit knowledge within the RIS, and the production of knowledge surrounding the projects, was the need for social interactions for knowledge production (emphasised in the RIS literature) and also the transfer of knowledge (emphasised within the management of knowledge literature).

Table 9.2: cross case analysis of the RIS mechanisms for the school retrofit projects 1 - 5

School retrofit project / RIS mechanisms		Project 1	Project 2	Project 3	Project 4	Project 5
Knowledge production	**Tacit knowledge**	• Meetings and EEM funding advice (interaction between LA energy officer and school headmaster). • Training (interaction between EEM suppliers and EEM installer).	• Meetings / presentations for EEM adoption (interaction between local authority and school staff).	• Changes made to the controls / use of the heating system (interaction between LA building management team and school).	• Choice / selection of EEM contractors and funding (interaction between the local authority and the school). • Solar PV process of adoption / implementation (interaction between the EEM supplier and school).	• Choice of EEM / EEM implementation (interaction between LA energy team, EEM contractors and school). • Conversations / instructions on how to use the EEM (school finance manager and school headmaster).
	Tacit / explicit knowledge	• Energy auditing documents/ EEM advice and energy education (interaction between LA energy assistant and school end-users). • EEM explanation / user guide (interaction between EEM installer and end-users).	• Energy auditing documents / advice (interaction between LA energy assistant and school staff). • EEM use and manual (interaction between EEM installer / supplier and school staff).	• Energy auditing documents / advice (interaction between LA energy assistant and school staff). • Internal learning for the EEM (interaction between EEM contractors and institutions).	• Energy auditing documents / advice (interaction between LA energy assistant and school staff). • EEM operation / issues (school site controller and finance manager). • Presentations for EEM choice / use (interaction between the school staff and governor).	• Energy auditing documents and advice (interaction between LA energy assistant and school staff). • Demonstrations and information exchange, i.e. learning by doing (interaction between the EEM installer and EEM suppliers).
Proximity	**Physical proximity**	• Majority of EEM contractors located within the region.	• Majority of EEM contractors located outside of the region.	• Majority of EEM contractors located outside of the region but close to the regional boundary	• Many EEM contractors located outside of the regional boundary.	• Majority of actors / actor groups located within the regional boundary.
	Spatial proximity	• Relationships, meetings and advice (interaction between LA energy team – school). • Relationships (interaction between EEM contractors - school staff).	• Communication / information exchange for EEM assessment (interaction between EEM estimator and EEM surveyor). • Communication links weak in regards to tools required for EEM installation (interaction between EEM surveyor and EEM installer).	• Communication exchange (interaction between LA energy team and EEM estimator). • Communication exchange and relationships (trust) (interaction between LA energy team and EEM supplier).	• Meetings, communication / knowledge exchange (interaction between local authority and school staff). • Communication exchange and relationships (interaction between school staff and EEM contractors).	• Meetings / advice / communication exchange (interaction between LA energy assistant and school staff). • Information exchange (interaction between school staff and EEM installers). • Communication exchange / relationships (interaction between school finance manager and head teacher).
Embeddedness		• Within the local authority: working relationships and occasional social interactions. • Within the school: between the school site controller and school staff.	• Within the local authority: working relationships and occasional social interactions. • Between the LA energy team and school staff: exchange of information, transfer of knowledge (presentations, advice on EEM). • Between the school community (school staff, parents and pupils).	• Within the local authority: working relationships and occasional social interactions. • Within the school between school staff. • Between the EEM installer and EEM supplier.	• Within the local authority: working relationships and occasional social interactions. • Within the school: between finance manager and school site controller. • Between school staff and EEM contractors. • Between school staff and school pupils.	• Within the local authority: working relationships and occasional social interactions. • Within the local authority: LA energy team and building management team (use of an in-house PM). • Within the small EEM contractor firms: hiring within the firm and learning.

9.5 RIS mechanism: proximity - physical and spatial

The delivery of all five projects captured the range of physical distance that can occur between actors / actor groups, i.e. the variation of distance in terms of internal or external location to the regional boundary for each project. Captured in two projects (projects 1 and 5), for example, the majority actors / actor groups were located within or very close to the regional boundary. The remaining three projects evidenced great variations of physical proximity between EEM contractors and the local authority. This physical distance, however, did not appear to have an effect on the spatial proximity between actors, project communications and relationships between those actors involved (i.e. no difference in the physical proximity extremes). The EEM installers and EEM suppliers, for instance, appeared to have good communication links, even though there was a large physical distance between these actors in the majority of projects. Various EEM installers relied on the EEM suppliers to gain information about the EEM and attend EEM training events, which were noted as useful for the EEM contractors. In each project, the local authority had built strong relationships with the school end-users, demonstrating social skills by both actors and evidencing trust within the networks.

The RIS literature links physical proximity, i.e. the physical distance between elements within the RIS, to the ability and support of greater of communication and knowledge exchange. The findings, however, did not see a strong correlation concerning the distance between actors / actor groups and the level of interactions. The LA energy team, for example, did not appear to interact or gain greater knowledge from those EEM contractors within the regional boundary to those outside of the boundary. There were instances where the LA energy team had a greater rate of communication exchange regarding the EEM design and implementation with some EEM contractors than others, but the results did not indicate the physical proximity had an effect on these interactions. Furthermore, the literature connects the geographical dimensions and proximity to the production of both tacit and explicit knowledge, i.e. tacit knowledge tends to stay within the regional boundaries, whereas explicit knowledge can easily be transferred. There were indications this was the case as key actors / actor groups (primarily the local authority) tended to have greater face-to-face interactions and project meetings concerning the projects, with those EEM contractors within the regional boundary. Similarly, regarding the EEM adoption process, the investigation noted a greater use of emails and communication via telephone calls by the LA energy team to EEM contractors located outside of the regional boundary. Furthermore, a great deal of EEM explanations by the local authority to the school end-users was that of tacit knowledge, where the LA energy team and building management team were able to visit the school. The literature also references regional proximity in terms of the recognition to localised capabilities, i.e. the idea that RIS firms will locate in close proximity to resources. Due to a number of EEM contractors having the ability to attend training events and close communication with other EEM contractors (suppliers) located outside of the region, the research did not support the localised capabilities idea. It appears that, possibly due to the availability of different types of communication and interactions, the degree of physical proximity may not have such a crucial effect on innovation with the RIS.

Spatial proximity, the less physical / intangible actions, such as greater levels of interactions within a RIS, was emphasised as beneficial to the region in terms of knowledge flows and innovation. This idea was clear within the case study, where spatial proximity was evident between the school site controller and the EEM contractors (projects 1, 4 and 5), and the school finance manager and the EEM contractors (projects 4 and 5). The presence and effect of spatial proximity within the network, i.e. strong relationships and communications regarding EEM advice between actors / actor groups, was further supported as the school staff demonstrated an understanding and made considerable efforts to adopt the appropriate EEM for the school buildings.

9.6 RIS mechanism: embeddedness

Embeddedness appeared to be evident and of greater clarity within the actor groups of the network (as oppose to between actors / actor groups). The local authority demonstrated high levels of embeddedness throughout the five projects, where interactions and strong relationships were evident between the LA energy team and LA building management team. The level of embeddedness was distinct through EEM funding negotiations, for instance, which required the LA energy team to carefully project manage and justify the suitability of the EEM selected for the school. Similarly, project 5 further evidenced embeddedness and relationships between the LA energy team and LA building management team through the recruitment of a project manager from within the LA building management team (specific to solar PV adoption). Similarly, high levels of embeddedness were also noted within the projects where the school staff, primarily the school head teacher, school finance / business manager and school site controller, evidenced strong relationships. These interactions and greater levels of trust between actors were connected to the knowledge produced and transferred, such as the justification of adopted EEM and explanations of how to operate the EEM.

It was difficult to identify and fully understand the level of embeddedness surrounding the delivery of the projects, possibly correlating to the lack of detail and clarity of this mechanism within the RIS literature. It was also difficult to separate interactions associated with spatial proximity and embeddedness within the case study. Of those actors / actor groups recognised as having greater levels of embeddedness, however, there were indications of more opportunities for learning and information / knowledge exchange. The LA energy team, for example, evidenced embeddedness where communication rates were high, and both the energy assistant and energy officer attended training and demonstrated a high level of understanding around the EEM procedure. Similarly, considerable levels of embeddedness were demonstrated in project 4, between the school finance manager and school site controller, evidencing strong working relationships and information exchange and learning around the EEM.

9.7 The challenges associated with the required skills for the delivery of LZC buildings

The investigation evidenced two challenges associated with the complexity of the skills required by the construction sector and its clients during the delivery of LZC buildings. First, findings highlighted the issue associated the initial identification of the required skills for the construction sector and its clients, i.e. an awareness of the skills being employed for the projects. Each project was unique in terms of the building, the combinations of EEM adopted and the various actor / actor groups involved, which resulted in the application of different skills for the delivery of LZC buildings within the region. The complex skills required, such as the type of technical skill (knowledge of the EEM and previous experience associated with the EEM), appeared to cause confusion due to being unique to the EEM and different buildings. Similarly, the projects also evidenced an absence, leading to further issues, of the more general skills (e.g. communication skills), where certain actors / actor groups were unaware of their importance towards the delivery of the projects. The complications with the identification of the required skills were further highlighted through the various meanings by key actors / actor groups of what different skills entail. It appeared vital in the projects that actors / actor groups became aware of the relevant skills and how to apply them to complete the project. Furthermore, the research captured the need for actors / actor groups to recognise and understand whether the required skills were new skills (i.e. the application of training required), existing skills or a combination of both new and existing skills.

Furthermore, following the identification of the required skills to deliver the projects, the second challenge was connected the development of new skills or further enhancement of existing skills for the construction sector and its clients. The complications within a number of projects were associated with the need for relevant information and training to gain the required skills to adopt the EEM. More specific to school end-users was the need to gain relevant knowledge of how to operate the EEM effectively, such as basic IT skills and knowledge of the EEM controls. The challenge for the EEM contractors primarily surrounded the development of technical skills, and further knowledge of how to apply them to the different projects. Data collection (an interview and observation) with an air source heat pump (ASHP) trainer, for instance, highlighted the complications associated with gaining the knowledge of required skills, and the challenge of the application of skills to a different technology and situation. The explanation and challenge with the installation of the ASHP summaries both challenges, the initial identification of skills required (which was the bigger issue highlighted during the interview), followed by the knowledge of application (where in many cases where the learning and further training were required).

Chapter 10 Conclusion

10.1 Introduction

This chapter will summarise the research findings in connection to the aim and objectives established for the investigation (see section 1.3), and broader research problem (see section 1.2). Following this, the contribution to the regional innovation systems (RIS) theory and skills theory, implications for policy practice and methodology will be discussed. Finally, limitations of the investigation and particular areas that would be of value for future research will be set out.

10.2 Summary of research findings

The aim of the research was to identify, and better understand, the skills required for the development and the implementation of low and zero carbon (LZC) buildings within a region. As shown in table 10.1 below, each of the key actor groups involved in the investigation required both primary and secondary skills for the delivery of LZC buildings (i.e. the adoption of energy efficient measures (EEM)) within the region. Primary skills were those that were principal to the development and implementation of the LZC building projects, by the key actors / actor groups involved. Whereas secondary skills were essential to the delivery of LZC building projects within the region, but less common to actors / actor groups in terms of use. The differentiation between primary and secondary skills is valuable to the research, as the classifications provide guidance to the construction sector and its clients regarding the skills vital to development for the delivery of LZC buildings, should training and education be options within the regional network. The work recognises that resources by actors / actor groups may be limited, and clarity is needed for those skills that should be addressed first, if skill development is available. By stating the skills as either primary or secondary is a method of understanding the cluster of skills required by the five case studies. A range of skills were evidenced for each school retrofit project for the different actors / actor groups involved during the delivery of the LZC building, and the classifications identify those key required skills for each actor group. The primary and secondary classification will assist the identification of training required for the key actors / actor groups within this investigation, and potentially be of value during the explanation of some of the challenges faced by the construction sector and its clients. The research is not purporting this finding of primary skills and secondary skills can be generalised for every LZC building retrofit project, i.e. the generalisation is for the case study and purpose of this research. To further explain the primary and secondary skills required by the key actors / actor groups, table 10.2 provides definitions for each of the key skills, which were derived from the case study findings.

Table 10.1: primary and secondary skills for each actor group

Key actor group	Skills	
	Primary	**Secondary**
Local authority	• Energy management skills • Project management skills • Communication skills	• Technical and non-technical knowledge of the EEM
EEM contractors	• Technical skills • Technical skills (electrical) • Technical skills (previous EEM experience) • Communication skills	• Technical skills (knowledge of the EEM) • Energy management skills • Co-ordination skills • Building structure and construction skills (basic and in-depth)
School end-users	• Communications skills • Project management skills	• Research skills • Energy management skills • Basic IT skills to operate the EEM adopted • Technical and non-technical knowledge of the EEM

Each of the six objectives set out at the beginning of the investigation (see section 1.3), will be presented and discussed in connection to the research findings, as evidenced from the empirical case studies (see chapters 4-8). Each objective is explained in turn.

Objective 1: Identify key actors involved in the delivery of LZC buildings within the region, and their roles that contribute to this process.

The findings identified that three key actor groups are dominant to the regional network for the delivery of the LZC building projects: the local authority (LA), the energy efficient measure (EEM) contractors and the school end-users. Each key actor group had a specific role(s) for the delivery of the LZC building projects. First, the local authority (the energy team and building management team), played a significant role in driving the LZC building projects for the schools through the provision of information and funding support to the school end-users. The local authority further investigated and specified the most appropriate EEM for each project and EEM contractors for the work (see sections 4.2 and 4.4.2 for further detail). Second, the EEM contractors (estimator, surveyor, designer, supplier and installer) were primarily involved during the EEM adoption and activities surrounding the planning, design, implementation and post completion of the EEM. Finally, the school end-users (school staff, parents, pupils, governors and community), were involved in making key decisions surrounding the most appropriate EEM for the school, and in some instances, contributed to the choice of EEM contractors (see sections 4.4, 7.2 and 8.2) and EEM funding (see section 7.2.2).

Table 10.2: skill definitions of the required primary and secondary skills for each actor group

Key skill definitions: **Energy management skills:** the ability to carry out an energy audit, and have an understanding of the EEM to assess the more appropriate EEM for adoption. Closely associated with an EEM knowledge and processes during the development and design stages of the project, i.e. early stages prior to EEM implementation. **Project management skills:** the ability to organise and co-ordinate the project in terms of planning the project, through to the EEM design and implementation, and post implementation of the EEM. PM skills can be referred to as either hard skills (e.g. an association with the EEM technology) or soft skills (e.g. the ability to build relationships). The majority of PM skills are of an existing nature, i.e. not a new skill, and incorporate a level of previous experience of the job role / tasks. **Communication skills:** the ability to interact and convey information (i.e. communicate effectively) to other actors / groups of actors involved within the project. The ability to provide information of the EEM and educate actors / actor groups. Closely connected to interpersonal skills to develop the required effective communication and build relationships, and further linked to the broader social skills classification. **Technical skills:** skills linked specifically to the EEM (usually a renewable / advanced technology EEM- solar PV, air source heat pumps, energy efficient boiler). The ability to understand and install the EEM, and further knowledge of how to use the appropriate tools (including specialist software) for the EEM survey, design and installation. **Technical skills (electrical competencies):** the knowledge and understanding of individual electrical components of the EEM and EEM system (e.g. ability to electrically wire the EEM). **Technical skills (previous experience of the EEM):** previous experience surrounding the EEM to understand the EEM delivery process and EEM adoption procedure, and further recognise potential problems that can be encountered during the planning, design and implementation stages. A level of confidence is required for the EEM implementation process that is associated with previous EEM experience. **Technical skills (knowledge of the EEM):** a broad knowledge, understanding and ability to explain the advantages, disadvantages, short term and long term challenges of the EEM in terms of its technical attributes. **Co-ordination skills:** the ability to organise and arrange an appropriate date / time to carry out EEM estimations, surveys and installations. The co-ordination of EEM adoption is essential for effective delivery of the project. **Building structure and construction skills (basic and in-depth):** the understanding of building fabric, knowledge of construction, the tools required for successful EEM integration and potential challenges associated with EEM adoption. **Research skills:** the ability to independently investigate a potential EEM and range of EEM options for adoption, and further explore to gain an understanding of how to operate the adopted EEM components and EEM systems. Research skills are associated with media (e.g. the internet, television and the paper), and questioning experts in the area of EEM adoption. **Basic IT skills to operate the EEM adopted:** the ability to operate the EEM, and understand the installed (primarily computer) components required to make changes, and further maintain the adopted EEM and system. **Technical and non-technical knowledge of the EEM:** technical knowledge (as above), possessing a broad knowledge and understanding of the technology, and the ability to explain the EEM in terms of its technical attributes. Non-technical knowledge surrounds an understanding of the EEM that is not of a technical nature, such as EEM paperwork prior to installation (EEM tariffs and payment) and commercial benefits of the EEM.

Objective 2: Identify and explore the EEM adoption process for the LZC buildings and the level of involvement from the key actors in this process within the region.

All five case study projects, through the procedures adopted and guidance by the local authority, highlighted a generic EEM adoption process for the reduction of energy consumption within the school buildings (see section 4.2 for further detail).

The common procedures adopted by the LA energy team were evident throughout the four stages of the school retrofit project process (planning, design, implementation and post completion) (see section 4.2). During the planning stage, initial contact was made to the school, i.e. school head teacher / finance manager, to seek the possibility of an energy audit, and evaluation for the potential of EEM integration. Alternatively, there were instances where the school contacted the LA energy team to seek EEM adoption advice, which was then followed by an energy audit. The priority measures considered for adoption following the energy audit were low cost EEM and fabric methods (energy education, loft and cavity wall insulation, lighting upgrade and glazing area), followed by renewable technology (solar PV, solar thermal and air source heat pump). During the design stage the most suitable EEM for adoption were assessed and the LA energy team liaised with the appropriate EEM contractor (designer, estimator and surveyor) for the work. The implementation stage of the project involved the installation of the adopted EEM by the chosen EEM contractor, where communication was made to the LA energy team and the school staff to arrange an appropriate date / time for the installation. In the post completion of the EEM stage, the EEM contractor (installer or supplier) provided a handover to the school.

The five projects highlighted the wide range of EEM options for the delivery of LZC buildings (see section 9.3.2 table 9.1), where each school was unique in terms of their type and combination of EEM adopted, and EEM contractors. The EEMs identified during the period of data collection were either in the development stage, the implementation stage, or in the process of being explored for adoption in the near future.

Furthermore, it was evident that each key actor group contributed to the development and implementation of the adopted EEM at different stages, and further experienced different levels of involvement (see table 10.3). 'High' involvement states the actor group were involved at the majority of stages during the EEM adoption process (planning, design, implementation and post completion), and had significant contribution to key decisions of the EEM adoption process. 'Medium' involvement indicates the actor group were involved in a number of project stages and had an input to key decisions surrounding the EEM adoption process. 'Low' involvement implies the actor group were aware of the EEM adoption and contributed to suggestions for EEM delivery, but had little direct impact on the process. The local authority, were involved throughout the entire project process from planning to post completion (see figure 4.1 in section 4.2); the EEM contractors were predominantly involved during the design and implementation stages, but also had input during the initial planning stage and post completion stage. The school end-users (mainly school staff) were involved or consulted throughout all stages of the project, but certain members of the school staff had a more active role during the planning and post completion stages of the projects. The project stages where actor groups were not involved in any EEM decisions are clearly stated as 'not involved.'

Table 10.3: key actor involvement during the EEM adoption process

Key actor group / EEM adopted	Local authority		EEM contractors					School end-users				
	Energy team	Building management team	Surveyor	Estimator	Designer	Installer	Supplier	Staff	Pupils	Parents	Governors	Community
Double glazing	Medium	Not involved	High	Not involved	High	High	Medium	High	Not involved	Not involved	Not involved	Not involved
Lighting upgrade	Medium	Not involved	High	Not involved	High	Not involved	Medium	High	Not involved	Not involved	Not involved	Not involved
Lighting survey	Medium	Not involved	High	Not involved	n/a	Not involved	Not involved	Medium	Not involved	Not involved	Not involved	Not involved
Half hourly meter installation	Medium	Not involved	Not involved	Not involved	Not involved	High	Not involved	Low	Not involved	Not involved	Not involved	Not involved
Smart meter installation	High	Not involved	Not involved	Not involved	Not involved	High	High	Low	Not involved	Not involved	Low	Not involved
Heating system and heating controls (BMS) updated	Medium	High	Not involved	Not involved	High	High	High	High	Not involved	Not involved	Not involved	Not involved
Solar PV	High	Not involved	High	Not involved	High	High	Medium	High	High	Not involved	High	Not involved
Solar thermal	High	Not involved	High	Not involved	High	High	Medium	High	Not involved	Not involved	Not involved	Not involved
Loft insulation	High	Not involved	Low	Low	Not involved	High	Medium	Low	Not involved	Not involved	Not involved	Not involved
Cavity wall and loft insulation survey	High	Medium	High	High	Not involved	Not involved	Not involved	Low	Not involved	Not involved	Not involved	Not involved
Air source heat pump (ASHP)	High	Not involved	Not involved	Not involved	High	High	High	High	Not involved	Not involved	Not involved	Not involved
Energy education	High	Not involved	Not involved	Not involved	Not involved	Not involved	Not involved	High	High	High	Not involved	High

Objective 3: Explore key actors' interests and negotiations surrounding the EEM adoption process to identify and further understand the type, significance and meanings of required skills for the delivery of LZC buildings within the region.

The key actor groups evidenced a number of interactions and negotiations surrounding the adoption of the EEM. The negotiations further identified the key skills required, highlighting skill variation and complexity associated with both primary and secondary skills for the delivery of LZC buildings within the region (see table 10.4). Furthermore, findings evidenced key actors possessed both similar and contrasting meanings connected to the skills required for the projects. In relation to the meaning of a 'skill', where actors were able to define the term, its definition was linked to the ability to perform a particular function, involved a form of learning, and the association of an individual's ability to complete a particular job (i.e. the skill is unique to that person). The definition of ‘project management skills’ was associated with actions that involved the organisation of the project at all stages of the EEM adoption process. Certain actors, however, applied the use and actions of ‘project management skills’ solely during the planning or design stages of the project. The views and actions involved with a ‘technical skill’ captured a link to the need for knowledge attached to the EEM adopted, and an understanding of the use of tools or equipment for the integration of the EEM. Similarly, the actions related to ‘energy management skills’ were also linked to the understanding of the adopted EEM.

The prevailing literature emphasises the need for ‘new skills,’ (Construction Skills 2010) ‘green skills’ (Energy UK 2014) and ‘low carbon skills’ (RIBA 2008) for the delivery of LZC buildings. The key findings evidenced both the required ‘energy management skills’ and ‘technical skills’ involved an element of ‘new skills’ to understand and further adopt the EEM, but also required ‘existing skills’. The association of both ‘technical skills’ and ‘energy management skills’ with the adopted EEM links the possibility of these skills being connected with the terms ‘green skills’ or ‘low carbon skills,’ as the literature also emphasises these skills to involve the integration of LZC technology (Killip 2008). However, there was little reference in the key results that indicated ‘energy management skills’, ‘technical skills’ or any of the required skills found in table 10.1, were known as ‘green skills’ or ‘low carbon skills,’ i.e. no actors / actor groups used these skill terms, or few actors / actor groups understood the meaning of green skills and low carbon skills.

Objective 4: Identify activities and exchanges between key actors in support and development for the skills required for the delivery of LZC buildings within the region.

The adoption of the EEM and surrounding project network highlighted activities and exchanges between key actors / actor groups, which aided the development of skills required to deliver the LZC buildings. The local authority (i.e. the LA energy team) promoted learning within the project network by attending training courses within the local authority, and encouraged localised learning within the region. The EEM contractors, mainly EEM suppliers, were significant to skill development as provided a number of training activities (i.e. workshops) and additional EEM information to EEM contractors and school end-users within the project network. The findings highlighted the importance of skill development for the delivery of LZC buildings within the region, and challenges associated with skill deficiencies and lack of skill development (see objective 5 below). The key findings are consistent with the current literature, which suggests the need for training, learning or an up-skilling of the workforce to develop the required ‘new skills,’ ‘green skills’ and ‘low carbon skills’ (HM Government 2010, Energy UK 2014) for the delivery of LZC buildings. Furthermore, as both ‘energy management skills’ and ‘technical skills’ were associated with the local authority, EEM contractors and school end-users, results correspond to prevailing literature that states the need for skills development for both the construction sector (Home Building Skills 2013b) and its clients (SDC 2010).

Table 10.4: primary and secondary skills required by key actor groups

Key skills	Local authority	EEM contractors	School end-users
Energy management skills	Primary	Secondary	Secondary
Project management skills	Primary	N/A	Primary
Communication skills	Primary	Primary	Primary
Research skills	N/A	N/A	Secondary
Technical skills	N/A	Primary	N/A
Technical skills (electrical competencies)	N/A	Primary	N/A
Technical skills (previous EEM experience)	N/A	Primary	N/A
Technical skills (knowledge of the EEM)	N/A	Secondary	N/A
Technical and non-technical knowledge of the EEM	Secondary	N/A	Secondary
Basic IT skills to operate the EEM adopted	N/A	N/A	Secondary
Co-ordination skills	N/A	Secondary	N/A
Building structure and construction skills	N/A	Secondary	N/A

Objective 5: Explore primary challenges experienced by key actors during the delivery of LZC buildings within the region.

The actor / actor group interactions and negotiations during the projects highlighted two challenges for the delivery of LZC buildings within the region. First, interactions by the local authority (internal and external) evidenced regional level policy pressures and the need for the local authority to comply with the policy demands. Pressures for the local authority to comply with regional energy reduction targets (15% by 2015, 40% by 2020), which were specific to the regional area under investigation; the LA sustainability strategy (2012 – 2020); and the consideration of Localism Act demands, such as sourcing EEM contractors locally if possible. Second, the investigation findings captured the challenge related to the need for the development of the key skills required for the delivery of LZC buildings within the region. Results captured the need for skill training and development for the three key actor groups (local authority, EEM contractors and school end-users), involved in the delivery of LZC buildings Issues regarding a lack of skill development, primarily associated with the local authority and school end-users. Findings revealed the local authority were aware of the necessary skill development and processes were in place for future training to gain the required skills. In contrast, even though the school end-users lacked fundamental skills required to understand and operate the EEM, very little was mentioned in terms of the desire to learn or become educated to gain the skills needed. In regards to further skill development, it is likely the challenge is related to actors being unaware of the skills that require development.

Objective 6: Critically reflect and contribute to the current understanding of the RIS theoretical framework and prevailing skills theory.

The investigation demonstrated the adoption of the RIS theoretical framework, which helped to direct the research in terms of the identification of the region (i.e. RIS 'elements' and 'mechanisms') surrounding the LZC building projects (see section 2.5.2 for RIS components and characteristics), and further applied during data collection and data analysis (e.g. the framework acted as a guide for the coding of data). The key ideas and meanings associated with the RIS framework for the research were provided by the prevailing RIS literature (Doloreux 2002, Cooke 2004, Asheim and Gertler 2005, Doloreux and Parto 2005) (see section 2.5 for further detail), which aimed to predict and describe the innovativeness of a region. The current understanding of the RIS framework, however, provided ambiguous accounts for a number of RIS characteristics, and much of the RIS literature lacked empirical evidence to support the fundamental arguments. The primary issue was a lack of knowledge surrounding the need for connections between RIS components, and speculation as to whether every element and mechanism is vital to a RIS for innovation within the region. The investigation demonstrated an understanding of the current RIS framework (see section 2.5.3 for a framework summary), and further adapted the framework following the research findings, combining the skills required within the region (see section 10.3 and figure 10.2 for the adapted RIS framework).

The prevailing construction skills literature provided an insight into dominant skills for the construction sector, where a large proportion of investigations focussed on the need for 'project management skills' and 'communication skills' at a project level (see section 2.3.3). The literature, however, lacked meanings of what both project management skills and communication skills actually consisted of, and little indication of how to gain these skills, and further possibility of other skills required for the construction sector. The construction innovation literature investigating LZC buildings was also studied for the investigation, which stated the need for skills for both the construction industry and its clients (i.e. local authorities and end-users of LZC buildings) (see section 2.3.4). The required skills suggested, however, were referred to as 'green skills,' 'low carbon skills' and 'new skills,' where vague descriptions of what these skills actually comprised of were provided. Furthermore, very few, or opposing definitions of the required skills were given, and there was little reference or direction in terms of how to gain these green skills (i.e. no suggested guidance on training). The investigation highlighted the key skills required during the development and the implementation of LZC buildings within a region, for both the construction sector (i.e. the EEM contractors for the school retrofit projects) and its clients (i.e. the LA energy team and end-users of the school buildings). First, the key skills for the local authority consisted of energy management skills, project management skills and communication skills. Second, the EEM contractors (estimator, surveyor, designer, installer and supplier) required technical skills, ranging from a knowledge of the EEM technology, use of the tools required for EEM implementation, electrical components of the EEM and experience, and communication skills. Finally, the school end-users (school staff, pupils and the school community) required communication skills and project management skills (see section 9.3.2 for further detail of the required skills for each key actor group). The research findings were also able to provide definitions for each of the required skills for the delivery of the LZC buildings. The definitions and meanings of skills were evident from the analysis of interviews with the key actors of the school retrofit projects, and observations of actions surrounding the development and the implementation of the EEM within the school buildings (see table 10.1 for key skills required and skill definitions). Furthermore, the investigation was able to comment on the subject of green skills required for LZC buildings, where little evidence was found for the recognition of these skills by the construction sector and its clients. There were, however, indications associated with the need for new skills associated with the EEM technology adopted, allowing the investigation to build upon the existing skills theory (see section 10.4 for the contribution to skills theory).

10.3 Contribution to regional innovation system (RIS) theory

The RIS theory seeks to describe, explain and predict the innovativeness of a region in connection to the regional characteristics and the surrounding RIS. The current RIS framework identifies with a developed RIS (see section 2.5.1 for a RIS definition) in terms of its contribution, and benefits to the surrounding region, and possibly beyond (i.e. boundary regions). RIS theory focuses on the consideration of RIS characteristics (also known as components), which can have an effect on innovative activity (see figure 10.1 below). The principal RIS framework fundamentals (see section 2.5.2 for further detail) of focus within the investigation consisted of: RIS elements, the more tangible characteristics known as firms, institutions, knowledge infrastructure and policy orientated regional innovation; and RIS mechanisms, the intangible and dynamic characteristics that are referred to as interactive learning, knowledge production, proximity and embeddedness (Doloreux 2002).

10.3.1 Current understanding of the RIS framework

The RIS literature reviewed explained the RIS concept, how the framework originated, evolved (Doloreux 2002, Doloreux and Parto 2005) and compared to others (e.g. national and sectoral innovation systems) (Chung 2002, Chang and Chen 2004), and offered descriptions in great detail surrounding the roles of the individual RIS components (see figure 10.1) (Asheim and Isaksen 1997, Doloreux 2002, Chang and Chen 2004, Chaminade and Vang 2008). The existing RIS framework, as shown in figure 10.1, created from the RIS literature reviewed (see section 2.5.2), however, demonstrates weaknesses and provides the opportunity to build on the theory. First, the theory is normative in nature, and there is little specification and evidence of how the framework can be applied to regions of contrasting characteristics. As supported by Asheim and Coenen (2005), in terms of guiding regional innovation policies, the framework needs to adapt to specific regional circumstances and contexts, i.e. no one framework fits all regions. Second, the definitions of a region (Doloreux and Parto 2005), RIS and innovation systems (Evangelista et al. 2002, Chang and Chen 2004) are unclear, which can cause much confusion in terms of identifying a region and actually applying the framework (possible reasons for the following problem). Third, there is little evidence that captures the framework being empirically tested. There are studies that have applied the RIS theory (Doloreux 2003, Asheim and Coenen 2005), but further work is required for remote or peripheral areas (Doloreux 2002), as outer regions can have contrasting characteristics that affect innovation capacity (Tödtling and Trippl 2005). It would also be of value for the framework to be examined for those areas that are known as developing or less successful (Doloreux 2002, Chaminade and Vang 2008). Finally, in connection to the previous problems, i.e. the framework being normative and less empirically tested, the prevailing RIS literature appears solely descriptive in terms of what is required for innovation within a region (Doloreux and Parto 2005). The framework identifies what is required for a RIS and promotes the opportunity for insight into the RIS processes. In support of understanding the more complex nature of a RIS, it is thought the advantage of a systems approach framework is its systemic dimensions, such as the details of elements interacting (Chaminade and Vang 2008).

The research empirically tested the current RIS theory by applying the RIS framework to a RIS and region, identifying the required skills associated with innovation (in this case the EEM adoption) for the region and conducting in-depth analysis. The key results of the investigation were then used to adapt, and build upon, the current RIS framework (see figure 10.2), and further describe and explain a regional innovation system and connections to the skills required to deliver LZC buildings within the region.

10.3.2 Adaptations to the current RIS framework and the required skills

The primary contribution to the RIS theory is empirical evidence that captures the existence and fundamental need for interactions and connections between the components within the system. There are studies that place emphasis on the requirement of interactions and interplay within the system (Evangelista et al. 2002, Chaminade and Vang 2008), but there is little description on how and which RIS components are required to connect / communicate to encourage innovation. Figure 10.2 has been adapted to highlight the involvement of elements for the generation of interactive learning within the system. It was of importance to connect interactive learning to knowledge infrastructure as, in contrast to solely firms involved in interactive learning (Chaminade and Vang 2008), key results captured both firms and institutions, as part of knowledge infrastructure, a support to knowledge flows and regional innovation through learning interactively. Linked to the RIS elements, and expanding on the elusive accounts of their roles from the literature (Doloreux 2003), the research emphasised the multiple functions of RIS elements. The investigation agrees with the vital role of firms within the RIS, their value for the production and transfer of knowledge (Doloreux 2002) and innovation activities within the firm (Evangelista et al. 2002). Similarly, the role of institutions are important to regional learning through formal roles (Edquist 1997) and the transfer of information (Johnson et al. 2002). To expand and adapt current ideas of the RIS framework, the roles of institutions cannot be downplayed, as they contributed to the transfer of valuable information, but also knowledge within the innovation system, demonstrating both formal and informal roles. The study suggests a RIS requires contributions from both firms and institutions of the RIS (possibly more so the roles of institutions), and the incorporation of interactions to encourage learning to generate and transfer knowledge within the system.

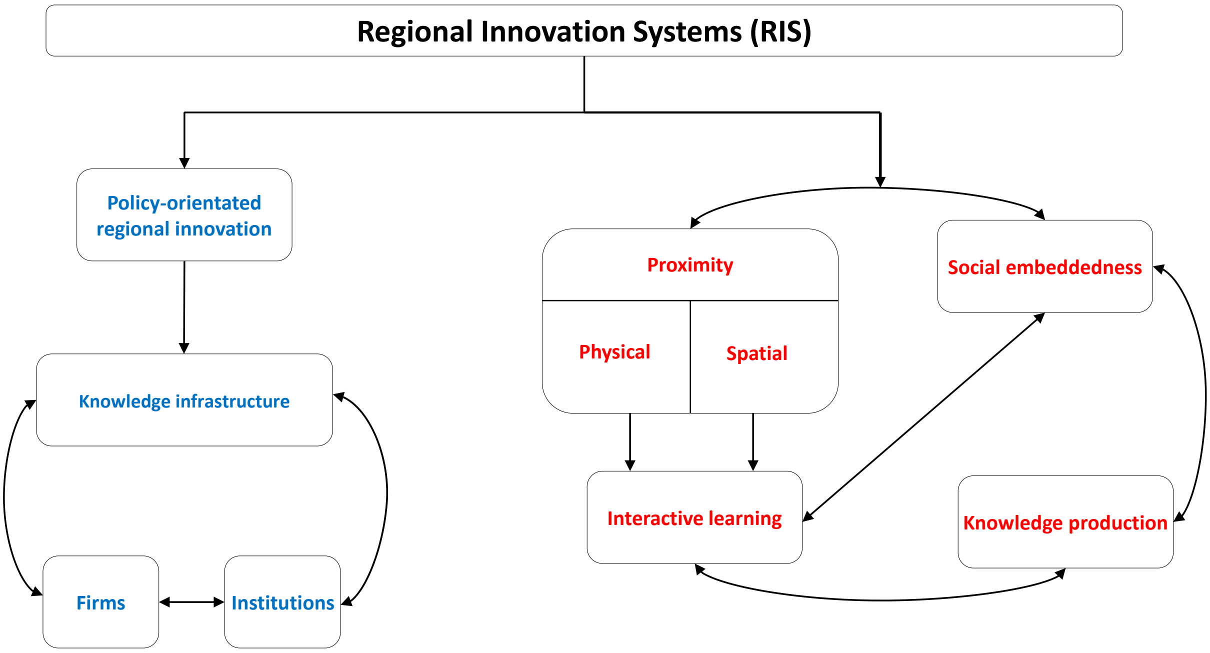

Figure 10.1: RIS framework (Doloreux 2002)

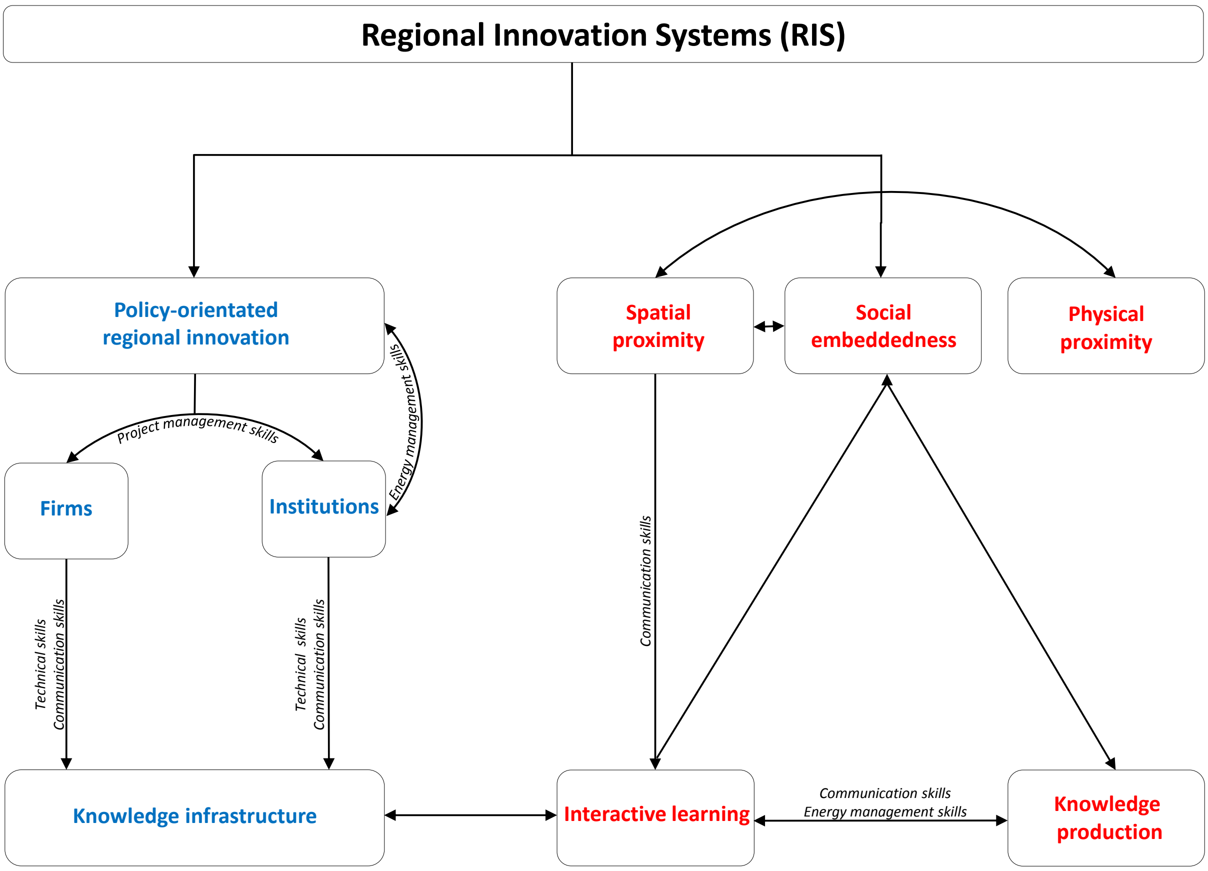

Figure 10.2: adapted RIS framework and required skills

The key findings are consistent with the literature regarding the presence, and influence to a certain extent, within the system to the involvement of various 'RIS mechanisms' (interactive learning, knowledge production, proximity and embeddedness) (Asheim and Isaksen 1997, Doloreux 2002, Doloreux 2003, Chang and Chen 2004). Similar to RIS elements, the literature provides more of a detailed description of mechanisms to explain what a RIS consists of. There is little reference to interactions and, more importantly as apparent from the key findings, the existence and dominance within the RIS of certain mechanisms more than others. Similar to discussions (Simmie et al. 2002, Chaminade and Vang 2008), the research identified the significance of interactive learning (more so effectively), to the innovation system (i.e. vital to aid regional innovation and skill development). The actions associated with learning interactively, and its value to the innovation system, were highlighted through a combination of this mechanism and knowledge production. This statement sits in contrast to specific RIS descriptions, which do not explicitly emphasise the interactive part of learning (Cooke 2004), or highlight the important connection of this mechanism to aid the function of knowledge production within the region (Doloreux 2003). There are suggestions within the literature to the necessity of learning and interactions surrounding the generation of knowledge (Lundvall 1992, Maskell and Malmberg 1999). The findings, however, enhance this idea and propose that a mechanism in isolation may not aid innovation within the system, as effectively without the other. Furthermore, key results gave significant value to the type of knowledge created within system. The findings are consistent with the literature, which emphasised the complications in understanding and sharing tacit knowledge (Lundvall 1992, Morgan 2001), and further demonstrated the improvement in understanding and benefit to the system of explicit knowledge. The final mechanism and significant change to the RIS framework (figures 10.1 and 10.2) is the separation of proximity, i.e. physical and spatial proximity. The term proximity, its direct and in-direct influence on communications, interactions, knowledge transfer (Autant-Bernard et al. 2013) and economics (Doloreux 2002) within the system, and variations associated with this mechanism (geographical, physical, spatial, and relational) highlights the ambiguity of the RIS component. The research findings identified both physical (i.e. distance between elements within and surrounding the regional boundary), and spatial proximity (relationships, communications and social characteristics between elements) with the case study. In contrast to the literature, which offers little distinction of either type of proximity being beneficial to the system, but merely discussions of effects of different types proximity in general (Doloreux 2003, Chang and Chen 2004), it is worth noting the impact of spatial proximity on the system, as oppose to physical. Table 10.5 (below) describes a brief summary of the adaptations to the RIS framework from the investigation.

Table 10.5: comparison of existing and adapted RIS framework

RIS framework characteristic	Existing RIS framework	Adapted RIS framework	Empirical evidence for the adaptation (from the case study)
Description of a RIS	• The identification and description of RIS characteristics / components for regional innovation. • A lack of clarity on how to apply the RIS framework to different regions.	• The identification of the need for interactions between RIS components (elements and mechanisms) for regional innovation. • The idea that regional differences may result in variations of the RIS framework.	• The interactions between RIS components (e.g. the negotiations around all five school retrofit projects), both within and between elements and mechanisms, were essential to the delivery of the LZC buildings within the region. Firms, for example, needed to interact, communicate and exchange documentation with knowledge infrastructure to innovate within the region. • The investigation studied one region. A number of characteristics, such as region size, regional boundaries, firms, institutions and energy reduction targets were specific to that region. Regional differences and RIS characteristics may result in diverse interactions, decision making processes, and required skills for the delivery of LZC buildings.
RIS elements	• A focus on firms being an important link to knowledge infrastructure and learning within the RIS. • The presence and importance of formal roles by institutions within the RIS.	• The recognition of both firms and institutions being a vital part of knowledge infrastructure. • The recognition of the impact and dominance of both formal and informal roles by institutions within the RIS.	• Both firms and institutions were important sources of knowledge within the region. Institutions, such as the LA energy team, were essential to the provision of knowledge regarding the EEM adoption (i.e. education to school end-users) and the EEM procedure (i.e. information to EEM contractors). EEM contractors (firms) provided training to other EEM contractors. Both firms and institutions were connected to the knowledge infrastructure mechanism within the region to gain EEM information and further EEM understanding. • The LA energy team had both formal roles (e.g. establishing energy targets and training) and informal roles (e.g. having irregular meetings and discussions) with other actors in the region.
RIS mechanisms	• Learning is vital within the RIS to encourage regional innovation. • Both learning and knowledge production are significant to regional innovation. • The type of knowledge produced and transferred within the RIS plays a role within the innovation system. • Both physical and spatial proximity are of equal importance to the RIS and regional innovation.	• Interactive learning (effectively) is key to enhance innovation within the region. • The combination of interactive learning and knowledge production are essential to promote and enhance regional innovation. • Explicit knowledge is of greater benefit to learning within the RIS and plays a significant role to regional innovation. • Spatial proximity, as oppose to physical proximity, is dominant within the RIS and plays a vital role towards regional innovation.	• The investigation evidenced the need for actors / actor groups within the region to learn interactively, i.e. communication or interactions in order to understand the EEM information. The school end-users, for example, required an explanation of the EEM and its use following the installation. Either the EEM contractors or LA energy team were required to explain the EEM. In the cases where no or little EEM information was given, many projects evidenced issues with the adopted EEM. • Interactive learning was important within the RIS and region (as mentioned above) for the delivery of LZC buildings, but learning primarily was associated with information (i.e. gaining EEM information). The investigation highlighted the production of knowledge was required to understand the EEM. The LA energy assistant, for example, required learning around the EEM process (e.g. knowledge of payback periods and costings), but also required knowledge to understand how to actually apply these procedures within a project. All five school retrofit projects emphasised the effects of both the interactive learning and knowledge production mechanisms for innovation. • In each school retrofit project where the EEM had been adopted and explained by either the local authority or EEM contractors, there was greater success in terms of the school end-users understanding and being able to control the EEM settings. Hence, less resistance by the school end-users for the use of the EEM and greater possibility of energy reduction within the building. • The investigation highlighted the strong relationships between regional actors / actor groups. Interactions and communication was made via emails, phone calls, formal and informal meetings, and posted documentation. Regardless of the physical proximity, due to evidence of a number of EEM contractors being located outside of the region, actor / actor group interactions and regional innovation did not appear to be affected.

In terms of the skills required for the delivery of LZC buildings within the region, and further links to the RIS and its components, the investigation evidenced a range of skills for various actors / actor groups throughout the framework (see figure 10.2 and table 10.6 below). There were a number of dominant skills, however, that were essential to the RIS for its development and innovative potential.

First, and most central to the RIS framework (i.e. key to a number of actors / actor groups), were ‘communication skills.’ The occurrence of communication skills, more specifically effective communication, was essential for actors / actor groups to interact and further build social relationships. The need for communication skills was prevalent within the interactive learning mechanism, where meetings, informal conversations and documentation exchange were the most common forms for interaction, and further learning between firms and institutions (dominant to the knowledge infrastructure element). Communication skills were also required for knowledge production to occur within the RIS (closely connected to interactive learning), and spatial proximity, for the building of relationships and establishing a ‘connectedness’ (as referred to in the RIS literature) between actors / actor groups, both internal and external to the region.

Second, ‘project management skills’ were required by both the LA energy team (LA energy officer) and school end-users (school site controller) for the decisions surrounding the EEM contractors. The choice and evaluation of the suitable EEM contractors concerned the cost, availability and previous experience associated with the EEM contractor. The LA energy officer required project management skills throughout all stages of the project, in order to choose the appropriate EEM contractor, organise the cost, procedures during the design and implementation stage, and manage the firms following implementation (i.e. EEM documentation handover stage). The school site controller required project management skills primarily during the planning stage of the project.

Third, the presence of ‘energy management skills’ to components, such as the knowledge production mechanism, was essential to understand and use the knowledge produced. This finding links to the RIS and management of knowledge literature that emphasises the need to understand the knowledge produced. The firms and institutions of the RIS can transfer knowledge between one to another. However, if the recipient does not understand how to use the knowledge (e.g. the EEM use within the LZC building), innovation may not occur or be successful. Similarly, energy management skills were linked to the interaction between institutions and policy-orientated regional innovation. There was a fundamental need for the local authority to understand the energy reduction targets (as stated within the Carbon Management Plan and Sustainable Strategy document), implement an appropriate EEM to reduce carbon emissions within the region, have a form of knowledge around energy reduction techniques and understand the EEM funding process.

Finally, 'technical skills' ('electrical,' 'previous EEM experience' and 'knowledge of the EEM') were linked to the knowledge infrastructure element. In order for training to occur by actors / actor groups, specifically by the EEM contractors (e.g. EEM suppliers to EEM installers), knowledge associated with a technical nature was required. An understanding around a specific trade (such as technical electrical knowledge), for example, and knowledge of the EEM functions, were present during EEM contractor training. Furthermore, there was also an association with communication skills required for the RIS element knowledge infrastructure to develop innovation within the region. The transfer of knowledge, and understanding around the EEM during training and workshops, evidenced the requirement of effective communication between actors / actor groups.

As shown in figure 10.2 and table 10.6 (below), the key skills required for the delivery of LZC buildings were widespread within the RIS and relate to a number of RIS components. What is interesting is the combination of different skills brought into play within the RIS components and the dominance of communication skills.

10.3.3 The concept of a region

During the application of the RIS framework, the concept of a region, how it compares to surrounding areas (clusters, territories and districts) and what it consists of, requires a form of understanding (Cooke et al. 1997, Doloreux 2002, Asheim and Coenen 2005). The research identifies with the idea that a region can be defined by its distinct characteristics (governance and physical characteristics), but further supports the concept that there can be non-physical dimensions of a region (Doloreux 2002). The application of a RIS framework identified a RIS that spanned outside of the physical regional boundary, capturing unique relationships, social interactions and cultural commonalities between actors / actor groups within and surrounding the region. This idea that physical boundaries have little effect on regional interactions corresponds to the findings of the mechanism physical proximity, and the definition of a region that incorporates both the tangible and the intangible regional characteristics (see table 10.5 for further detail on RIS elements and mechanisms).

Table 10.6: the skills required for the delivery of LZC buildings within the adapted RIS framework

Element / mechanism interaction	Skills required	Explanation of the required skills	Empirical evidence for the required skills
Policy-orientated regional innovation / institutions	Energy management skills	• Energy management skills required by policy-orientated regional innovation and institutions (elements), in order to understand the pressures to reduce energy reduction and carbon dioxide emission targets within the region.	• Energy management skills required by the LA energy team (institutions) to understand the policy pressures (UK and regional), such as the energy reduction and carbon dioxide emission targets for the region. The LA energy officer, for example, required energy management skills to understand how to comply with targets stated in the Carbon Management Plan and Sustainable Strategy for the region, and further understand the more suitable methods for building energy reduction and appropriate EEM for the school buildings.
Institutions / firms	Project management skills	• Project management skills required by institutions and firms (elements), particularly during the initial planning stage of the projects, in order to organise the project (labour and material resources), plan for the duration of the building retrofit.	• Project management skills required by the LA energy team (institutions) to organise the school retrofit projects throughout all stages of the project. The planning of the appropriate EEM for adoption and hiring of EEM contractors (firms), for instance. • Project management skills required by the school end-users (institutions) in projects where the school site controller had the responsibility, and knowledge, to decide the most suitable EEM contractors (firms) for the EEM adoption.
Firms / knowledge infrastructure	Communication skills Technical skills	• Communication skills required through the interaction by firms and knowledge infrastructure (elements), in order to gain project information and knowledge of the EEM. • Technical skills required during the interaction by firms and knowledge infrastructure (elements) (e.g. the attendance of training centres) to understand the EEM.	• Communication skills required by the EEM contractors (firms) to arrange and interact with EEM assessors and trainers (knowledge infrastructure), and further communicate in order to gain information around the EEM. The need for communication skills was evidenced within the training academy (school project 2 and training events stated in interviews). • Technical skills required by EEM contractors (firms) during the attendance of training sessions to understand (not solely gain knowledge) the EEM for adoption, methods of EEM implementation and the processes involved in the post-completion stage.
Institutions / knowledge infrastructure	Communication skills Technical skills	• Communication skills required through the interaction by institutions and knowledge infrastructure (elements), in order to gain information of the project process. • Technical skills required through the interaction by institutions and knowledge infrastructure (elements), in order to understand the process of EEM adoption and potential EEM challenges.	• Communication skills required by the LA energy team (institutions) to interact, and gain information for the project and EEM available for adoption, which was provided by training bodies, funding bodies and universities. • Communication skills required by the school end-users (institutions) to interact with the LA energy team (knowledge infrastructure) and gain information on the EEM selection process, payback periods and dates / times of installation. • Technical skills required by the LA energy team, primarily the LA energy assistant attending EEM courses (training bodies) and training with the LA energy officer, to understand the energy auditing process and the EEM characteristics.
Spatial proximity / interactive learning	Communication skills	• Communication skills required for actors to interact and learn within the RIS. The ability to interact, learn from each other a build relationships within the RIS, enhances the spatial proximity. Interactive learning can take many forms of communication (e.g. informal conversation and email)	• Communication, and the need to communicate effectively during learning, was seen throughout all five school retrofit projects. Many instances where the LA energy team were communicating with the school end-users (primarily head teacher and finance manager) and learning around the EEM process (e.g. how to use the EEM and dates for installation), the spatial proximity (relationships, connectedness) was enhanced between the actors / actor groups.
Interactive learning / knowledge production	Communication skills Energy management skills	• Communication skills (effective communication) required for actors to interact, negotiate and build relationships, in order to gain knowledge from each other regarding project information. • Energy management skills needed in order to gain knowledge of the EEM adopted within the school retrofit projects. Knowledge can be generated through interactions, but energy management skills are required to be able to understand and use this knowledge surrounding the EEM.	• Communication skills required for the LA energy team, the EEM contractors and school end-users to interact, learn and gain knowledge was evident during project meetings (LA energy team / school staff and pupils), through the exchange of emails / informal conversations to gain knowledge on the project progress, EEM process and post-completion advice. • Energy management skills required for the LA energy team and the EEM contractors during the energy auditing process (LA energy officer / LA energy assistant) to gain knowledge of the EEM (e.g. how the EEM will reduce energy, the costings and challenges), and the process of EEM adoption.

10.4 Contribution to skills theory

The research findings can shed further light in connection to the research problem surrounding the rhetoric of the need for 'new skills' for the delivery of LZC buildings (Construction Skills 2010, Home Building Skills 2010), and further discussions for specific 'green skills' (SDC 2010, Energy UK 2014) and 'low carbon skills' (RIBA 2008, Jagger et al. 2012) for the construction sector and its clients. The prevailing construction skills literature offered vague descriptions of what the new skills actually consisted of due to undefined terms, little empirical evidence to support the proposal of the skills, and lack of clarity regarding any contrast between new skills, green skills and low carbon skills.

The key findings captured the need for specific skills / skill sets, for both the construction sector and its clients, for the delivery of LZC buildings within the region. The dominant skills required were associated with specific job roles of the key actor groups (the local authority, the EEM contractors and school end-users of the LZC buildings) involved in the development and the implementation of the projects. The required 'project management skills' highlighted this link between the actor / actor group roles and the skills, where project management skills differed between a LA energy officer and school site controller. The use of project management skills for the LA energy officer further supported the literature in terms of the close connection with required 'communication skills' (Dainty et al. 2005b) during the delivery of the LZC buildings. The LA energy officer, for example, needed communication skills, and to understand the type of information to provide different actors / actor groups involved in the project (i.e. 'effective communication' and 'active listening' evident) (Fisher 2011, Janthon et al. 2015), and further fulfil the project manager role. A similar situation was highlighted for the school site controller, where communication skills and project management skills were required in combination (i.e. a skill set). The findings, however, revealed a greater focus on the initial planning stage for this actor and agrees with the current literature on the importance of this stage for a project manager (Edum-Fotwe and McCaffer 2000). The research findings (all five LZC building projects) have drawn attention to the requirement for project management skills and communication skills, but also a number of other key skills for the delivery of a project (see tables 9.1 and 10.1). Project management skills and communication skills were essential to actors / actor groups during the school retrofit projects. However, other skills such as 'energy management skills' and 'technical skills,' were also necessary for the construction sector and its clients to deliver the LZC buildings. Furthermore, similar to previous investigations (Briscoe et al. 2001), there was evidence for the possibility of 'specialist skills' within project management skills. As these specialist skills differed within each project (i.e. due to the EEM adopted and the building structure), similar to the prevailing literature (Dainty et al. 2005a), the complexity of the project manager roles and associated skills was highlighted. To offer further insight into the actor / actor groups' understanding of the required skills, empirical evidence captured actor meanings of the required skills and was able to define the specific skills (see table 10.2).

The findings revealed little reference to the terms green skills or low carbon skills by those involved in the delivery of the projects. Despite this, the case study did provide insight for the need and type of new skills required to deliver LZC buildings. In agreement with the literature, the new skills required within the investigation were associated with the use of more advanced equipment, such as the EEM adopted within the building projects (HM Government 2010), and also the ability to use tools required for EEM implementation (Construction Skills 2010, Home Building Skills 2013a). These key skills were energy management skills and technical skills by the construction sector and its clients. Furthermore, reiterating the idea within the construction skills literature (Home Building Skills 2013a), both energy management skills and technical skills were not solely consisting of new skills for the construction sector and its clients, but a combination of new and existing skills needed for the delivery of LZC buildings within the region. The findings suggested the required new skills were related to the need for knowledge surrounding the technology, while existing skills were required in order to apply this knowledge. The fundamental need for existing skills to understand how to integrate the EEM, especially for the EEM contractors implementing the technology, cannot be stressed enough. The need for both new and existing skills for LZC buildings is touched upon within the literature, but the importance of actually understanding the skills and the knowledge of how to apply them is not emphasised enough. In support of this finding, the management of knowledge literature offers insight on how to manage knowledge following its production (see section 9.4). It would be valuable, however, for the skills literature to emphasise the type of existing skills required for LZC buildings, the importance of understanding of these skills and how to apply them to the EEM adopted.

Furthermore, it is of benefit to highlight the complexity within the current skills literature due to the range of terms used. The EEM adopted with the case study, which included both fabric and technology measures, are referred to within the literature and known as 'renewable technology' (Aldersgate Group 2009), 'advanced technology' (Xu et al. 2015) or 'LZC technology' (Killip 2008). There is a need to draw attention to the different types of EEM terms that can be used to highlight the range of EEM that can be implemented, and further complexity of the required skills. A number of the above terms for the EEM adopted were also evident within actor / actor group conversations during the delivery of the school retrofit projects. The majority of terms were used interchangeably within the investigation, but appeared to refer to the advanced technology being adopted within the building (i.e. referring to the same EEM adopted).

In regards to implications or challenges associated with the required skills for the delivery of LZC buildings, empirical evidence highlighted the necessity of skill development, more specifically the guidance / education for new skills associated with the implementation and use of technology within the buildings. To facilitate decisions associated with the development of required skills, and the possible constraints on resources, the research separated both primary skills and secondary skills needed for the construction sector and its clients, primary skill development being of most benefit to the delivery of the building projects (see table 10.1). Primary skills being those that were most valuable and recommended as urgent in terms of gaining the skills through training. Whereas secondary skills were those that were still important to actors / actor groups during the school retrofit projects, but did not appear as crucial during the stages of project delivery (i.e. less urgent in terms of training). As highlighted previously, the research understands the generalisation of primary and secondary skills cannot be applied to every LZC building in terms of its retrofit, but aids this investigation in terms of emphasising the key skills required for each actor group. The classification of primary and secondary skills, for example, may mitigate problems and ease decisions for the local authority when allocating further education, training courses and localised learning within the region.

10.5 Implications for policy practice

The adapted RIS framework identifies, describes and explains what is required for innovation within a region, and provides indication of the actions that can aid the delivery of LZC buildings within a region. It would be of benefit to the local authority (Wokingham Borough Council) to adopt RIS thinking within its transition plan. The LA policies, such as the local emission reduction targets (15% by 2015 and 40% by 2020), the LA Sustainable Environment Strategy and the Carbon Management Plan, having such an influence to drive energy reduction and deliver LZC buildings within the region, can be directed in line with the RIS framework. The challenge for the region is the management of the RIS framework. The RIS literature, and enhanced understanding by the empirical findings, describe and explain the requirements to predict the innovativeness of the region. The issues, more specifically for the local authority, may surround how the LA energy team manage and use the framework (such as encourage interactive learning and mobilise interactions within the region) to design, implement and further monitor interventions within the RIS. Furthermore, as mentioned previously (see section 10.4 above), one of the challenges associated with the delivery of LZC buildings were the required skills, specifically the development of new skills for the construction sector and its clients. The research has identified the key skills that are required, specifically the primary skills if training and education should be available. Implications for the local authority can be created by policy pressures, such as the

Localism Act (DCLG 2011) and sustainable community demands (Egan 2004, SDC 2010). The pressures relate to the sourcing of labour and materials within the region, supporting local businesses (DCLG 2011, LGA 2013a), and the consideration of employment and skill enhancement at local (SDC 2010) and community levels (Dixon 2011). Potential conflicting interests of policy demands for the local authority were demonstrated within the key results, which presented the majority of the LZC building project networks to span outside of the region. The challenges surround how the local authority can develop the required skills for the delivery of LZC buildings within the region, but also take into account the demand and interests at local and regional levels.

10.6 Implications for methodology

The RIS concept can still be referred to as new or in its 'embryonic state' (Doloreux 2002), where few discussions and research on the topic of RIS contributes to the framework through empirical evidence. Furthermore, where the RIS framework has been applied and tested, much of the work focuses on distinct or unique regions (i.e. few suggestions or findings can be applied to regional areas with similar characteristics), or those regions that were already be deemed successful (Doloreux 2003).

The RIS framework gave guidance for the identification of a region (see section 1.1 for a region definition), the key RIS characteristics and components contributing to innovation within the region (see section 2.5.2) and further support for the analysis of the data (see section 3.8 for an explanation of the use of the RIS framework during data analysis). The limitations of the RIS framework centred around insufficient information regarding the boundaries of the regional network and the requirement of further detail connected to the inclusion / exclusion of RIS components, which were both addressed through the application of the socio-technical network analysis (STNA) (see section 3.4 for further detail). The STNA mobilised the investigation through the application of a socio-technical network (STN) surrounding the LZC building projects and ensured this was the focus of the investigation. The STN provided guidance of how the RIS framework applies within an empirical setting (i.e. how RIS components act and evolve within the region), how to conduct data collection surrounding the case study, and further aided the analysis of the data collection by highlighting actor interests and negotiations. By combining both the RIS framework and STNA methodology, as opposed to using either in isolation, the weaknesses of each approach were addressed, and a greater understanding of the investigation was achieved.

10.7 Limitations and areas for future research

The research involved a single case study approach (i.e. a regional local authority) and five cases (five school retrofit projects) located within the region. The limitations of this study surround the investigation solely on one local authority and one region, where both can be modified for areas of future research. First, it would be valuable to investigate the delivery of LZC buildings within a region with the focus on a different local authority. Additional insights towards the potential diversity amongst local authorities, the regional and surrounding (RIS) networks, and approaches within the local authority region, would be of benefit to possibly extend research findings. The investigation involving another local authority may provide information on distinct policy drivers and the approaches taken by the local authority to meet requirements, specific local authority procedures and further use of resources, which can all contribute to the delivery of LZC buildings within the region. The local authority under investigation were required to reduce carbon emissions by 15% by 2020 and 40% by 2050, employ local contractors where possible and use the local authority preferred suppliers. Other local authorities may be required to comply with individual, and perhaps contrasting, regional emission reduction targets and unique local authority strategies. The potential variation of regional policies, local authority targets and procedures in place, may highlight different approaches for the local authority, and region, to reducing building energy demand, identifying a variation of LZC building delivery challenges and possibly diverse skill sets required.

Second, the study of a different regional area, or research that combines the study of two different regions (i.e. contrasting regional characteristics), would be of interest to expand details and concepts within the RIS framework. The region selected for the research was guided by the definition of a region, but had distinct characteristics to those of the surrounding five regions (see section 3.6.1). Investigations consisting of regions that have both similar and diverse characteristics and RIS components to that of the case study would be advantageous. There may be the opportunity to support or add to the current findings associated with the region of Wokingham. Also, regions investigated that have different characteristics may have contrasting findings to that of this research / case study. Due to possible effects of varied characteristics on regional innovation, as suggested by the RIS framework, different influences towards the innovativeness of that region (and possibly surrounding regions) may be experienced. As mentioned previously, further empirical work engaging with the application of the RIS framework is required (Doloreux 2002, Doloreux 2003). It would be of value to investigate the skills needed to deliver LZC buildings within regions of different components to that of the case study. In relation to the findings from the research investigation, further elaboration involving research surrounding the variation of possible RIS elements (e.g. firms and policy orientated regional innovation) would be beneficial.

In connection to regional characteristics, the investigation involved case studies of school retrofit buildings. This was due to the timing and resources available to the research. The local authority were enthusiastic towards a collaboration for the local energy scheme school projects, willing to provide access and working on the initial phases of the school energy reduction and retrofit programmes, during the time of data collection. Future research may look to investigate housing, how this change to the unit of analysis affects the regional network, and possible challenges and skills required by the construction sector and its clients to deliver LZC housing within the region. Similarly, a reduction to energy consumption in commercial buildings within a region may support the findings surrounding the skills required for LZC buildings within the investigation, add to the knowledge of skills needed from this research, or enhance current research by extending to a different building type.

In regards to the RIS framework findings, as mentioned previously, the challenge for the local authority is the management of the framework. The empirical evidence elaborates further on the RIS literature, providing not only the description of RIS characteristics, but enhancing the explanations of interactions to predict innovation within a region. It would be of value to investigate how the local authority can use the adapted framework to enhance the innovativeness of the region.

Moreover, the complexity surrounding the required skills for the delivery of LZC buildings was emphasised within the research. There were challenges in terms of the variations in required skills for different actor groups and job roles (see section 9.3.2), the initial difficulty in identifying the skills to deliver LZC buildings and the need to develop these required skills (see section 9.7). One of the recurring skill issues, for example, centred on an understanding and knowledge of the adopted EEM. In terms of skill development, the research evidenced an initial interest and desire by actors / actor groups to invest in the development or further enhance required skills surrounding the projects. Furthermore, key actors / actor groups within the network, primarily the local authority and EEM suppliers, demonstrated roles towards skill enhancement through learning and knowledge production during the delivery of LZC buildings within the region. Due to time constraints and the scope set out for the investigation, the research was unable to determine the potential for skill development in relation to those skill sets required for actor / actor groups involved in the projects. It would be of benefit to add further detail to the challenges surrounding skill development for the actors / actor groups within the region. Additional insights towards the most effective type of skill development, appropriate methods to promote learning and further engage those involved within the regional projects, would be most valuable to extend the investigation and contribute to further work. This future research will build upon the research findings and potentially provide insights regarding a suitable means of learning for each actor group (i.e. internal learning, external courses or EEM contractor workshops).

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Appendix A: initial meetings held with the LA energy officer to discuss a potential collaboration

Date / time / location	**Meeting / present**	**Key points**	**Further discussions / comments / outcomes**
15.07.13 10am at the local authority (LA) offices	• LA energy officer • Researcher	• Introductions and information about the University of Reading and School of Construction Management and Engineering. • Conversations surrounding the potential of a collaboration with the local authority and the projects they are involved in.	• Three projects the local authority are interested in: energy company obligation (ECO), collective switching and local energy schemes.
07.08.13 10.30am at the University of Reading	• LA energy officer • Researcher • Primary supervisor • Secondary supervisor	• What the research investigation consists, i.e. what the research is looking to find out, aims / objectives. • How can the collaboration be of benefit to the local authority. • The possible data collection options (observations, interviews and a review of relevant local authority documentation). The next steps to collecting data and how.	• The ECO project and local energy schemes are of interest. Either one project or a combination of them both.

Appendix B: brief given to the local authority to propose a research collaboration

Request for research collaboration with Wokingham Borough Council and the University of Reading

Introduction

The School of Construction Management and Engineering is undertaking a programme of research on various aspects of sustainability in the built environment. One aspect of this research is a PhD study by Whitney Bevan (under the supervision of Dr Shu-Ling Lu and Prof. Martin Sexton) on the role that regional innovation systems (RISs) have in the transition to sustainable environments.

Wokingham Borough Council's 'Sustainable Environment Strategy: 2010-2020' sets out an action plan to promote and implement energy conservation, energy efficiency measures, renewable energy technology, and a reduction of fuel poverty within the region. This strategy is closely linked to the Carbon Management Plan, also adopted by Wokingham Borough Council. At a meeting on 15th July between the energy officer (Wokingham Borough Council) and Whitney Bevan (University of Reading), the low carbon projects identified below were viewed as possible areas for research collaboration:

- **Energy Company Obligation (ECO) Project** - aims to support energy efficiency, energy saving measures and the possibility of the implementation of renewable energy technologies within housing in Wokingham.
- **Collective Switching** – aims to encourage residents of Wokingham (approx. 157,000) to switch energy supplier for a cheaper tariff and implement energy efficiency measures (guided by energy suppliers), reducing fuel poverty in the area. This is a partnership involving other local authorities.
- **Local energy schemes** – aims to promote energy efficiency and renewable energy technologies within public properties (such as schools, libraries). In addition, there is an emphasis on the social elements of the projects, for example, reducing employment within the area and up-skilling / re-skilling of residents. An example of this was the Local Authority Pioneers project which involves working with a nearby council.

Regional innovation systems and a transition through low carbon projects

- The regional innovation system (RIS) recognises the importance of geographical location for knowledge generation and innovation. The RISs understand that innovation is a localised phenomenon that is highly dependent on physical and human resources, which are location specific and impossible to reproduce elsewhere.
- This doctoral research is interested in connecting and understanding how RISs can best support Wokingham - a transition to sustainable environments with a particular focus on energy. There is scope for investigating how transition pathways are translated into low carbon projects (such as the ECO project, Collective Switching and local energy schemes); and, how these projects are translated and implemented into practice.

Objectives

1. Understand the principal interests and expectations of key stakeholders (e.g. Wokingham Borough Council) involved in the various low carbon projects.
2. Understand the drivers / enablers and barriers of Wokingham Borough Council for the development and implementation of the proposed low carbon projects.
3. Understand current and/or potential challenges that Wokingham Borough Council encounter from within and around the Wokingham region when proposing and developing low carbon projects.
4. Understand the role of low carbon projects and the ways in which they support the delivery of sustainable environments within Wokingham.

Information gathering approach

- Interviews and potential focus groups with individuals and organisations who are involved in discussions around the development and implementation of low carbon strategies and projects (e.g. energy and planning teams at Wokingham Borough Council).
- Observations of meetings and workshops where relevant low carbon projects are discussed.
- Review of relevant documentation, e.g. reports, meeting minutes.

Time

- One year beginning summer 2013.

Outputs

- Reports on the research findings (challenges, enablers / drivers, barriers and recommendations for Wokingham Borough Council).
- An account of 'good practice' for the various projects identified within Wokingham Borough Council (potential application to other local authorities employing similar schemes).

Reference

WBC: Working Borough Council (2010), Sustainable Environment Strategy: 2010-2020, Wokingham, Berkshire.

Appendix C: brief given to the local authority to explain the proposed focus of the investigation

Research collaboration proposal between Wokingham Borough Council and the University of Reading: Local energy schemes

The aim of this project

Local energy schemes were identified as potential projects for research collaboration at the 7th August meeting between the energy officer (Wokingham Borough Council), and Whitney Bevan, Dr Shu-Ling Lu and Prof. Martin Sexton (University of Reading). Local energy schemes are on-going projects by Wokingham Borough Council that aim to promote energy efficiency, energy conservation and renewable energy technologies within public properties (such as schools and libraries) in Wokingham. In addition to a focus on energy, there is an emphasis on the social elements of these schemes, such as a reduction in unemployment within Wokingham and up-skilling / re-skilling of local residents. Education (lessons on looking after the environment, renewable technology demonstrations) within the schools involved in the energy schemes (to staff and pupils) is also an aim of Wokingham Borough Council. Previous installation of energy schemes include the upgrading of lighting and insulation in local schools, and renewable technologies.

This aim of this collaborative research is to understand how Wokingham Borough Council (WBC) uses the local energy schemes within public buildings to generate and sustain the capabilities and technologies to deliver low and zero carbon buildings in Wokingham. The investigation is looking to study 3-5 local energy schemes, possibly 2 previous completed schemes and 3 on-going projects (schools and / or libraries). The objectives below relate to data collection for both completed and on-going projects.

Project objectives and information gathering approaches

Project objectives	Information gathering approaches
Identify key stakeholders involved in the local energy projects (e.g. Wokingham Borough Council energy team, funding organisations).	• Observation of local energy project meetings. • Review of relevant documentation (e.g. The Carbon Trust recommendations and funding advice).
Identify and understand the interests and expectations of key stakeholders of the local energy schemes.	• Interviews with key stakeholders. • Observation of local energy project meetings.
Understand the drivers / enablers for Wokingham Borough Council for the development and implementation of both the on-going and completed local energy schemes.	• Interviews with the energy team at Wokingham Borough Council. • Review of relevant documentation (e.g. WBC environmental strategy information).
Understand current and potential challenges that Wokingham Borough Council encounter from within and around the Wokingham region when developing and implementing local energy schemes.	• Observation of local energy project meetings • Observation of on-site work by the project team (implementation of insulation, lighting etc.) to deliver the local energy schemes. • Review of relevant documentation (e.g. energy audits).

Deliverables for Wokingham Borough Council

- General finding report. Reports on challenges, enablers, barriers and recommendations for the development and the implementation of the local energy schemes investigated.
- Lessons learnt report. Reports on the issues experienced during the planning, development and implementation of the local energy schemes and possible solutions that can be replicated for future schemes and low carbon projects.

Appendix D: interview protocol

University of Reading

An investigation of the skills required to deliver low and zero carbon buildings

INTRODUCTION

The aim of the interview is to investigate the skills required during the development and implementation of the low carbon building projects (e.g. schools) by Wokingham Borough Council.

The interview will consist of the following sections with discussions surrounding the relevant topics:

Section 1 aims to collect background information about you, such as past experience and your job role.

Section 2 aims to discuss relevant information surrounding the low carbon building project and your involvement. This section will further seek to gain an insight into your experience and knowledge surrounding the skills required for the project.

Section 3 is designed to offer you an opportunity to discuss your ideas or issues concerning the interview, or comment on further topics that may be relevant to the research investigation.

SECTION 1: Background

- Can you briefly describe your career history?
- Can you briefly describe your current employment and job role?
- What are your thoughts of the term low carbon buildings?
- Have you been involved in previous low carbon building projects? If so can you tell me a little about them?
- Do you have a personal interest in low carbon buildings? Do you, for example, have any energy saving measures in your home?
- Are you aware of the current requirements surrounding low carbon buildings? Have the requirements had an impact on previous projects you have been involved in?

SECTION 2: The low carbon building project

A. About the low carbon building project

- How did this project come about? How did you become involved in the project? At what stage did you become involved in the project?
- What is your involvement / role within the project?
- Who do you communicate with regarding the project?
- What were the drivers for the delivery of the project i.e. what was the motivation, if any, for the implementation of energy saving measures applied to the project?
- Were there any specific requirements for the development and implementation of the project? If so, can you give me examples please?
  Did you make any decisions regarding the energy saving measures implemented for the project? If so, can you give me an example please? Who else was involved in this decision?

B. Skills required for the low carbon building project

- What skills are required / do you need for your role within the low carbon building project? Can you give me examples please?
- Are the skills specific to this project or have you applied them to previous projects? If you have applied the skills to previous projects, were they low carbon building projects?
- If specific skills were required, how did you know which skills were needed and how did you develop the skills? Was there any support for you to develop the skills?
- Did you experience any challenges during the development and implementation of energy saving measures for the project? Were any of these challenges associated with skills? How were they resolved?
- Are there any specific skills (or perhaps new skills) you have gained during this project that are relevant or can be applied to upcoming low carbon building projects?
- Do you think the skills required for low carbon buildings may change in the future, if so can you give me an example of how? What do you think are the challenges, if any, to obtain these skills?

SECTION 3: Reflect on the interview and close

- Do you think there will be changes to buildings in the future (during the next 5 years perhaps) in terms of developing low carbon buildings? If so, can you give me an example of the type of changes that may be introduced?
- Do you think any of the changes to building requirements will influence your job role or your business? If so, how do you think they will influence your role or business?
- Are there any ideas or issues you would like to discuss regarding the interview?
- Do you have any questions regarding the interview or research project?

Thank you very much for the interview and your co-operation with the research project. A transcript is available on request. If you have any further questions please do not hesitate to contact me.

Appendix E: an example of an anonymised semi-structured interview

Interview SU11

SU11 is a contractor hired by LA11 to do an initial survey for insulation works of seventy plus schools within the region. EO11 then decides which of 3 contractors is hired to carry out the insulation work. SU11 has carried out the insulation work on a school [unsure of the school] and going to do school project 1 in the near future, but SU11 has surveyed all 5 school projects initially. SU11 has his own small business (EC11), where contractors will be hired for the larger / more complex projects.

WB: Can you start by telling my about your involvement with the School project 1 project please?

SU: OK, well it all initially came about with EO11, he found my web page- which is all about property assessment, data capture and basic assessment for energy saving measures. So insulation measures, solar install.

WB: This is what your company does, insulation, solar PV…

SU: It's a small company, sole trader company and it was set up as just myself really, to go out and asses buildings and report back on what needs to be done. So the initial work that EO11 had was exactly that, a list of 70 odd schools that he needed cavity wall and loft insulation measurements.

WB: So EO11 specifically said cavity wall or loft insulation?

SU: Yes that specific

WB: But do you as a company offer a number of things I may refer to as low carbon.

SU: Yes of course, carbon saving measures.

WB: Is that what you refer to them as, carbon saving measures?

SU: Yes I would call them carbon saving measures yes. There is an awful lot of tie in's there with FIT's things like that, but in essence its carbon saving measures.

WB: As we are talking about topics and definitions, I will come back to your job role, I say low carbon buildings. Do you have a definition for that or do you say low carbon measures?

SU: Sorry I don't know what you mean.

WB: I use the term low carbon buildings. Do you come across that term day-to-day or do you use a different term?

SU: I'm aware of what you mean by low carbon buildings, but what you have to appreciate is everything I go and look at certainly isn't. It's a very very high carbon building. And the idea is we look to give recommendations to reduce that really. The thing I guess you have to appreciate is you are coming from it from an academic stamp. I look at beat up old buildings and go back and recommend methods to improve them. And again I can tell you are coming at this from a really different angle to me.

WB: Do you think there are such things as low carbon buildings? Can there be?

SU: Well certainly lower carbon buildings.

WB: and that is what you do?

SU: Yes that is exactly what I do. I don't get involved in new build stuff. What I do is retrofit, basic nuts and bolts, carbon saving measures. There is nothing technical about what I do. The only technical bit about what I do is finding ways to do it safely. So, the hardest thing that I find, certainly with things like loft insulation and certain panel installs for that matter, the hardest thing is being able to get physical bodies in place safely to do the work, that's the hardest bit about what I do. It is dead easy, you could walk into a room and say it needs a heat pump, a biomass boiler would fit in there, insulation is needed. That's very easy because its very obvious. The general run of the mill stuff I don't tend to get involved with anyway because there are better people out there. For instance, you have 300 houses to insulate the loft. Now that's not really my bag cause there are insulation contractors out there, who, to be fair don't really give a monkeys, they'll bang a load of insulation and make everyone all happy. What I tend to do, and it's a niche really, what I tend to do is stuff that bigger contractors don't want to do cause it's unsafe, or not worth their while to go do it. So they tend to ignore it, push it to one side and go in and go look for the easy stuff.

WB: OK so you might have different challenges than the everyday insulation contractor I might talk to then?

SU: Yes

WB: So your biggest challenge is health and safety?

SU: Very much so yes, certainly when we are working at a height. Day to day, visiting sites, doing assessments for various sites, it's easy and generally on the ground. The most difficult thing you have to do is drill a hole in the wall, but when you come to fitting the stuff, that brings challenges all on its own.

WB: Can you give me an example of when you get out there and this challenge, or with the schools maybe, what were your biggest challenges doing some of the measures?

SU: This school, and the name of it escapes me, it's a very unusual, bearing in mind out of the 70 schools I assessed, I only quoted for works on two of them. The rest of it went to big contractor, cause there was nice easy lofts.

WB: So one was School project 1?

SU: Yes one of them was School project 1, the issue there was the suspended ceiling. It has to come down partially to enable you to fit the insulation, before the suspended ceiling is reinstated again. It's not really any health and safety issues there really with it that one. The only real issue is the wiring and lighting you have to be careful of when you are installing the works. But, the reason I quoted that got like that, and I have to talk to EO11 about that, either the quotes from the main contractors were either declining it or they were quoting it so outrageously high because they didn't want the work.

WB: Yes so they knew it was difficult.

SU: Yes exactly.

WB: That difficulty with the wiring and suspended ceiling was that specific to it being low carbon or perhaps just to do with the building?

SU: Just to do with the building, I don't find low carbon issues. The only issue I ever have is finding a way of fitting the low carbon measure. I don't…I'm trying to work out the angle of where you are coming from.

WB: What I am trying to ask in terms of skills, is are the skills and challenges around low carbon buildings or as it seems in your work, just issues with buildings?

SU: Yes I could just as easily be replacing tiles on a roof or digging up someone's patio. None of these challenges are low carbon specific, they are building fabric challenges.

WB: So the wiring and lighting was the issue in School project 1?

SU: The wiring and lighting and the fact that the job required some… wiring and lighting, a normal MC21 would have been aware of it and they would have done exactly the same as I did, would have left insulation out around any heat generating and lighting appliances things like that. To stand a 75 mil gap you have to leave around appliances, they would have been fine with that. The issue there is, what you've got is a bunch of monkeys who want to get the job done as quickly as possible and get home as quickly as possible. For School project 1 you can't approach it like that cause to partially remove a suspended ceiling and reinstate it is something that takes a little bit of time and care. No great level of skill, you have to just approach it with a slightly different mindset.

WB: So it is the time...what about accuracy, would a skill say you having to be more accurate?

SU: I think you are reading more into it than you need to.

WB: What do you think your general skills that you need are?

SU: Do you know what the biggest thing, the biggest thing is that I do a proper job. That's the biggest thing. I don't approach…when I quote a job I sit down and I work out any material involvement and I and work out how long it's going to take to do it properly. I quote it accordingly and I either get it or I don't, and if someone comes back and says SU11 you're a little bit high there, I say go get a monkey to do it then, no problem at all.

WB: I can tell just by observing you, you are thorough.

SU: You have to be cause the problem is if you're not you end up doing a poor job, and for someone like myself who works on his own, and I don't have a multi-national company to hide behind. Firstly, the vast majority of my work is referral, so I live and die on the quality of my last job – all the time, all the time. And secondly, I can't afford to be revisiting stuff to put right something right that wasn't done properly in the first place. So, I wish I could say I was magic and have skill sets that no one else has, but I don't. It's just about being thorough careful and conscientious.

WB: For me those are skills in itself?

SU: Maybe, maybe yes. The other skills I have are no more or less than others in the industry.

WB: What would you call your jobs role? You are the manager of your company.

SU: Cor blimey, yes technically I am the owner of my company. What is my role? It depends on what I am doing, I can be site supervisor, sub-contractor supervisor, I can be energy assessor, I can't wear one hat. I have done in the past when working for multi-nationals, I have been responsible for one specific area but now I can't afford that privilege, and I'm not specific about the work I do either. I take on all sorts of stuff, a huge and varied sort of work load. The way I decide whether or not I can do that, I stand back, look at the job, take stock of it and decide if I can do it myself or have a contractor in and whether I know enough about it to police that contractor properly to make sure it's done properly.

WB: I don't think that that's a perhaps a skill in itself, the fact that you need to have a range of knowledge of these things to do everything?

SU: It's not unusual for me to take a job that's new to me, never seen, never done anything like it before, but you can stand back and look at where the building is now, where it needs to be at the end of it and I can sit back and look at that process and say I can do that, that, that and that, and achieve that. I can go to see everyone I need to see, get prices together and put forward a proposal with regards to price and how we are going to do the job safely and the like.

WB: Can I ask if you go for a job and you need a skill to do it, how do you learn? Do you book yourself into a training course, a book, go around a colleague that has done it before.

SU: No I've been in and around buildings all my life. I'm not a builder by any stretch. I could build a wall if I needed to, I wouldn't be the fastest or best, I'd much rather pay someone else to do it. I've been in and around the building industry all my life and you talk about carbon saving measures and stuff like it's something new and specific, it's not mate it's just home improvement that's all it is.

WB: Yes ok.

SU: the one that I have installed and I wish I could remember the name…

WB: I can ask EO11.

SU: That was really bizarre as it was a roof construction method that I have never seen before in my life, it was a steel construction but it wasn't flat, it was a really odd one…the roof was . Now the problem, the steel itself had 1.8 metre centres, which was substantial enough to walk around on, but between the 1.8 metre centres you've got a lath and plaster ceiling surface you can't walk on, you can't even drop a tool on its really fragile. The only way we could do that, it had to contract an entire working platform through the whole of the centre of that roof, so on the steels that were running through, going the other way, I literally had to.

WB: So you had to do or start one job before you could do the insulation job?

SU: That's exactly right! I had to physically get people up there to do the work. This here… [points to drawing] this is physically too small to get someone in and the roof is too fragile to put any weight on. So what we came up with there…well you have to insulate this section there, cause if you insulate this bit and don't insulate this bit you get. This bit is all nice and warm because you have insulation on it but this bit is freezing cold a no insulation at all. So what you get is chronic condensation issues in here. Cause you got a lot of warm air in this room, running the length of the building, and they'll just end up dripping, running with condensation. You can't leave them un-insulated so we had to come up with a way of getting insulation all the way down to this area here [points to narrow spaces on the drawing]. The way we did that is that we built a tool to do it.

WB: A little innovation then really?

SU: Yes! In essence. That was only way I could come up with a way to do it. Have you ever seen the way pizza people take pizzas out of an oven?

WB: A long pole?

SU: yes, and if you want a better word, one with a shovel on the end of it. The same width as a role of insulation. I used it to take the insulation down into where it needed to be.

WB: So this is where your care and attention comes in?

SU: Yes, well no one else would have done that, they would have said it wasn't possible through health and safety issues within the ceiling. I believe I was the only one who actually put in a proposal for that.

WB: I expect EO11 was glad of that.

SU: Well he got the order and I have been paid for doing it.

WB: So when I talk about training, how do you get your training? On the job? What is your method of learning?

SU: Well look I'm a GD assessor and a domestic energy assessor, I know my way around SAP, but again, I don't know. Being an energy assessor, unless you are producing energy performance certificates or green deal assessments it's a qualification and lets people know that I kind of know what I'm doing with regards to SAP, but when it comes to stuff like that its quite easy to tell if a loft has got no insulation. You put your head in there and you see, you know what it's got no insulation. I don't need a 2 week training course.

WB: Did you go on training courses for them [GD assessor and domestic energy assessor]?

SU: Yes

WB: Weeks, days, half days?

SU: I did both by distance learning, and I guess to get the pair of those, probably 50 hours.

WB: Do you think you learnt any new skills?

SU: Do you know what, yes I did. It kind of opened my eyes to identifying property age. I hadn't really given that much thought before. When you start talking about SAP, the age of the building makes a big difference on its energy performance as certain assumptions are made. So yeah it made me more aware of that type of thing. Do I use it day to day in my work, absolutely not.

WB: But they [training course for GD and energy assessor] were valuable?

SU: umm, they were valuable in that I've secured work as I've got those qualifications, but the qualifications themselves make no difference to the way I approach things.

WB: So you secured the work by letting them know you were a GD assessor?

SU: Yes

WB: and you needed this to be able to do things?

SU: According to the people I was talking to yes, but to actually go and do it

WB: So your clients ask for GD assessors?

SU: yes that's it. The only time you need a GDA qualification is if you are doing GD assessments.

WB: So you do the insulation, but if you are insulating someone's home who is insulting for GD that where you need the qualification?

SU: Exactly, GD is all to do with finance, and repaying that finance through the energy savings you make after having the measures fitted.

WB: So you have done insulation, anything else?

SU: Yes insulation, solar – solar install -solar PV only on domestic. So you are talking about installs upto 4 kWs, 7 and a half thousand pounds worth.

WB: So do these measures still apply to what we are talking about? Any specific skill around it?

SU: Oh no solar is a bit different.

WB: Oh OK.

SU: In fact solar is completely different, yeah, I don't fit solar myself. I sub contract people to do it as there are very specific training and registration requirements.

WB: you sub contract to engineers?

SU: Well electricians really. Again it's quite odd because you have got your electrician, 40 years' experience, nothing he hasn't seen, nothing he hasn't done. Done all sorts. Can he go and wire up a solar panel, do you know what, no he can't. Because he hasn't taken the course that says he can do.

WB: So he can actually do it [wire the solar panel], have the ability?

SU: yes.

WB: But he can't as he hasn't taken the course?

SU: Yes

WB: So you need to look for the contractors who have taken this course?

SU: it gets even worse than that. Although he is an electrician and he is qualified to do this, he is qualified to take the output from an inverter and plug into a distribution board so that the solar system works, OK. He is perfectly qualified to do that, he could do anything in that house. He could strip every single wire out of that house and put it all back in again. He is qualified to do that. But, because he is not MCS registered, he is not allowed to touch solar panels. Now I've been MCS registered, I'm not now but I have been MCS registered, and do you know what, its 95% paper work and procedure. Its like ummm, whats the best way to describe it, its....

WB: Like an admin course?

SU: Yes thats exactly what it is!! You must approach customers in this way, you must... MCS registration is appalling and its keeps an awful lot of contractors away from an industry where they are qualified.

WB: But this is what you need to look [MCS registered] for when hiring people to install PV?

SU: Certainly, yes.

WB: is there anything else you look for when hiring contractors for PV?

SU: Generally, you can't always work with people you know, but I tend to work with an awful lot of people I have already worked with, and I go a lot on referral. I'm not beyond popping on to Google and finding someone if I need to. I suppose you could call it an interview process, I may go onto site and talk to them about how they are going to do things. I'll talk to them about the standard of workmanship I am after if my company wants to hire then, and what my company expects from them. Depending on the answers and how confident I am about them is who gets the work.

WB: So your impressions of them as well really?

SU: Yes. Bearing in mind, I wouldn't say a lot of the time, but it's not unusual for me to take on work without a contractor to fit it. I'll go there and quote the work, but won't necessarily get anyone involved unless I have secured it. That's not unusual. I'll talk to people, get generic quotes, can you quote me on this. But until I get the work I won't waste peoples by taking them out to site.

WB: So once you know you definitely have the job you can say I have work for this?

SU: Yes, but that also puts you in a position where you say I can do that no problem at all. Then they say oh fantastic here's an order. Then go oh I have to go and find someone for that now!

WB: OK I get you. You live on the edge SU11.

SU: haha I do, a little bit.

WB: Do you think there will be any challenges for you in the future, perhaps in terms of skills, or the requirements for low carbon buildings?

SU: Well, yes, yes...kind of, maybe. Bearing in mind I am faced with a job that requires certain skills, I'll go out and find someone who has that certain skill. I won't go away and take...I don't know, if I needed to fit thermodynamic panels, I wouldn't go off and take part F gas course or anything like that. I'd go away and find someone who did.

WB: Can I ask why you do that, is it easier for you?

SU: yes! I can't stop work every time a little bit different comes up, that requires a different qualification or city and guilds certificate. I cannot stop work for a week and go off and get that. There is the cost of it and the time it takes to do it, so the only thing I can do is go out and find someone who does. My, I suppose you could say, my biggest skills set is my ability to go and sell myself to people like EO11.

WB: Which you did.

SU: yes it would appear so yes. The other thing is I don't lie to people either. If I'm sitting there talking to EO11 for the first time and talking about my background in the insulation industry. Ive worked there for decades now. I'll sit and explain that to him and say look I'm perfectly capable of going out an assessing these buildings for you and I'm more than happy if you want to come out with me for the first few to have a look and stuff like that.

WB: yes I came out with you.

SU: yes, but if it comes to... and I see the opportunity to see something that needs doing I'll quote. What will happen is the vast majority of stuff you're better off going to a national insulation contractor, they'll do it for you quicker and really cheap. But I guarantee there will be stuff that they don't want to do. That's why I like to quote for you. I've got a team to help do it, I won't be doing it myself, but if you have anything awkward that requires a bit more care, a bit more lateral thinking to get it done then I'm your man.

WB: So when you come up against things such as solar panels, and you go out, you subcontract. Are there any other things you come against that you do things like that. For instance, the insulation you can do that yourself, the PV you subcontract. Anything else comes in like that... solar thermal?

SU: If EO11 phones me up tomorrow and says I have a solar thermal install I need you to look at, I'd say no problem at all. I'd go out there, id take measurements and the data I believe a contractor would need to do or give me an accurate quote to do the job. As it happens I know solar thermal installers that I have worked with already. I'd send that to them, they'd send me a quote, id put a margin on it and send it to EO11. I'd say look EO11 this is what we are going to do, this will be the contractor.

WB: Would you have to say you trust this person?

SU: yes.

WB: So with the School project 1, there is insulation to do, and you said you need another quote for that. So you need to go through another proposal?

SU: Yes that's it yeah.

WB: Are there any other works you are going to do with the school?

SU: No. Not as far as I am aware. I have looked at 2 other schools with EO11 with regards to solar installation. One of them, the first one was quite bizarre because we turn up and I say to EO11 this is a good roof and could work really well for you. As we are walking around the building the pair of us spot, and I say EO11 I don't think that crack is a good idea, a big crack on the side of the building. It is suffering with subsidence. We identified that on site, and since that they are not proceeding with solar as the building is unstable.

WB: That has only just been found out?

SU: Yeah and that was found out just by EO11 and myself walking around the building.

WB: Thank goodness you were there then.

SU: That is the other thing see. I know for a fact that 90% of contractors, solar contractors would of taken the order, fitted the work.

WB: So ignored the subsidence?

SU: Yes, I see it all the time. They will fit anything.

WB: Because they want the work?

SU: Yes. Bang it out, get paid, and forget about it.

WB: So there is another school where you are installing PV?

SU: Yes. Well, not doing it, I have a quotation to submit. But I have reached another impasse with LA11. Although I have worked with EO11 and done a few jobs with him. As far as I am aware all the feedback has been good. SU11 is star, he does good work, gets the work done – no nonsense. But, I have a solar job to quote, I have LED lighting replacement to quote.

WB: Quote for a school?

SU: No library [LED for the library]. A boiler replacement and LED lighting replacement as they have a load of T5's there. There is solar at the schools and a solar cleaning project as well. Solar panel cleaning on 13 of the schools. I would be ideal for that.

WB: Interesting. Do you think there are any skills required for that [solar cleaning]?

SU: Again, health and safety. There is no skill involved in washing a window, that's all it is, is washing a window.

WB: I like how you put the example on something that is general.

SU: Well it is. How do you clean a piece of glass? Get up there with some detergent. Get it sorted.

WB: Would you say a lot of the skill involved surrounds logistics, how you put things together?

SU: ye, but again you are bigging it up too much. All the renewable technologies they are retrofit to existing technologies. Your heat pumps, your biomass boilers, you solar panels, they are modular. They are a self-contained unit and all you have to do is integrate it into the house. Nothing hard about it at all. There is more involved to fitting a patio than there is with solar panels.

WB: So apart from your contractors who have been on these training courses [MCS registered] and got what you refer to as just a certificate at the end of the day.

SU: They are, what it does, the qualifications and the certificates, what they do is give peace of mind to strangers. It means that if you want to deal with a strangers, they have been on a course and can do everything for you. It doesn't mean they are going to do a proper job, it doesn't mean they are going to turn up on time, it doesn't mean they are going to fit it properly, it doesn't mean in 6 months time you are not going to have a number of issues. But it does mean they have been on a course.

WB: So it is about giving the clients that peace of mind, just like I think that is what you do with EO11, you give him that peace of mind. Possibly a managerial skill, a social skill?

SU: I'm a sales man. You've found me out, I know nothing haha.

WB: What I mean is EO11 needs to be able to trust you.

SU: What you do is, you go out and speak to an awful lot of people, don't tell lies, be absolutely honest with them. You make them aware of what you can do, what you can achieve and also what you can't achieve. You don't tell lies to people. You'll see an awful lot of people, some will some wont, move on to the next one.

WB: I'm sure EO11 knows how thorough you are, as I have seen during observations of the schools.

SU: Yes

WB: Coming back to the schools with insulation, can I ask how you contract- such as materials. Do you contract and supply the materials or does EO11 do that?

SU: No its supply and fit so I'll go out and buy them. I'm trying to think where I bought the insulation from for the last one. It was an odd place where you wouldn't necessarily of thought of..

WB: Again, it is somewhere random, or do you have to know and trust them?

SU: No when it comes to buying things

WB: is it the cheapest?

SU: Well it all depends. If you have time specific requirements on what you are buying then no it's not the cheapest. If you are buying 600 square meters for delivery sometime next week it doesn't really matter, then you are going to find the cheapest possible place. If you are buying a specific component to renovate a solar panel for instance and it must be on site on the 27th August then you go to someone that you know makes it.

WB: Do you have to have any sort of skills to know what insulation to order / buy, or know which part of the solar panel to order?

SU: Yes but it isn't hard. Once you've been around the systems for a little while.

WB: How do you know that? Is it experience?

SU: Yes, well do you know what, the first, probably, 10-12 years of my career was around buying and selling things in the engineering industry. Bearing transmissions, pneumatics systems, things like that. So for the first half of my career I bought and sold them. The way I made my money there was kind of before the internet. The way I made my money was that someone would come in and say SU11 I need one of them. Oh fantastic what is it? I don't know it came off my printing press. What does it do? I'm not really sure...OK leave it with me. I'd take that [part] and I'd work on it, work on it and work on it, until I found out what it was and where I could buy it from. Then I used to buy it for them. An awful lot of basic stuff if you like, people would come to me and say I need one of these my factory has stopped. I need one of these and now. OK it is in Norwich I'll have it here for you now in 3 hours, the part is going to cost you this much, taxi going to cost you this much. Do you want it? Yes bang! They have it in the 3 hours. You can charge accordingly to that, but again it's that attention to detail and making sure that what you tell people is going to happen bloody well happens. Next time something brakes they come back to you and say can you get me one of them again? First decade of buying and selling things, really set me up for the degrees of commitment, accuracy and generally making sure that what you promise to happen, happens, and it has got to happen. I come out of engineering into the cavity and loft industry, this phenomenally accurate industry where if you told someone something was going to happen it bloody well had to happen, or factories stopped. Then into the carbon saving industry- this horrible loose baggy industry where no one really tends to give a **** about service and you know. It was a real eye opener for me to go and work for a national insulation company. If I have 100 customers during the course of the week, if one complains to me that's a disaster. When I was working for a national insulation company 100 customers 80 would complain. It was like what am I going to do about this. Just appalling and the industry itself.

WB: With regards to insulation, what would they complain about?

SU: Everything from the assessor arriving and walking dirt on people's carpet, to installing drilling through single skin walls and pumping people's pantries full of insulation.

WB: When you are ordering things from the carbon saving measures, do you think it is getting more difficult to source or maybe identify the materials? For example, was it difficult to identify and source materials for the School project 1 school for the loft insulation?

SU: Ah no it was a little different as School project 1 was encapsulated insulation. You cannot put normal insulation on top of a suspended ceiling as all the fibres and stuff can come through.

WB: So again it was that suspended ceiling problem?

SU: So what you do is you buy insulation that is encapsulated in PVC in bags, for want of a better phrase. I had never bought that before but 20 minutes on google and I found out where to get it from. If I couldn't find it on google I'd contact one of the hundreds of people in the industry and ask them.

WB: So it is important who you know as well?

SU: Yes it is.

WB: So there are no other training course you have been on to do with low carbon saving measures?

SU: No, unfortunately it is all down to experience really. That in itself becomes increasingly difficult to function within the industry. Especially when it comes to things like the Green Deal and the funding that comes from utilities, the money for the homeowner that helps fund things like cavity and loft insulation. The amount of paperwork and registration that you have to go through to be able to claim that sort of funding is prohibitive for an awful lot of companies and certainly for me. I have the experience and the skill set to go through and do it, but you know what, I don't want to cause I wouldn't burden myself with it, with the auditable procedure that you have to follow. You have to open up your company to outside agencies that will come in and audit what you are doing to make sure Mrs jones paper work is in a file etc. I can't burden myself with this.

WB: So this is not what you do?

SU: No. People come to me and say can you do this SU11? Yes when you want it done? Tomorrow. Job done.

WB: I completely understand what you mean. One of the last things to ask as I've taken up a lot of your time, are there any skills you would like to have? Possibly like a wish list of skills you think you may need to deliver low carbon buildings in the future?

SU: um [long pause]

WB: For possibly the carbon saving measures you are putting in the schools, such as the PV that you are going to be doing?

SU: Well I'll be contracting that out.

WB: And the tick-list you have for your skills for contractors for PV- is the MCS accreditation?

SU: That is specific. If the company hasn't got that… I can go and install it myself but because I'm not MCS accredited I can't claim FIT.

WB: Do you have any interaction at all with the users?

SU: when you say interaction, do you mean after the job or monitoring?

WB: well throughout the project? I know you speak to the council [EO11], and when we visited School project 1 for a survey you spoke to the handyman, the headmaster.

SU: Oh OK no I'll speak to whoever I need to speak to. If you want to talk about skills…what I've found very early on is that you need to be able to talk to people at their own level. So you need to be able to doff the cap to people like an EO11, say all the right things and not swear, but you also need to get hold of the handyman, go out the back have a cigarette and a chat with them, see what the headmistress is like and see if I can get away with working on a Sunday. Things like that.

WB: so it's about trying to build that relationship with them?

SU: Yes and I find that easy

WB: So any skills post low carbon measures? After they have the carbon saving measures in place?

SU: If you are talking…

WB: Do you have to educate them [the users]?

SU: Something like solar PV, do you have to educate them? Well, don't take a screw driver to it madam, cause you'll hurt yourself. If you are going to use a tumble dryer try and use it during the day to use the free electricity you are using. But no not really. Solar PV it is what it is. You fit it, it sits on the roof and generates electricity.

WB: What about solar thermal? Have you ever educated the users for this?

SU: Again, solar thermal, the only interaction you should have is with your thermostat. If you want your water hotter, you turn it up. If you want it colder you turn it down. That's it. I don't know a good installer, its completely modular. You wouldn't expect to build someone a new brick wall and tell them how to use it or look after it, cause it's a brick wall and it just sits there.

WB: So it's the same with low carbon measures?

SU: Yes, you fit a boiler, you forget about it for a year, then someone comes along and services it. A PV array or solar thermal array, or GSHP, they are all the same. They are just a modular thing, you fit, forget and service once a year. You don't need educating as such. The only education you need is maybe a lifestyle change to utilise the energy a little better.

WB: Did you have to say anything to the people at School project 1? Any challenges with them?

SU: the school that we did fit [unsure of the school], kind of an unforeseen issue really. The loft hatch was in the school kitchen. I did the survey and the install, and I physically got up there and did that myself, because it was such a challenging install. I went to work with the guys on site myself.

WB: So the challenge was the loft hatch?

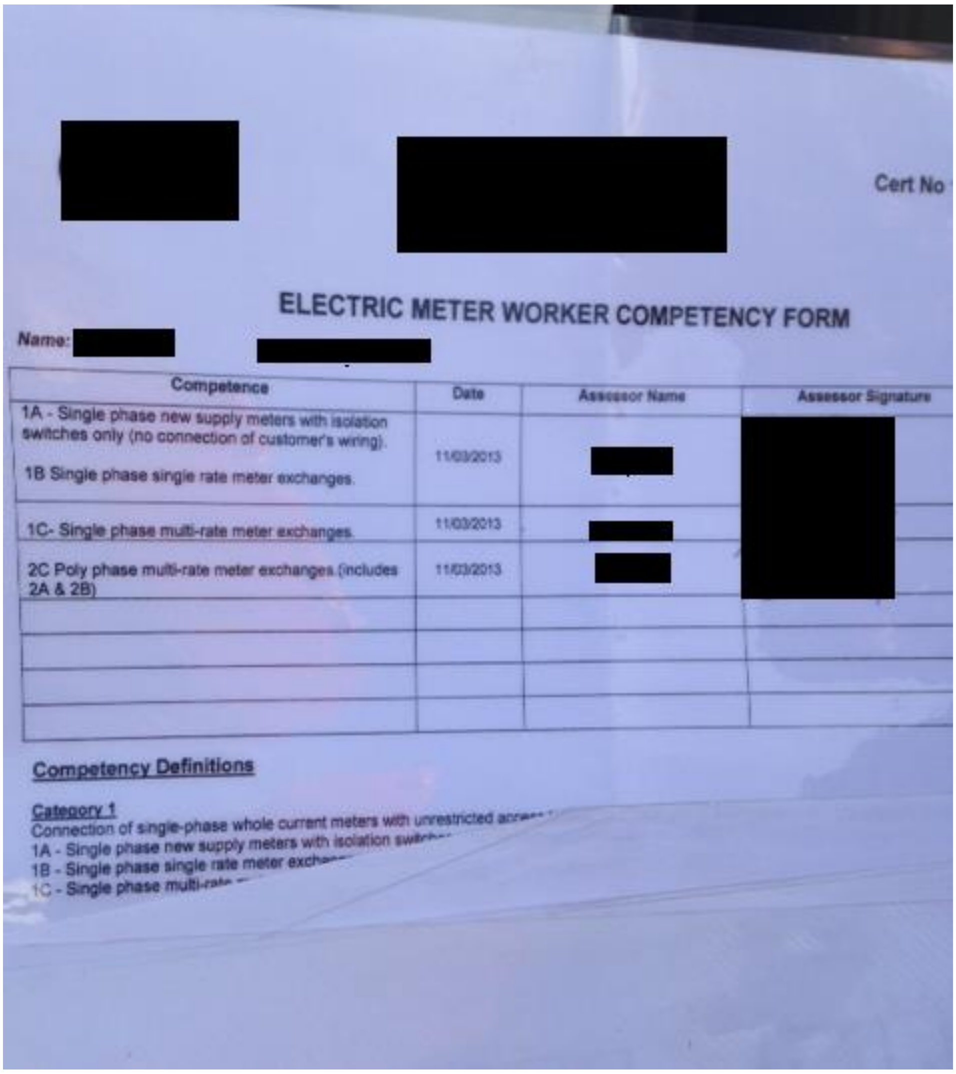
SU: Well the loft hatch was in the kitchen and I never really gave much thought to it. I chipped up on site with all my materials and spoke to the chaps on site. Got in the loft hatch with the material, shut the hatch and got working in there. However, an inspector came along and had a merry fit because we had gone in the kitchen and accessed the loft while the school was open. Stuff wasn't being prepared whilst we were going up and down and stuff like that but yeah she had a merry blue fit over that. She came in and said we couldn't work like that, creating dust and stuff. So we stopped for two hours whilst they prepared lunch, but they complained about it.

WB: Have they had anything else at that school [unsure of the school]? Just insulation?

SU: Not as far as I am aware.

End of interview

Appendix F: an example of competency form for a smart meter installer (EEM contractor)



[redacted] [redacted]

Cert No

ELECTRIC METER WORKER COMPETENCY FORM

Name: [redacted] [redacted]

Competence	Date	Assessor Name	Assessor Signature
1A - Single phase new supply meters with isolation switches only (no connection of customer's wiring). 1B Single phase single rate meter exchanges.	11/03/2013	[redacted]	[redacted]
1C- Single phase multi-rate meter exchanges.	11/03/2013	[redacted]	
2C Poly phase multi-rate meter exchanges (includes 2A & 2B)	11/03/2013	[redacted]	

Competency Definitions

Category 1
Connection of single-phase whole current meters with unrestricted
1A - Single phase new supply meters with isolation
1B - Single phase single rate meter exch
1C - Single phase multi-