The Take Up and Use of Green Technologies in Low Carbon Communities: A Case Study of North West Cambridge

Rosalyn Kristina Old

Department of Land Economy
University of Cambridge

Robinson College

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Preface

This thesis is submitted according to the requirements of the Degree Committee of Land Economy. It does not exceed the regulation length of 80,000 words including footnotes, references and appendices.

This thesis is the result of my own work and includes nothing which is the outcome of work done in collaboration except as declared in the Preface and specified in the text. It is not substantially the same as any that I have submitted, or, is being concurrently submitted for a degree or diploma or other qualification at the University of Cambridge or any other University or similar institution except as declared in the Preface and specified in the text.

I further state that no substantial part of my thesis has already been submitted, or, is being concurrently submitted for any such degree, diploma or other qualification at the University of Cambridge or any other University or similar institution except as declared in the Preface and specified in the text. It does not exceed the prescribed word limit for the relevant Degree Committee.

Summary

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Against the backdrop of climate change, governments around the world are introducing requirements for new developments to be built to much higher sustainability standards. As urban areas face population growth, we are seeing new-build urban extensions planned to provide mixed-use, low carbon communities. Embedded within these sites we often see a range of different green technologies and features designed to reduce the energy and carbon footprints of the area.

There is, however, uncertainty around the impact of green technologies in housing, with housebuilders being urged, incentivised and required to provide sustainable features in new developments. Yet the impact of such technologies requires take up and use in the building sector and appropriate behaviours of occupants so that technologies are used effectively and energy and carbon reduction is achieved.

This research aims to establish how occupant behaviour can be influenced by design and programmatic features of the community and the resultant effect on the energy and carbon outcomes of a site. The University of Cambridge's North West Cambridge development is the main case study, with a focus on the postgraduate student and postdoctoral researcher communities which will be the main occupants in the first phase of development.

Through application and extension of the principles of nudge and social practice theories, comparison case studies play a part in identifying the role of human interaction with urban visual signals in encouraging low carbon behaviours and delivering on the potential of low energy, low carbon technologies. The project evaluates which policy, programme, and built environment design instruments linked with green technologies will have the greatest impact in delivering environmentally-sustainable behaviour and associated carbon savings.

There are two core questions which the study addresses:

1. Which features of a community (design, technology, policies, programmes etc.) cause people to adopt low energy and carbon behaviours?
2. If they adopt these behaviours, how does that change the energy and carbon 'footprint' of the community?

Using interdisciplinary methods, the study uses primary data analysis to create behavioural groupings which are then matched to energy profiles. By linking specific policies, programmes and urban design features to each group, we can project technology take up and use across a site population, in building a series of scenarios which are then used to calculate resultant energy and carbon reductions across the site.

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In memory of Mary Anderson and Allan Old Snr, for always inspiring me.

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1 Introduction

1.1 Introduction

This first chapter of the thesis sets out the backdrop to our study. We explore the broad aims of the sustainable development movement, the role of cities in addressing climate change related issues and the impact that this has had on the urban development sector.

We then move on to explore some of the recent location and strategy trends in sustainable urban development. We provide an overview of our key case study – the University of Cambridge's North West Cambridge development (abbreviated to NWC) – before setting out the research aim and questions. Finally, we present the conceptual framework upon which the study is built.

1.2 Sustainable urban development

Here we set the context by exploring the background to sustainable urban development.

Climate change

Climate change is one of the biggest challenges facing humanity. The warming of the earth's atmosphere due to greenhouse gas emissions is leading to large-scale environmental changes which, without significant mitigation or adaptation, threaten flora, fauna and human life across the planet.

Over the past few decades, steps have gradually been taken at all levels to address the level of human-created greenhouse gas emissions and put plans in place to mitigate against the worst impacts. We are now seeing ambitious sustainable development strategies at international, national and local levels attempting to slow emission rates by more efficient use of energy and management of resource use. There are several definitions of sustainable development, including the well-known Brundtland definition of "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (Brundtland, 1987) and various ways of balancing environmental, economic and social sustainability in different contexts.

Internationally and nationally, discussions around ways to address climate change challenges have resulted in various initiatives such as the United Nations Sustainable Development Goals and carbon targets at various levels.

The role of cities

As former United Nations Deputy Secretary-General Jan Eliasson put it, "cities are where the battle for sustainable development will be won — or lost if we fail" (Eliasson, 2015). We are seeing global patterns of rural to urban migration and population growth (and are likely to see an increase in climate migrants), which combined put additional pressure on cities to implement the infrastructure required for support of larger populations on quick timescales. Cities require significant energy and resource supplies and as living standards increase, so does the demand for these increase, creating larger urban hinterlands. There are physical challenges such as provision of resources and space for housing, infrastructure and services, as well as the social issues associated with crowding and inequality. Urban authorities must decide where to prioritise their efforts between a whole range of social, environmental and economic issues.

The scale and complexity of the challenges to make our urban areas sustainable should not be underestimated – but neither should the potential for energy and carbon savings, as 75% of global energy consumption comes from cities and by 2050 70% of the world's population could live there (Eames et al., 2012). This means that there is an opportunity to focus efforts for energy-saving on the areas with the highest levels to reduce.

In addressing these issues, there are significant opportunities for urban areas to tackle several challenges at once. Research into the interplay between such issues and movement towards policies which address more than one problem means that cities have the opportunity to address concerns such as resident wellbeing and quality of life, while at the same time reducing emissions. As new accommodation is built, there is a window to incorporate features such as green technologies to ensure that developments meet more than one societal need.

By their very nature, cities provide more efficiency in terms of energy use than more rural areas. For example, the desire to live close to jobs and services means that urban dwellers are willing to live in high density residential accommodation. This higher density of people per square mile means that

infrastructure such as public transport has much higher use and therefore returns on investment, as well as lower emissions per person.

Current trends

Against this backdrop, governments are imposing requirements for new developments to be built to much higher sustainability standards. As urban areas face population growth, we are seeing more new build urban extensions provide mixed use, low carbon communities. Within these sites we see a range of different green technologies designed to reduce the energy and carbon footprints of the area.

There are various mechanisms put in place in the UK and elsewhere to make this a reality, from regulation on the design of new sites (e.g. planning system requirements) to policies and programmes to encourage individual take up and use of green technologies (e.g. the UK Government Green Deal home improvement scheme).

There is also a movement towards interdisciplinary research and implementation in this field. Sustainable urban development sits not only at the intersection of architecture, construction, planning and engineering. There is now an increased focus on using sociology, psychology and place-making theory, with a focus on places for people, to make sustainable cities a reality.

Our study context

This research aims to establish the achievable energy reductions from influencing occupant behaviour in such communities, by factors such as design and programmatic features of the community. The University of Cambridge's North West Cambridge development is the main case study, with comparison case studies playing a part in identifying the role of occupant behaviour in delivering on the potential of low energy, low carbon technologies. The project will evaluate which policy, programme and built environment design feature instruments will have the greatest impact in delivering environmentally-sustainable behaviour and associated carbon savings.

Using energy and carbon as sustainability metrics and looking at usage patterns linked to behavioural groups, the core intellectual question focuses on how policies, programmes and the

urban environment itself encourage people to interact with green technologies in ways which best contribute to energy and carbon reductions across new urban developments.

This study is, by the nature of the topics it discusses, interdisciplinary. It bridges qualitative and quantitative methods in exploring themes from the fields of land economy, sociology, urban design, psychology and energy policy amongst others. By bringing these subject areas together in one study, we have an opportunity to look at these issues in a more holistic manner, with the advantages from each area combining to provide recommendation outcomes for the built environment as a whole.

1.3 New build low carbon communities

Here we give an overview of sustainable urban development trends

Sustainability in cities

Cities are taking various practical steps to encourage carbon savings through making new urban developments more sustainable in their energy and carbon outcomes.

At a national or local government level, strategic structures can be put in place to ensure that development follows certain sustainability standards. These can be in the form of regulations (e.g. car parking requirements), policies (e.g. UK Government's Green Deal) or strategies and visions (e.g. The Walkable City - Stockholm City Council, 2010).

Each of these instruments will be taken on by the designers of urban development projects and interpreted in the way which they think will be best for the site. A range of different trends have come through in the design of such developments as waves of different instruments and technologies have been tried.

Location trends in urban development

The location for development can be a key factor in its success and there have been different attitudes to this question of where to locate new development in cities. Urban development models

show how most cities have morphed from activity focused in the core of the city, growing outwards in zoned rings (Burgess, 1925), expanding to single-family homes in suburbs to a situation where the population living in the centre has declined and the urban fabric has become dispersed at the rural-urban fringe. From this starting point of the typical suburbanised city, there are three main options for development – brownfield sites, the rural-urban fringe and building entirely new cities.

Brownfield sites (vacant plots which were previously developed, within the urban area) present an opportunity to develop within the existing urban structure. There are several advantages for developers choosing these sites, like BedZED in London. They are often located in central areas where previous buildings have been demolished, meaning that existing infrastructure is in place and there is an expectation that at least similar style development will be allowed on the site, speeding up the planning permission process. On the other side, previous use may mean large costs to decontaminate particularly sites in industrial districts (Niemietz, 2014), costs are high due to location and careful planning has to be undertaken to ensure that the building construction is possible within the site and its access routes. These type of developments present opportunities to increase urban density and provide more well-connected, city-centre mixed use projects, with lower carbon outcomes than the following options.

Building on the rural-urban fringe follows the trend of the suburban movement, but there is a modern trend of doing so in a manner which both continues the trend of density out from the existing built environment while carefully integrating the bordering natural area into the design of the site. Advantages of urban extension sites include building on greenfield land (which does not have the challenges of building on previously-developed land), less limited space and natural surroundings. Disadvantages include lack of infrastructure links, less desirable location for accessing services and potential greenbelt restrictions on development. The North West Cambridge site is built on such a site on the edge of Cambridge.

The third main option is to build new cities entirely outside of existing urban areas. This type of development is often more utopian – a chance to trial grand ideas of how you can build a city from scratch, with no constraints linked to existing urban environments e.g. Masdar City in Abu Dhabi. There are however significant costs involved in designing an entire city from (under) the ground up and while there might be opportunities for lower carbon living in the design, the issue remains that we cannot simply abandon our existing cities to start again – we have neither the money nor the land.

Strategy trends in urban development

Within the developments that have been built over the past few decades, there have been several trends in ways to work towards sustainability and lower carbon outcomes.

Pedestrianisation of streets and squares has been a trend since place makers such as Gehl (Gehl, 2006) started to question the benefits of prioritising cars in our urban structure. Cities started to see the benefits to businesses as well as to social wellbeing and the environment from turning central streets over to active travel (walking and cycling).

With the development of more advanced technologies, developers started to think about how we could apply these to cities. The trend for smart cities arose to advance our systems and improve the ease of life in the city (Caragliu et al, 2011). Green technologies formed part of this embedding of technology into the urban fabric. However, there have been movements against this as trends move away from simply improving technological efficiency towards focusing on human behaviour as a way to reduce emissions and create sustainable cities, as simply monitoring does not necessarily reduce emissions by itself.

Five-minutes-city is a concept created to increase the use of public and active transport in urban developments (Maas, 2002). The Nordhavn development in Copenhagen illustrates this strategy being applied to the design of the site. The idea implementation there is that wherever you are on the site, you should be no further than a five-minute walk from a transport node e.g. a bus stop or metro station. This makes the lower-carbon modes more attractive as they are the default option and the urban area is better connected as a system.

A similarity can be drawn to the blue and green city strategies, where the emphasis is on ensuring a constant presence of water and/or nature throughout a site. The idea is that more regular presence of nature (even in small bundles) has greater impact than having the same space in one lot. The benefits of nature on a site and the resultant behaviour change are explored in further sections.

1.4 The North West Cambridge site

Introducing the main case study site.

A case study of the North West Cambridge site underpins this research. This method of having a central case study was chosen as a response to the fact that the site in question is currently under construction, and therefore can offer insights at the cutting edge of sustainable urban design, as well as providing a unique university-owned site context to explore. As Yin (2017) sets out, one of three main reasons to undertake case study research is where the subject of the study is "a contemporary (as opposed to entirely historical) phenomenon". As the site has been under construction throughout this research, it seemed appropriate to frame it as an evolving case study, focusing on plans and predictive analysis, while using current data from similar populations and contexts to give as realistic a picture as possible.

Additional case studies of similar sites at different stages of their construction or life are used to supplement the main case study. The methods are explored in more detail in the methodology chapter.

Vision and purpose

The University of Cambridge has embarked upon the single biggest capital project in its history and the biggest investment by any UK university (Pagano, 2014) – to transform 150 hectares of farmland in the North of the city of Cambridge into a mixed-use sustainable development (North West Cambridge, 2012). Planning permission was granted in August 2012 to go ahead with the project with a primary aim of addressing two needs: affordable accommodation for the university's staff and postgraduate students and fostering future growth in research and development. It is hoped that the development will relieve pressure on supply and costs of housing in the city and ensure the continued presence and impacts of the 'Cambridge Phenomenon' which aids the economic growth of the country at large.

Sustainability

North West Cambridge (NWC) has a masterplan built on an overarching vision of an environmentally sustainable development. This has been set out in various levels of detail from the overall carbon reduction strategy in the planning application to the design codes which architects for each lot must

follow e.g. “all dwellings have to meet the Fabric Energy Efficiency Standard (FEES), CfSH Level 5 and there are also provisions for decentralized energy generation”(Georgiadou et al., 2012).

While the necessary sustainability reports and recommendations have been provided for the planning application and by developers of the site[1], this study goes beyond their scope, by investigating likely behavioural groups within the future resident population and by matching the best-fit specific policies and urban design elements to each set of individuals.

Phase one

Phase one (of three in the development) has been under construction throughout this study, with the primary school as the first occupied building and the first residents moving in in July 2017 (NWC, 2017).

In its first stage, the site will consist of the following elements:

Accommodation	Facilities
700 homes for qualifying University/College staff	1 Form of Entry Primary School
325 postgraduate student rooms	University run café
450 market homes	Community centre
	Nursery Facility
	Doctors surgery
Infrastructure	Police touchdown facility
Public, green space and landscaping	Supermarket
Roads and transport routes	Retail units
Energy Centre	Hotel
	Senior living home

Figure 1: NWC phase one elements

Main case study

The North West Cambridge site has been chosen as the main case study development for this research as a unique example of a mixed-use urban development project by a university which focuses on creating a community initially composed of postgraduate students and postdoctoral researchers[2]. This is an opportunity to explore the specific behavioural traits within these

[1] For example, AECOM’s study: “Joining up the Dots: Sustainable Behaviour Change at North West Cambridge”
[2] The accommodation is available to key workers across the university’s staff who meet the selection criteria, however the focus has been on providing affordable accommodation for postdoctoral researchers in particular (NWC, 2012).

demographic groups living on such a site and what this means in terms of the success of the green technologies on the site in achieving energy and carbon savings.

These millennial+ resident groups have specific characteristics in terms of the combination of practical considerations such as mobility between postdoctoral and early-career positions (on a UK, European and global scale) and fixed-term posts reducing likelihood of property purchase. In addition, these highly educated groups sit within the academic community and as such may show specific trends in terms of attitudes towards societal challenges such as environmental sustainability. The young age range of these groups (18-35[3]) marks a transitional period in early adult life as these individuals move from structured study to early academic careers, which often sits alongside personal milestones such as marriage and children.

In addition, the spread of green features planned for the NWC site presents an opportunity to investigate how behaviour of the above groups might interact with the technologies planned for the site and the extent to which the design of the urban realm may encourage this. We use the examples of the community smart meter system and the site wide active travel plan in our research.

While NWC is the main case study example used in this thesis, the technologies, policies, programmes and urban features investigated are not specific to this site and the majority of aspects are additionally applicable to other similar sustainable urban developments in line with the broader aims of the study and its contribution to the field.

1.5 Aims and research questions

Presenting the overall aim of the thesis and the associated research questions.

Overall Aim

To explore the potential impact of community policies and programmes and urban design features on occupant behaviour in low energy and carbon communities and the subsequent effect on green technologies, using the North West Cambridge development as a case study.

[3] Majority age groups in our study were found to be 18-25 and 26-35.

This aim states the thesis' intention to provide further exploration of the bridge between human behaviour and energy and carbon outputs of green technologies. We expand on the existing research by incorporating the influence of urban design features on this behaviour and by focusing on a specific academic community within our main site. The combination of these elements presents a unique contribution to the field.

Research Questions

There are two core questions which the thesis addresses:

1. Which features of a community (design, technology, policies, programmes etc.) cause people to adopt low energy and carbon behaviours?

2. If they adopt these behaviours, how does that change the energy and carbon 'footprint' of the community?

The research questions set out the two main sections of the research, in the order in which they are explored.

The first research question sits in the field of the social sciences and looks at the sort of behaviours we can see in individuals which contribute to sustainable living. It asks for investigation of the range of factors influencing human behaviour and how we can adapt these to different groups of people for maximum effect. While there is a wide range of factors affecting human behaviour, we have chosen to focus on the key influences on this kind of human-sustainable behaviour interaction. These include urban design features, aspects of presentation and use of green technologies, policies and programmes.

Through analysis of data relating to behavioural factors we will create behavioural groupings within a population sample which each share behavioural traits. We then build upon existing literature and data to match these with energy use profiles in relation to our chosen technology examples.

Building on the behavioural groups established through the first question, the second question moves towards aspects of the more quantitative sciences and engineering. Here we set out a series of scenarios to explore what happens to a development's energy and carbon outcomes if the behaviours are adopted. We enter quantitative energy profile data into the Cambridge Retrofit

model to calculate energy and carbon outcomes for the North West Cambridge site under specific conditions.

1.6 Conceptual framework

Establishing the underpinning conceptual framework of the thesis.

This section will explore the thesis' conceptual framework set out in the diagram below (figure 2), represented as a flowchart of four boxes. Movement from one box to another is shown by arrows representing movement to the next stage of the research. The boxes relate to the different research questions, explained in further detail in the next paragraphs.

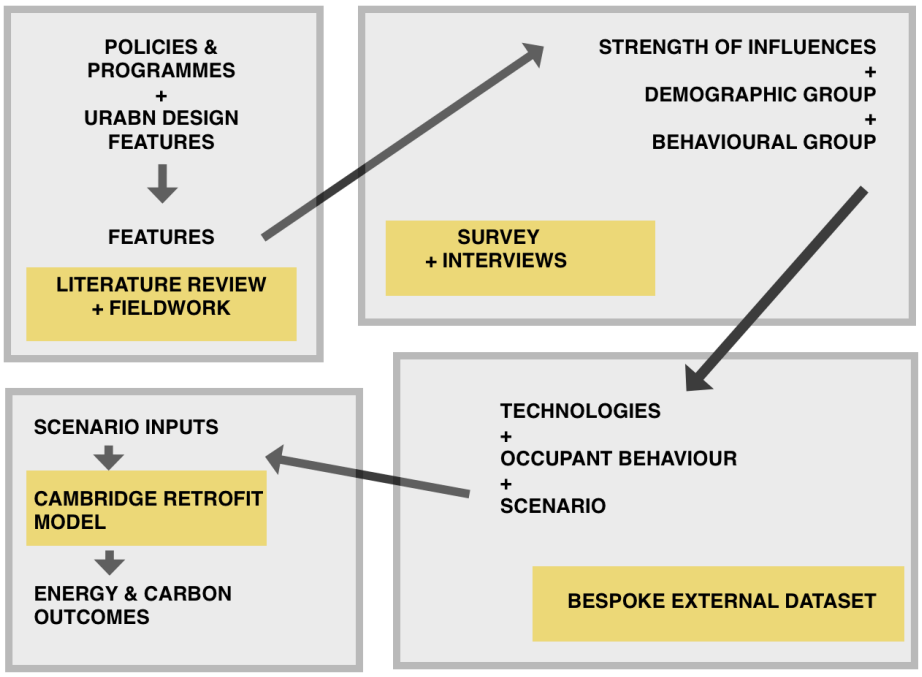


Figure 2: Conceptual framework diagram

The first stage of the framework is in the top left box of the diagram. Here we explore the concept that policies and programmes and urban design features create a set of features (e.g. visible green technologies in the streetscape or community-linked smart meters in homes) in urban areas. These features are the instruments attached to the policies and programmes and physical features of the built environment.

The literature review tells us about the types of features we might find here and (following the arrow to the top right box) starts to explore the resulting influences (the behavioural influences laid out in the literature review fit in here) that these features will have on occupant behaviour on a site.

The top right box explores the 'occupant behaviour' section of the research. Here we start to evaluate the strength of the different types of influence on residents' and users' behaviour. We add this to the backdrop of the different demographic groups that occupants fall into (in the case of North West Cambridge we focus on postgraduate students and postdoctoral researchers as a main group of key workers for the university). We then use data collected in surveys and interviews on all of the previous factors (and their personal values, norms and attitudes) to sort the occupants into behavioural groupings.

These behavioural groupings are taken down to the bottom right box where we start to link behaviour with use of green technologies. We combine behavioural groups with energy profiles created from the bespoke external dataset with likely occupant behaviour from the top right box and combine these to create a 'scenario' – to find the impact of achieving certain behaviours through targeted programmes or urban design features for the established groups on overall energy output of the site.

We then move into the final box (bottom left) where we are looking to find overall energy and carbon outcomes for the site based on a range of scenarios. For the chosen scenario we enter the energy profile inputs with associated green technology energy reductions and calculate overall energy and carbon outputs for the site, using the Cambridge Retrofit model.

The conceptual framework is closely linked to the research questions. The first question around factors influencing behaviour is examined in the first three boxes. The second research question overlaps with the first in the third box and goes on to the last box. The research questions and conceptual are tied together in the research process set out in the methodology chapter.

1.7 Chapter conclusions

In this chapter we have set out the background and context for the thesis topic area, exploring the themes addressed through the current societal context and existing literature.

We have then gone on to introduce the aims and research questions, explaining their basis and gaps in the subject field that they look to address.

Finally, we explored how these elements combine in the conceptual framework, which sets out the thesis journey, mapping the research questions with the different elements of data, analysis and calculations.

In the following chapter we will explore in further detail the theory and literature at the core of our research questions and the key contributions which this study can make to the field.

2 Human interaction with green technologies in the built environment: a review of current literature

2.1 Introduction

Setting out the literature

This chapter is an exploration of the knowledge that already exists, acknowledgment of the gaps in the literature, and setting out of how this research builds upon what already exists, and which of the gaps this study aims to fill. As explored in the background to this study, the subject of sustainable urban development is related to and intertwined with a whole range of topics. As we view the big global challenges as more and more connected, we must also incorporate this way of thinking into the solutions we put forward. While initial research on climate change and sustainable development has extended from within a variety of fields with specific perspectives (e.g. engineering for green technologies), we now know that we cannot find answers to these questions without looking outside of silos to the interactions between different fields. The very nature of this study means that it sits in the crossover area of several fields – some closely related and others less obviously so.

In this literature review we focus on those theories and topics at the very core of our thesis aim and research questions, from a variety of subject areas. We specifically look to research from the fields related to human behaviour and the places and ways in which we make our decisions (especially those related to use of green technologies): sociology, psychology, planning, energy, urban design, behavioural economics and policy.

In terms of the adoption of low energy and carbon behaviours, we look to review previous work around processes of and influences on human decision-making. From behavioural economics we explore decision-making systems and from psychology the way in which key internal and external factors influence our choices. We review previous literature on social factors influencing our human decisions, such as community and peers, which overlaps with social practice theory – a core concept upon which we build this work. From the field of sustainable energy policy, we explore motivations behind environmentally-conscious decision-making, and introduce the second key theory of interest – nudge theory.

To frame the relationship between human actors and the green technologies on new sustainable urban developments, we look to literature around the technology performance gap, the socio-

technological interface, green technologies themselves and how we can measure energy and carbon use. Concerning the energy and carbon 'footprint' of the community, we delve further into the subject areas of energy and carbon modelling to explore the base upon which we build the quantitative part of this study.

To understand the influence of the environment in which decisions are made, in the context of our study, we delve into the field of urban design and the impact of visual signals in consciously and subconsciously influencing human behaviour through an exploration of scale, nature, aesthetics and design of the home. We take a look at how nudge and social practice theories can be applied to the built environment.

Finally, we review the relevant literature on policy and programmes, points of intervention, combining instruments and social practice through policies and programmes.

In each of these areas, there are contributions from different fields. In this study we aim to find the most relevant from a range of fields, to explore how we can bring these together and build upon combinations of ideas can help solve aspects of global challenges in an interdisciplinary manner.

The range of fields related to this study is large, and so necessitates a focus on those more specific subject areas which are of key relevance to the particular research question. We do not, for example, explore in great detail the energy performance of specific green technologies or the behavioural impact of individual architectural features in the urban environment. Instead we look, for example, to the relationship between green technology performance and human decision-making, and the influence of specific types of features in the spaces between buildings, such as elements of nature.

Throughout the remaining chapters of the thesis, additional literature is brought in to support specific aspects of the methodology and analysis. A key example is literature exploring the possible methodologies, explored in chapter three.

2.2 Human decisions and what influences them

Introduction – processes and influences on decision-making

To understand the interaction between humans and green technologies in the urban context, we first have to understand the relevant processes and influences on human decision-making. In this section we look at influences on human behaviour including internal (decision-making systems, psychological factors), external (information sources) and social factors (demographics; norms, values and attitudes; peers and community; routine and lifestyle and other motivations). We introduce social practice theory and nudge theory as two core concepts relevant to this piece of work. Finally, we analyse current literature around behavioural groupings.

Influences on human behaviour

To investigate the ways in which behaviours affect technology performance, we must first look at the different factors influencing behaviour. When we establish these, we can start to investigate ways in which we can adapt these influences to encourage more 'good' behaviours in relation to sustainable development features.

There is a wide range of theory on behavioural influences across sociology, psychology and other fields. To explore the full range of influences on human behaviour would be beyond the scope of this thesis. Therefore, in this section we focus on those most applicable to the context of the use of green technologies on new-build sites and start to assess where nudge theory and social practice theory may interact with them. This section is structured into internal, external and social factors.

Internal factors

From findings in the field of psychology we know that there are different psychological systems affecting our decision-making. Two key examples are investigated in this review – decision-making systems and subconscious reactions – which both have a direct relevance for the way in which we make decisions about our behaviours. We do not include areas of psychology such as those concerning biological influences and mental health, as those are considered beyond the scope of this particular study.

Decision-making systems

Historically, behavioural economics has attempted to bring social elements related to human behaviour into the economic model context. While more adaptive than traditional macro- and micro-economic models, there are still some challenges in adapting behavioural economics models to this type of human behaviour context of how we make decisions.

Tversky and Kahneman (1974) investigated the heuristics involved in decision-making – that is to say the way in which our brains solve problems and calculate the best decision in that moment. Through findings from their experiments, they proposed that individuals apply three types of heuristics when making judgments in uncertain situations. These are representativeness (related to the probability of certain outcomes), instances or scenarios (assessment of frequency) and adjustment from anchors (something e.g. numeric to base the decision on) (Tversky & Kahneman, 1974). An application in a community context could be that the more often individuals see others in their community acting in a certain way, the more likely they may be to take that decision themselves, where they are uncertain of the most suitable way to act.

Kahneman later developed this work into his theory of two levels of individual decision-making, exemplified in the author's "Thinking, Fast and Slow" (Kahneman, 2011) which explores the 'fast' and 'slow' systems involved in our decision-making. He sets out the theory that our decisions can be made by a combination of either of the two systems – the immediate, emotional system one which is linked to human instincts and the second, slower and more analytical system two- and the biases which mean that we cannot rely on human rational decision-making (Kahneman, 2011).

In the context of our study, from this work we can take that consumers do not always make rational decisions (Kahneman, 2011) and so even if the stated values of a community point towards one outcome, in reality we may face another and we must bear in mind that some decisions be enacted without conscious thought (Kahneman, 2011). In designing the built environment and programmes for communities, we can think about which features will enact decisions from each system, although this may be difficult to predict. For example, if an urban feature is designed in a way that reminds subconscious system one of a threat, we could be less likely to engage in using that space. In terms of green technologies specifically, additional research in the office environment has shown that targeting energy reduction behaviours in appliance use requires specific targeting where behaviours tend to be habitual and automatic from system one (Kahneman, 2011).

In the context of this work in the field of decision-making, we can focus on factors in the frame of either those which can influence habitual decisions, or those which provoke an immediate emotional response.

Subconscious reactions

Secondly, various pieces of literature discuss our subconscious reactions to the physical environment around us. There are a range of reactions linked to specific features of urban areas which have an impact on aspects of our mood and wellbeing, which in turn affects our behaviour. A key example is mental fatigue in urban areas, which studies suggest can be remedied by the presence of nature (Kaplan, 1995). Specific examples of these psychological reactions to spaces we inhabit are explored in a later section of the literature review, on the influence of the urban environment.

External factors

In addition to the internal psychological factors explored above, there are a range of external factors which impact on human behaviours. We have narrowed our review of this literature down to those findings related to the types of factors which are likely to be found on low carbon urban developments. This means that we do not consider factors such as reactions to events occurring around an individual, climate (e.g. temperature) and political context.

Where we get our information from, the quality and reliability of the content and what we do with that information has the potential to influence our behaviour. To a certain extent, information may help to inform people's decision-making and so contribute to ultimate behaviour.

For example, if something is claimed to be detrimental to your health in a tabloid newspaper it will have a different impact to an article in a scientific journal, depending on additional factors such as individual's background, political beliefs, education level, range of information providers etc. Types of community on a site will affect sources of information and the impact that those have.

"Everyone thinks that they can solve the problems by giving out more information" (Guy & Shove, 2000) - presence of information doesn't automatically change behaviour, though. Kollmuss and Agyeman (2002) suggest a consensus amongst researchers that only a small amount of pro-environmental behaviour is caused by awareness and knowledge, and that as much as 80% of the motives for such behaviour are situational or internal (from Fliegenschnee & Schelakovsky, 1998).

So, while information is not the key factor that it was previously thought to be, it still plays a certain, smaller, role interacting with other factors.

Messaging is important, especially in terms of sustainable developments and the way that they are marketed and managed. “A holistic perspective in the vision and the overall objectives and the need for stakeholders to share a common vision; a clear follow-up process; and strong political incentives and supportive measures” (Yin, 2014) are all important in ensuring that information contributes towards the success of environmentally-driven policies and practices. For example, strategic early information on the environmental profile and clear unambiguous definitions are required to strengthen enforcement and legitimacy of objectives (Yin, 2014). Norm-based messaging (Ferraro, 2014) helps to ensure longer-term behavioural trends.

In the modern world, technology and networks are an increasingly important part of life and so “the internet, its representations and the different ways that people move through and engage with it, are integral to the processes through which it may become implicated in the making of interventions that will lead to a sustainable future” (Pink, 2012). The whole structure of society is now a network society, powered by “microelectronics-based information and communication technologies” (Pink, 2012). Therefore, there is a pressing need to “think in terms of forms of interrelatedness, of practices, of online platforms and of the offline environment (and its affective, material and sensory dimensions) that any user is in at any time” (Pink, 2012), to truly understand the way in which information is being accessed and may be affecting their decision-making and behaviour. It is important to remember, however, that “information alone cannot address the diversity of barriers that exist for most sustainable behaviours” (McKenzie-Mohr et al., 2012). Combined with peer group influence, new online communities are beginning to play a key role in the way in which groups of people behave.

This research is of particular relevance to our community smart meter example technology, which we will explore later, as it is a feature focusing on behaviour change through display of energy information to users. It also allows comparison with neighbours through a virtual community comparison space. The way in which this information is presented will have varying effects on the above in line with the considerations above. There is additionally a challenge in the volume of easily accessible information now available digitally, providing more routes to information as well as less quality control over the reality of the content people read.

Social factors

The way we interact with those around us and are influenced by the society in which we reside can have impacts on our behaviour. In this section we focus on norms, values and attitudes; peers and community; demographics; and lifestyle and routine. In order to focus the study on the interaction between individuals in communities in relation to their experiences in the built environment, our focus is specifically on interactions related to low energy and carbon behaviour, rather than other aspects of interactions and relationships.

Demographics

The demographic make-up of the residents or users of a site will have an impact on the types of behavioural patterns found in relation to green technologies. Specific demographic groups will be influenced differently by each of the factors of influence on behaviour explored in this section. Demographic groups link in with culture, norms and values and so it is important to remember that "two different groups can live in very similar environments yet have very different behaviour, because the effects of their surroundings are filtered through their culture" (Gallagher, 1993).

Demographic factors such as age, occupation, dependents and where someone is from can all have an impact on the factors in the remainder of this section. For example, transport routines will differ according to occupation and dependents. It is, however, unhelpful to generalise based simply on these criteria, since there is a whole spectrum of individual experiences as a result of interrelated factors.

Norms, values and attitudes

There is a growing consensus that individual and community behaviours are affected by norms, values and attitudes (Stern et al., 1995, Darnton, 2008). Indeed, environmental attitude has been found to be "a powerful predictor of ecological behaviour" (Kaiser et al., 1999) and indeed in 1995 Grob had found that "thirty-nine per cent of the variance in environmental behaviour was explained by the attitudinal components" (Grob, 1995).

Definitions:

Norm: "A standard or pattern, especially of social behaviour, that is typical or expected" (OED)

Value: "Principles or standards of behaviour; one's judgement of what is important in life" (OED)

Attitude: "A settled way of thinking or feeling about something" (OED)

One school of thought in this area is that if we can tap into what is behind motivation to act in a certain way, we can encourage certain behaviours, as "to achieve radical behavioural change... we need to shift focus away from focusing on people's self-interest and instead try to actively engage values that are related to sustainability" (Global Awareness in Action). This could however also be a part of self-interest if that concerns "enhancing the resource base and its life – thus enhancing, rather than destroying, planetary eco-systems and plant and animal species, including ourselves" (Trudgill, in Guy & Shove, 2000). This is a different perspective to Kahneman's fast and slow systems explored above, which suggests that even if we achieve buy-in through linking actions to values, the decisions of the subconscious brain could override this - we cannot rely on human rational decision-making at all times.

The aim in researching norms, values and attitudes is to explore the specific type of impact these have on the way individuals and communities make behavioural decisions further. While understanding that part of our decision-making we cannot control, research shows that values have a causal relationship with behaviours (Thogersen & Olander, 2002). By understanding better the individual (Pink, 2012) and their motivations, we can start to see what drives group change. Rather than seeing established norms, values and attitudes as "obstacles" (Guy & Shove, 2000), we can look at how to tap into these to encourage choices that are better for the environment while tying in with people's personal value systems, in line with beliefs and strengthening existing or new social norms. There is evidence to suggest that where consumers have internal environmental attitudes, they are more likely to make green purchases and are likely to have high product satisfaction, in addition to the finding that "an outwards environmental attitude facilitates the adoption of a general environmental behaviour" (Leonidou et al., 2010). This shows us that by building environmental attitudes, we can enhance likelihood of green behaviour and that those in our behavioural groups with high levels of environmental attitudes are more likely to behave in a sustainable manner.

Defra's environmental segmentation model (shown above in figure 3) "divides the public into seven clusters each sharing a distinct set of attitudes and beliefs towards the environment, environmental

issues and behaviours" (DEFRA, 2008). A similar approach will be taken in this project, through the grouping of individuals with similar behavioural traits within the samples of demographic population groups for the make-up of the North West Cambridge site.

A simplified example in line with DEFRA's findings might be that if we have labelled a certain group with similar values and attitudes towards the environment (amongst other factors – see Methodology) as, for example, "keen green" – where they are interested in environmentally-beneficial behaviour and have the potential to achieve it – we can then start to look at how likely they are to use an electric car charging point compared to other groups. They are more likely to invest in an electric car and believe in using greener energy, so are likely to be able to achieve a much lower carbon outcome in this area than other behavioural groups. There is a limit, however, on how well such methods can represent the full variety of individual experiences within a population, and the method of grouping will have an impact on the resultant clusters.

Young et al (2010) also highlight the issue of the 'attitude-behaviour' or 'values-action' gap, where consumers state a preference for greener products but then do not follow this in their purchases (in Carbon CAP, 2015). This fits in with the idea that, particularly in this field, consumers do not always make rational decisions (Kahneman, 2011) and so even if the stated values point towards one outcome, in reality we may face another. This presents a particular challenge in terms of predictive analysis based on qualitative data from a sample population.

As well as the psychological factors, we also think again about the environment in which decisions are being made (Global Awareness in Action). The core pro-environmental values, attitudes and norms may be present, but only triggered and brought to the front of decision-making by certain environmental factors such as presence of visual signals. This will be discussed in further depth in the Visual Signals chapter of the thesis.

Peers and community

We live our lives surrounded by other human beings and often adapt our behaviour to fit with the norms, expectations and reactions of those with whom we have close relationships. It is therefore worthwhile exploring the influence of peer and community groups on the behaviour of individuals on a site.

The types of community present on a site will affect the ways in which residents interact, establish norms, values and habits and ultimately behave. It is suggested that 5-20% savings can be achieved on energy from community-based initiatives (EEA, 2013). This may not translate exactly to the communities which will be found on sites such as North West Cambridge, where the accommodation available influences the demographic group present in the community, which will in turn have an impact on the types of behaviour exhibited in relation to green technologies.

Strength of community relationships and the presence of pro-environmental attitudes can affect the success of policies and programmes, according to The European Environmental Agency's report (EEA, 2013). There is agreement between the European Environmental Agency, the Carbon CAP report series and Gillich's research on the importance of the influence of community role models in encouraging participation in green incentives and the "need to identify opinion leaders and demonstrate (advertise) their shifts in behaviour" (Carbon CAP, 2015), in order to galvanise behavioural change from whole communities. This is explored in the survey and behavioural grouping aspects of this thesis.

When we have established groupings from our data based on current behavioural habits, the role of communities as "incubators for positive change in social norms and behaviours" (EEA, 2013) can be explored to gain insight into what causes individuals to change their behaviour, to become more environmentally-friendly. However, community figures could equally influence environmentally negative behaviours within a community.

Introducing social practice theory

Exploring how behaviours are established, maintained and developed through social networks

Social practice theory provides us with a means to analyse the operation of communities. In doing so we start by looking at patterns of behaviour, or practices, across the population. Social practice theory – set out in Giddens' view that "the day to day activity of social actors draws upon and reproduces structural features of wider social systems" (Giddens, 1984) - and the theory of planned behaviour, allow us to explore the "complexities of human social behaviour" (Ajzen, 1991). In our study we want to know how to encourage environmentally beneficial behaviours across a site's population and social practice theory says that the development of practices themselves leads to

behaviour change (Warde, 2005). Below we explore the ways in which if we create spaces for community to form, practices will develop and behaviour will change.

The social and physical environment in which practices begin to form will have an effect on the type of actions established. In this context "the density and character of social bonds is important for how practices travel and for the populations they encounter and attract" (Shove et al., 2012). Daily interactions form the basic interactions which build up to form communities which find shared interests and begin to form practices. The closer these bonds become, the more likely neighbours are to copy behaviours of those around them.

In academic communities in particular, there is an increased opportunity for 'social learning' through increased access to research, knowledge, educational opportunities and change-makers. Universities have a unique ability to change values, norms and processes due to their large variety of actors (and stakeholders e.g. industry) with different interests and knowledge (Sedlacek, 2013 and in Siebenhüner and Suplie, 2005; Luks and Siebenhüner, 2007). It is however, unclear whether communities in such spaces take the opportunities for 'social learning' to make changes to their own behaviour. On the NWC site the community will be academic by majority and so is a good case study in which to test such theories.

Routine and lifestyle

The patterns of everyday actions and movements of residents on a site will have an impact on the way they behave in relation to green technologies on the site. Established routines may make it easier or more difficult to establish regular and effective interaction with certain technologies and certain types of lifestyle (e.g. working from home, families) may demand greater energy use.

In considering how to ensure that green habits stick, "the challenge is one of imagining and realising versions of normal life that fit within the envelope of sustainability and that are resilient, adaptable and fair" (Shove & Spurling, 2013). There is however flexibility within routines and practices as "they are dynamic by virtue of their own internal logic of operation, as people in myriad situations adapt, improvise and experiment" (Pink, 2012). On a new site there is a unique opportunity for residents to start afresh with new habits.

We can take examples of everyday activities or routines to investigate the formation and role of practices in daily life. For example, the laundry context has been used as a study of energy consumption (Pink). Especially in the realm of sustainable development, we must consider that some individuals or communities take on certain practices purely because they tie in with their environmentally-friendly values and desire to "save the planet" – and so for them "doing activism is itself an everyday life activity, often performed in environments such as homes, gardens or local neighbourhoods" (Pink, 2012).

Given the predicted demographic breakdown of the site (based on accommodation lots) we can already have an idea of the basic everyday practices upon which the residents on the NWC site will build up their new lifestyles. These will impact on the time and action cycles of the facilities and urban space. For example, post-doc and postgraduate students are likely to spend most of the working day in university departments. Later on in the day more residents' activity is likely to be based on site. Routines will have a particular impact on transport systems within a site and it is important that well-connected low carbon transport options are embedded before high-carbon transport habits are formed (Hall, 2014). Susilo et al. found that the availability of residents' cars reduces the number of public transport and active travel trips (Susilo et al., 2012). Other factors such as taking children to school or including regular exercise in a routine will contribute to the use of certain features within the site.

One particular piece of research into transport mobility patterns has focused on behavioural groupings and one of the attitudinal clusters, named "consistent green travellers" suggested by Prillwitz and Barr (2011) closely matches our main projected site population. They suggest that this group are "often young professionals, [who] walk and cycle more" (Prillwitz & Barr, 2011). We can check this against our study population travel data in due course, taking into consideration the local data on this too.

Transport is a key part of routine to influence as it can account for a large portion of daily individual carbon emissions if energy-heavy options are chosen over lower or carbon-free alternatives. There is potential here in terms of cost too, as "The EU POLFREE programme correspondingly notes housing, food and mobility as the three most resource-intensive sectors (POLFREE P3.2 p9) and notes that wider resource concerns amplify the 'public good' benefits that could flow from policies to reduce resource consumption associated with these sectors" (Carbon CAP, 2015), focusing especially on transport, where "the lowest income quintile often spends around 8% of their total expenditure on

transport in most European countries" (Carbon CAP, 2015). Active travel (walking, cycling and other forms of people-powered movement e.g. skateboarding) is often promoted to address many of those concerns[4] and as such has been chosen as one of the key green features to be included in our analysis.

It is important to remember that policies and practices cannot be implemented in isolation from existing lifestyles and routines of residents living on a site, as "making interventions are not detached from what and who we are – they are processes we are part of" (Pink, 2012). We may conclude that "therefore everyday life is a context of human creativity, innovation and change and a site where processes towards a sustainable future might be initiated and nurtured" (Pink, 2012). If the site itself allows for and even encourages the development of sustainable practices and routines through its urban design, policies and programmes in place, it is likely to have more positive environmental outcomes.

Motivations

We know that it is not only financial motivations which influence interaction with programmes by consumers and that non-price motivated policies can have the same impact as those which are price-oriented (Allcott & Mullainathan 2010 in Carbon CAP, 2015). Other possible examples include "commitment devices, information provision or attentional devices, appeals to social norms or apparently small changes to prices, default options or transaction costs" (Carbon CAP, 2015). It can, however, be difficult to differentiate the impact of any one particular influence in an individual's decision-making.

In different demographic or behavioural groups, certain motivational factors will be stronger. For example, we know that in groups representing 'green attitudes', the primary factors affecting product choice were:

1) Environmental performance
2) Product manufacturing
3) Second hand availability (Carbon CAP, 2015)

[4] E.g. in Dutch towns discussed in "Good Cities, Better Lives - How Europe Discovered the Lost Art of Urbanism" Peter Hall (with contributions from Nicholas Falk), Routledge, 2014, Oxford

Getting the presence of motivational factors right for the groups present on a site is key to driving the early adopters towards behaviours that "will influence those further up the technology diffusion ladder" (Carbon CAP, 2015), as use of technologies moves outwards from the original users.

The DEFRA "Framework for Pro-Environmental Behaviours" (2008) followed a social marketing-based method to set out key behaviour goals, then assess people's willingness and ability to act on them. They established various common motivators ('feel good factor', individual benefits, being part of something, ease, social norm), barriers (external constraints, habit, disempowerment, scepticism) and crossover factors (lifestyle fit, self-identity) within the population sample, based on attitudes and built up with other variables. They clustered the UK population into seven population segments (using cluster and factor analysis of survey data combined with an algorithm – see methodology for further information), within which individuals shared "a distinct set of attitudes and beliefs towards the environment, environmental issues and behaviours" (DEFRA, 2008). This type of study is valuable for understanding the range of motivations across a population, as well as the key things within and between groups. We will explore this study in more detail in a later section.

Nudge theory

Nudge theory, coined by Thaler and Sunstein (2008), puts forward the notion that we can use certain tools to improve individuals' decisions in a variety of contexts, to encourage societally beneficial behaviour. Rather than using design to force people into making certain decisions, gentle nudges are used to make 'good' choices easier.

One definition of a 'nudge' is "any aspect of the choice architecture that alters people's behaviour in a predictable way without forbidding any options or significantly changing their economic incentives" (Thaler & Sunstein, 2009). It must be easy and cheap to avoid (Thaler & Sunstein, 2009). Nudging is seen as one of the key ways in which policymakers can put features and policies in place which aim to encourage more environmentally-friendly behaviour without demanding it by enforcement. However, this fairly light-touch approach does still leave the question open that "for environmental problems, gentle nudges may appear ridiculously inadequate" (Thaler & Sunstein, 2009). We must consider whether nudge theory can be applied to contexts on a larger scale – such as the built environment streetscape, as an environment in which decisions are made.

On a site such as North West Cambridge there is the potential to use nudges to encourage adoption of 'better' choices in everyday practices, which in turn contribute to energy and carbon reduction. Some Nudge (Thaler & Sunstein, 2009) examples include: "commitment devices" which help people make decisions that conform better to their long-term goals" e.g. saving money, "subtle changes in default options and the framing of decisions" e.g. opt-in vs. opt-out, "applications of norm-based messaging, goal-setting and technology that reduces decision costs" e.g. community energy comparison, free attic clearing and insulation[5]. Especially in initial plans and marketing literature, many sustainable urban development sites are described as being based on a principle that the design should reflect that the natural choice for people should be to walk, cycle or use public transport for their travel needs (see Nordhavn). For example, in the case of Hammarby Sjöstad, embedding design which encouraged the use of public transport and active travel infrastructure from the beginning helped reach a point where "two-thirds of all trips were made by public transport, bicycle or walking"[6]. This can be taken as design of a site-wide series of urban design nudges to encourage active travel.

In a policy context, sometimes "shoves" are implemented rather than subtler nudges, if there is a sense of crisis around the issue (Ferraro, 2014) and an urgent need to address behaviour (e.g. governments). There is a danger here though that "governments are likely to allocate their resources in a way that fits with people's fears rather than in response to the most likely danger" (Thaler & Sunstein, 2009). Policies need to fit into a strategic framework linked to overall carbon and sustainability targets, to have the best outcomes.

In terms of take up of technology itself, the way things are framed has an impact on action taken (Thaler & Sunstein, 2009). Creating defaults by including technologies in the construction of homes, for example, can have a very powerful impact (Thaler & Sunstein, 2009). However, this does raise a question of whether a resident using a technology because it has been 'imposed' upon them is true take up. In this case it will be deemed that there is no active take up of the technology, as no individual choice is involved.

[5] See also British Behavioural Insights Team (BIT) "The Nudge Unit" in "The Road to Sustainability: More Nudging, Less Shoving" – Paul Ferraro

[6] From 2005 survey of residents, quoted in "Good Cities, Better Lives - How Europe Discovered the Lost Art of Urbanism" Peter Hall (with contributions from Nicholas Falk), Routledge, 2014, Oxford

There are many factors affecting behavioural take up which we have explored in the other sections. Nudge theory is particularly relevant in this context and central to this research. Human interaction with technologies may be less effective where they do not get feedback on the environmental consequences of their actions, where there is no good nudge to encourage choices with delayed effects and where loss aversion is not overcome, meaning that people have a strong desire to stick with their current holdings (Thaler & Sunstein, 2009) and are less likely to take up new technologies or behaviours related to them. These barriers may minimise the impact of nudges in this context, or require them to be combined with a range of other instruments to have the desired effect.

Another consideration is the practical means in which this change is encouraged. "If you want to nudge people into socially desirable behaviour, do not, by any means, let them know that their current actions are better than the social norm" (Thaler & Sunstein, 2009) as their research has shown that those who become aware they are performing 'better' than the social norm tend to end up lowering their performance as they perceive leeway in their performance. Conversely though, if they are shown a simple positive visual signal alongside this indication of 'better' performance, e.g. a smiley face on an energy bill, they are likely to retain their 'good' behaviours (Sustainable Homes, 2014). This is applicable to the outcomes we might expect in terms of use of the community smart meter in our behavioural scenarios. Social practice theory gives another method of encouraging certain norms to form, explored later in the literature review.

Behavioural groupings

Being able to group individuals according to certain characteristics in relation to what influences their behaviour allows us to investigate how each of these groups may interact with technologies, the potential they offer in terms of energy savings and the likely spread of a site's population across the groups.

DEFRA produced a key model (figure 3) of population segments (DEFRA, 2008) which is a good demonstration of how to categorise and compare established groups in terms of the best ways in which to encourage them with policies, programmes and urban design features. The groupings here are placed on the chart according to their 'willingness to act' and 'ability to act', with the idea that appropriate policy steps can then be addressed to each type of group according to where they sit on the scales. Grouping the population within a study enables a strategic approach to solutions which can be tailored to groups rather than one-size-fits-all, or on an individual basis, saving resources but

aiming for more effective outcomes than a blanket approach. However, it should be noted that DEFRA's model was built based on attitudes because of the existence of the attitude-action gap (DEFRA, 2008) – where there can be a difference between an individual's attitudes and the behaviours they undertake in reality.

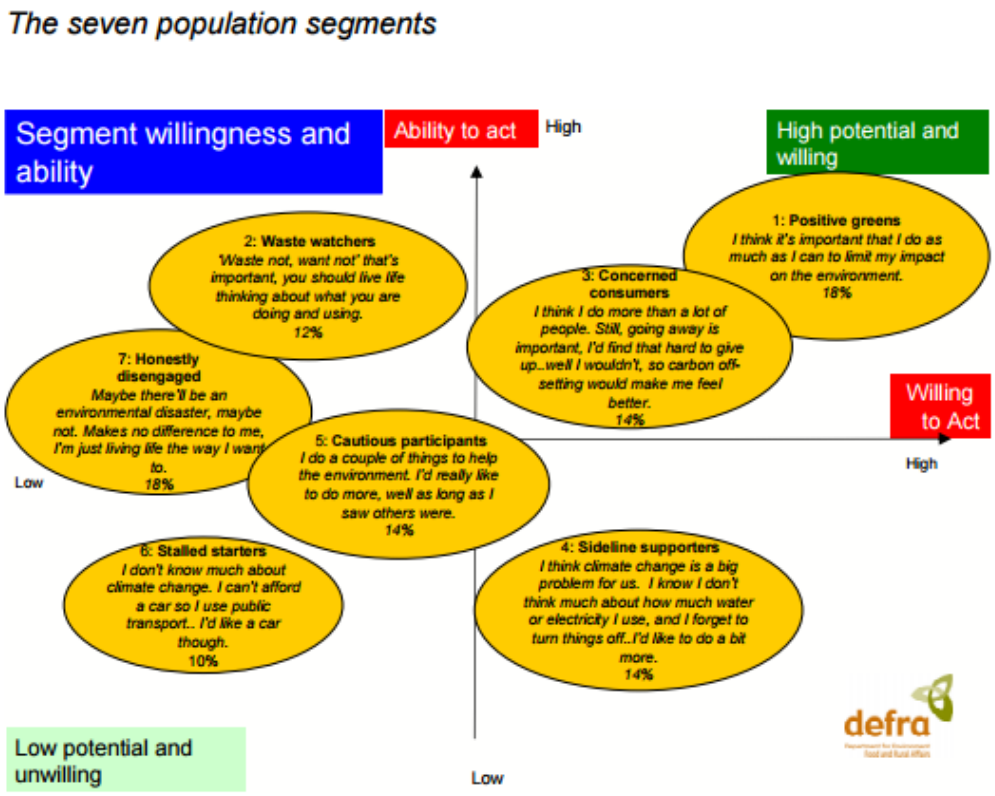


Figure 3: Model of the Seven Population Segments (DEFRA, 2008)

2.3 Human interaction with technologies

Introduction – moving beyond the techno-economic paradigm

Through the techno-economic paradigm (Guy & Shove, 2000), historically it was considered that technological efficiency improvements alone would be all that was required to reduce our energy consumption as individuals, communities and nations. Without having to consider human behaviour in the equation, it was thought that we should still be delivering energy savings year on year.

If we can influence the behaviour that individuals and groups exhibit when interacting with green technologies, we can help to increase use of energy-saving features on developments and so reduce

overall energy and carbon emissions. There are, however, several elements to this interaction which should be considered in this context.

Technology performance gap

There is an additional issue affecting technology stand-alone performance – the performance gap – whereby the design expectations in terms of energy efficiency are not met on completion and in use of the building or technology. For example, in a study of the impact of energy-saving measures in homes, Scheer (et al.,2013) still found a shortfall of approximately 36% in actual figures compared to what was expected technically.

Much of this has to do with construction techniques and monitoring of building quality and performance, but it is also a matter of calculations for energy performance underestimating the negative or positive impact that human interaction with the technology has in use. Where technology stand-alone performance can be improved upon by advancement of manufacturing, construction and monitoring, the human behaviour element is much more difficult to predict and rely upon to deliver energy efficiency.

One attempt to tackle this issue has been to design buildings at the very highest energy efficiency specification available, with the aim of minimising the adverse impact that human behaviour may have on energy-saving outcomes. A recent study (Foulds, 2013) focused on the use of practices (repeated routines as opposed to individual activities) in human behaviour in determining the impact of Passivhaus developments, in light of the performance gap phenomenon. The Passivhaus standard requires that dwellings are built in a specific way that minimises the input required by the resident to achieve energy and carbon savings, however there can still be a large difference in energy use due to variations in occupant behaviour (Tweed, 2009). This particular topic is explored in further detail in the Methodology and Results chapters, as findings from Passivhaus literature are used in the external dataset.

Other early attempts to increase energy efficiency in buildings and technologies have focused on the premise that if you give people more information on how a technology works and its impact there will be increased reliability of human actors in the delivery of optimum performance. Research across the fields of green technology use and behaviour, sociology and environmental psychology has shown this not to be the case, where many social conditions affect how information is perceived

(Owens & Driffill, 2008) in addition to a range of other social factors which will be analysed in the following sections of this report.

Socio-technological interface

The more recent debate in technology and human behaviour is set out succinctly by Janda (2011): "Buildings don't use energy: people do". As Cherfas (1991) put it, "we have analysed energy. We should have analysed human behaviour", for it has been proven that human behaviour plays a large and important role in shaping the impact of technologies used in everyday life (see Janda, 2011; Tetlow et al.; Chatterton, 2013 and Clarke, 2010). Previous research has shown that on a practical level, "In industrialised countries, about 45-55% of total energy use is influenced by consumers' activities" (Schipper et al., 1989). The scale of boundaries which are drawn around what counts as an individual's energy consumption will, however, affect such projections (e.g. should energy used in construction of homes be counted per occupant?).

There is a body of emerging literature on the impact of behaviour on various individual green technologies, for example around smart meters, which are used in a much more complex system of aesthetics, power dynamics and social settings than simply as a rational relationship between individual and machine (Hargreaves, Nye, & Burgess, 2010). Indeed, as we move further from the economic assumption of rational human choices, further attention is being paid to the factors surrounding those decisions that we do make and why.

There is a common conclusion now that "behavioural changes may be needed to reach the emissions targets and that the targets may be reached at lower costs if behavioural changes are achieved" (Carbon CAP, 2015). Later sections look in more detail at what these changes constitute and how we create the factors which influence them through policies, programmes and the built environment.

The influence of human behaviour

The issue of the 'value-action gap' (Blake 1999) is of relevance to our study as it looks at why we often do not do what we say we will. In other words, human beings often have a different perception of their behaviour to what we observe in their actual behaviour. This is a complex issue

and one which we can attempt to mitigate for in our study, but cannot address fully due to the scope required.

In our study we look at "pick up" or "take up" rates of technologies, which can refer to two different processes in the green technologies field. Firstly, this may refer to the take up of a technology – the active steps taken for an individual to become a user of a technology. It is important to note here that an individual may have already been 'opted in' to using a technology by default, predetermined by the nature of the built environment (e.g. where a technology is built into a house that an individual moves into). The second use of take up refers to the pick up of certain behaviours which are relevant to the use of a technology. This, again, is an active choice of an individual to assume a set of behaviours in their interaction with that technology. The focus in this research is on the second – the take up of behaviours, however information on the take up of technologies is required to look at the second aspect.

In terms of take up of technology itself, the way things are framed has an impact on action taken (Thaler & Sunstein, 2009). Creating defaults by including technologies in the construction of homes, for example, can have a very powerful impact (Thaler & Sunstein, 2009) in terms of take up. However, this does raise a question of whether a resident using a technology because it has been 'imposed' upon them is classified as true take up. In this case it will be deemed that there is no active take up of the technology, unless some aspect of individual choice is involved.

There are many factors affecting behavioural take up. Nudge theory is particularly relevant in this context and central to this research. Human interaction with technologies may be less effective where they do not get feedback on the environmental consequences of their actions, where there is no good nudge to encourage choices with delayed effects and where loss aversion is not overcome, meaning that people have a strong desire to stick with their current holdings (Thaler & Sunstein, 2009) and are less likely to take up new technologies or behaviours related to them.

There are many ways of attempting to increase take up of technologies and the associated behaviours required for efficient use. Many of the resulting policies are consumer-based. Critics would, however argue that this can be problematic at times as policies should not "have the effect of wholly 'individualising' responsibility for the environmental crisis solely on end-users" (Carbon CAP, 2015), where end-users are just one part of the system and a part in which (seemingly irrational) behaviour plays a large part, providing a lack of control over outcomes.

Green technologies

In this thesis we define green technologies as a "technology whose use is intended to mitigate or reverse the effects of human activity on the environment" (Oxford Dictionary). While this could cover a wide range of examples, we narrow our focus to those suitable for placement on a new build site.

In the context of new developments, green technologies can exist as part of buildings, or the spaces between them. Kilbert (2016) set out a three point rationale for creating high-performance green buildings: that they set out an ethical and practical response to environmental sustainability, that they almost always make economic sense (despite higher initial costs) and that they recognise the impact of the building on human health. There are three main relevant categories into which we consider green technologies: plug load, heat and transport (for more information on categorisation/features of different technologies see the Carbon CAP reports, 2015). In this section we explore key examples of each, and how they relate to human behaviour and energy saving.

Plug load

By plug load, we refer to technologies which are related to electrical supply.

Photovoltaic arrays

Solar panels are one of the most known renewable energy generating technologies. Parida et. al. (2011) see solar energy as "the most abundant, inexhaustible and clean of all the renewable energy resources".

There are two different kinds – solar thermal heats water, whilst photovoltaic panels generate electricity (GreenMatch). While initial set up costs can be high, there is now a trend towards these being included in the construction of new buildings, rather than added later by the purchaser.

Smart meters connected to community intranet

Smart meters "a system that includes an electricity or gas meter plan an in-home display which will provide near real-time information to consumers on their energy consumption" (Energy Saving Trust, 2013). These have been designed to give easy access to information on energy and gas consumption in households, to encourage people to consider their consumption and hopefully adapt behavior in light of that knowledge (see information section for why this may not be as simple as that). In some cases these are being designed to connect via the internet to other homes in the

neighbourhood, meaning that the programme can become a collective endeavor – perhaps using tools of comparison or community targets.

However, there are certain challenges in terms of resolving concerns about the availability of this information, getting people using the technology and keeping users engaged beyond the 'honeymoon period' of the new device (Energy Saving Trust, 2013).

Heat

District heating (CHP source)

District heating is a system whereby buildings across a neighbourhood can all be served by a network of pipes for heat supply from a central source (Lund et. al. 2014), creating economies of scale. In some countries, particularly in Scandinavia, this system is widespread e.g. "46 per cent of the Danish net heat demand is met by district heating" in a scenario-based study (Lund et. al., 2010), but in the UK it is not yet commonplace. This system can be combined with a renewable energy source to have the biggest energy and carbon savings. Due to the network nature, however, this is easiest to implement at the start of a development rather than retrospectively, although the energy source can evolve.

Natural ventilation/cooling

Also known as passive cooling systems (and often an integral part of Passivhaus design), these provide an alternative to systems such as air conditioning by careful design of the building and mechanical systems to enable temperature control without excessive energy consumption, reducing a building's cooling load (Santamouris, 2005). The limits of such systems may be tested by increased temperatures due to climate change.

Transport

Active travel

Modes of travel which are people rather than vehicle powered (e.g. walking, cycling, skateboarding etc.) are better for human health due to the physical activity, the environment due to no emissions, the public purse due to costing less than infrastructure vehicle (Public Health England, 2016) and public spaces, due to taking up less room. While the benefits are widely discussed, there is less literature bringing together the ways in which urban design and policies and programmes can be

combined to encourage active travel by communities. This is one of the areas this study will investigate.

Electric car charging points

As climate change has raised the awareness of the pollution caused by emissions from petrol and diesel powered vehicles, moves have been made towards the development of more effective electric vehicles (although this requires that the electricity used to charge the vehicles is sustainably harnessed - Klöckner et. al. 2013). With this comes the necessity to provide charging points. The availability and convenience of using these may determine electrical vehicle purchase and use levels.

Measuring energy and carbon use

This study does not specifically consider the measurement of energy and carbon use, other than in terms of the inputs entered into the Cambridge Retrofit Model. This data, however, originates from external sources, and so we do not broaden the scope of this study to consider the processes of energy and carbon use measurement.

2.4 Decision-making in the urban environment

"The city as environment, the city as a setting for behaviour" Edward Krupat (1985)

Introduction - subconscious reactions to our surroundings

As Krupat (1985) put it, cities “have the potential to pull people apart and to bring them together, to produce constraints and to create opportunities”. In the frame of environmental-social psychology, we can view the city as an environment and setting for behaviour to take place (Krupat, 1985).

Urban areas are often designed with aims of addressing economic or social needs by providing services, premises or accommodation, or with financial incentives through land development value. It can often be seen that buildings are designed for purpose with little concern about the interaction of the building with the urban structure surrounding it, or indeed the people who use it and the space around the building. As the discourse shifts towards improving the interaction of architecture and the spaces between buildings, we find a range of literature emphasising the impacts of our surroundings on a number of aspects of human life. An example of this is the framework of

sustainable behaviours by Williams and Dair (2007) which is the first of its kind to include a wider range of considerations from different fields and how they apply at neighbourhood-scale.

In this section we focus in on the subconscious reactions of humans to features of the built environment, in relation to reactions which will encourage or discourage use of the space and the take up of environmentally beneficial behaviours. As psychogeographer Ellard puts it, "wherever we go, our nervous systems and our minds are massaged by what we experience" (2015) and so the way we design our cities directly impacts upon the decision-making functions of those living in them.

Krupat's perspective of the human experience of the built environment (1985) built on previous work (Rapoport, 1977; Warr & Knapper, 1968) which set out a set of filters through which we experience urban environments: physical (the real world), cultural (meanings we assign to things), and personal or subjective filters. Carmona et al. (2003) suggest that in this study of semiology (or semiotics) – of signs and their meanings – it's important to consider that while the stimuli to the senses may be similar for everyone experiencing an environment, the way in which they react to those sensations will differ.

Visual signals in the urban realm

Everywhere in the streetscape between buildings there are visual features which send signals that encourage us to behave in certain ways. We have chosen to bring this focus into the thesis as a way of considering the behavioural influence of the interaction between the physical spaces and the communities that experience them, in addition to the non-physical factors. These visual signals can be in the physical 'hardware' of the built environment, for example use of materials in facades and surfaces – hard materials such as concrete may send a message of authority and be less welcoming than softer materials - or 'softer' structures such as water features (e.g. underpinning the site plan - Hall, 2014) or visual corridors to a natural landscape.

The type of signage around a site will have an impact on behaviours, but also on attitudes towards ownership of space. For example, a sign marking the street as a shared space between pedestrians and vehicles will have a different effect on behaviour to another saying "no cycling or ball games".

Jacobs discussed the ways in which art can be a very powerful influence in the urban environment:

> *"We need art, in the arrangements of cities as well as in the other realms of life, to help explain life to us, to show us meanings, to illuminate the relationship between the life that each of us embodies and the life outside us. We need art most, perhaps, to reassure us of our own humanity. However, although art and life are interwoven, they are not the same things. Confusion between them is, in part, why efforts at city design are so disappointing"* (Jacobs, 1961)

While many pieces of public art are seen as having a positive aesthetic and sometimes behavioural impact on the urban environment, to have the biggest impact the art must be relevant to creation of everyday sustainable choices and practices in the community using the space. For example, in Amersfoort in the Netherlands, Peter Hall explains that "every phase of the development involved artists who worked with the new residents to achieve a sense of belonging and ownership through the creation of art" (Hall, 2014). This is further explored in the fieldwork, interview and visual signals sections of this report.

While aesthetics in urban spaces are important, we must remember that at their core cities are always growing and changing, they present "life at its most complex and intense" (Jacobs, 1961) and so while we can create coherent aesthetics on a small scale, a whole city cannot be a work of art (Jacobs). Urban design has seen waves of 'utopia' type designs for whole cities, such as the Garden City, City Beautiful and Radiant City movements and while their aims might be honourable, it can be argued that they were "primarily architectural design cults, rather than cults of social reform" (Jacobs, 1961).

Another aspect of creation of environmentally sustainable behaviours is the visibility of green technologies. It is argued that "when the energy solutions blend into the environment, the overall effect is more visually satisfying" (Malmö Stad), however having clearly noticeable technologies is more likely to remind people of their existence, the aim of the technology and how they can use it in their everyday life. Priming is important here – subtle influences (in the built environment in this case) can increase the ease with which certain information comes to mind (Thaler & Sunstein, 2009). If a green technology can additionally be seen as a landmark in an urban area, it can perform a secondary purpose of providing clarity and function to the urban layout (Jacobs). Here interdisciplinary design between engineers and urban designers is important and can result in a situation where "new infrastructure is welcomed, not resisted" (Hall, 2014). However, there is an inherent risk in displaying green technologies – if space users do not find them aesthetically-

pleasing, there may be an impact on how likely they are to engage with it, just as we have explored with urban space design.

Scale and density

The scale and density of an urban environment, as types of passive design, have the potential to contribute to the sense of place – explored as the study of 'phenomenology', looking at people's conception of place (Carmona et al., 2003). As human beings, we interact best with objects which are on our scale – from everyday items which fit the ergonomics of the human body, to other human beings. This has been applied to the built environment in line with the hypothesis that we will be happier in environments at a human scale rather than much larger-scale buildings. There are additionally implications of density in terms of the number of people living in an area (which in turn will impact the viability of social practice development), how this affects the everyday life of residents and their ability to use facilities.

The key example of this is the design of the Disneyland theme parks' main streets, which appear to have been designed specifically to encourage feelings of happiness (Ellard, 2015) and comfort as well as nostalgia for the era of the traditional building design. As Montgomery puts it, "those unused top floors play a visual trick. They have been shrunk to five-eighths size, giving the buildings the comfortable, unthreatening aura of toys" (Montgomery, 2013). Using techniques like this in urban development projects can influence the mood of the population and therefore potentially the behaviour. There is, however, a more cynical side to this. Developers could potentially use such techniques to influence behaviour in ways that remove real human choice from such environments, by distorting the perceived reality of the space.

In terms of density and urban structure, orientation of buildings and street layout provide a good examples of how the design of a space can effect how people experience it. Carmono et al. (2003) suggest that winding streets can provide a greater sense of enclosure and a constantly changing scene. While this can provide interest and more natural variation, too much variety could become overstimulating or for users of the space.

Nature

Nature is perhaps the most written about example of our surroundings having an impact on the way we feel and act. Examples range from physical benefits such as Roger Ulrich's findings from his

experiment showing that hospital patients with views of nature recover more quickly, requiring less pain medication than those who do not (Ulrich, 1984), to psychological improvements such as "heightened mood, a relaxed nervous system and increased ability to focus and attend"(Kaplan & Kaplan, 1989)[7]. Nature has been shown to restore attention through gentle stimuli which allow other functions of the brain to recover, as opposed to the intense stimulation and direct attention required in cities (Berman et al., 2008).

The attitudes and moods of individuals with or without nature around them have also been studied. Kuo and Sullivan experimented with inner city neighbourhoods, showing that those in areas with vegetation felt happier and safer than those that did not (Kuo & Sullivan, 2001). Their emphasis, however, is on regular smaller pockets of nature, rather than one big space (Kuo & Sullivan, 2001), which Hall shows can be achieved through having "at least ten 'green points', such as nesting boxes or wild flowers, in every courtyard in each housing development" (Hall, 2014). There is also evidence that awe in nature can increase pro-social behaviour (Piff et al., 2015). It is difficult to isolate the effect of such influences, however, as often people make a habit of going to natural spaces for leisure purposes – and so may already be in a more relaxed and happy state than they are in day-to-day urban life.

In the context of our study, we can take the findings above to apply to sustainable development contexts by thinking about the positivity that residents will experience in natural settings, which in turn can increase the use of such spaces. As nature also encourages social behaviour, it can help encourage community-building through social interaction and perhaps extend to pro-environmental attitudes, by the means of benefit to others through environmental protection. In this study further research is undertaken on the impact of nature in helping to encourage sustainable behaviour.

Aesthetics

A good example of the impact of aesthetics on urban populations is in the work explored by Gehl, Montgomery and Ellard.

Gehl is known for his work around people in urban spaces. His central finding proposes that people are most attracted to spaces where there are other people (Gehl, 2006), rather than the space itself. One could argue that this means that there is no reason to provide well-designed spaces as people

[7] Quote from "Places of the Heart: the psychogeography of everyday", Colin Ellard, Bellevue Literary Press, New York (2015) p37

only care about who is using them, but it can be argued that you need to create the spaces *for* people to meet in, something to bring them together in the first place. If these spaces are not designed well, people will be more dispersed.

Montgomery and Ellard undertook a study with the BMW Guggenheim laboratory in New York, where they took participants on a walk past a range of streetscapes. Their findings were that humans need some interest in the urban environment – and that this participant feedback matched with the data gathered on their skin conductance levels at the same time. Ellard comments that blank facades "don't work at a psychological level because we are biologically disposed to want to be in locations where there is some complexity, some interest, the passing of messages of one kind or another" (Ellard, 2015).

While this provides backing for the urban design trends in designing places with elements of interest, Montgomery cautions creation of spaces with too much constant interest - "sustained arousal can be hard on your immune system and a combination of high arousal and low effect – in other words, feeling both excited and miserable – is obviously worst of all" (Montgomery, 2013). An example of this sort of space is a busy city centre street with noise and heavy traffic, which demands constant pedestrian attention to avoid dangers whilst crossing roads. Pedestrianised areas are a solution to ease some of the issues within that particular example.

In our study we can apply this logic at the micro-level and think about whether the aesthetic design of green features has an impact on whether individuals will engage with them, due to positive or negative effects of the aesthetics. For example, it is important that community smart meter units in accommodation have an aesthetically good design, in order to fit into the domestic setting and maximise likelihood of regular use by occupants (Lockton et al., 2008).

Design of the home

Individuals spend a large proportion of their daily lives in the home (or in the workplace) and so it naturally will be a significant influence on their behaviours. In this study we focus on the immediate environment of the green technology. In many cases this is outside in the urban realm, but at times we may apply the same principles to technologies in the home. For example, the community smart meter system will be based in the home but extending beyond that to virtual space and community interactions. As with the urban realm, if the design of such features in the home is aesthetically

unappealing, residents are less likely to have positive interactions with the technology (Lockton et al., 2008).

Extending nudge theory to the built environment

You can also break down use-related barriers by enforcing certain behaviours through design. While less subtle than nudges in the built environment, results can be more impactful. An example of this would be providing a comprehensive cycling network directly from residences to public facilities and workplaces (as planned for the Nordhavn development).

Through looking at how the urban environment nudges certain behaviours we can add to the analysis of where behaviours originate. Choice architecture greatly affects our decisions (Thaler & Sunstein, 2009) and so we must also consider how to use urban design in our new developments to construct environmentally-friendly behaviour. There are many examples of this in design of the urban environment, such as the Dutch developments built with no through traffic to encourage active travel close to the home (Hall, 2014) and make private car travel the less convenient option.

In the context of new sustainable development sites, the ability to create physical spaces where communities form has an impact on the types of norms, practices and individual behaviours established on the site. “Choice architects need to know how to encourage [other] socially beneficial behaviour” (Thaler & Sunstein, 2009) in their designing of such sites, both in terms of physical built environment and the policies and practices put in place. For example, “community gardens are less about gardening than they are about community” (Pink, 2012) – giving residents a space to take part in a communal activity also allows for the building of relationships. Where there is a strong community, peer influence in decision-making will be stronger. The need for conformity can produce a very persistent nudge (Thaler & Sunstein, 2009), which may help the site achieve its sustainability targets. The design of the built environment can additionally influence social practices, combining the central theories of this review.

Creating community – social practice theory in the built environment

We are more likely to want to spend time in a pleasant environment and so sustainable cities should be attractive places to live in (Jacobs, 1961). You also want to create a district that “makes it easy to have a green conscience” (Nordhavn), in order that targets may be met. When designing new built

sites, it is important to remember this - “there would be no places were it not for the comings and goings of human beings and other organisations to and from them, from and to places elsewhere” (Ingold 2008 in Pink, 2012) - and plan for social interaction. When we provide high quality spaces for people to go, the aim is that community interaction levels will increase, giving improved conditions for practices to develop and spread.

Spaces for cultural and leisure activities allow residents to utilise public space in their community, taking ownership of the space and developing relationships with other residents. A space can become a place when it starts to mean something for the people who use it and if we pay attention to how this happens (Pink, 2012), we can start to plan the best environments for this.

The closer a community that is formed, the more likely that social practices will be formed, as “practices cannot be understood as being performed in isolation from the wider environments of which they are a part” (Pink, 2012). The practices that form are more likely to be environmentally-beneficial if the urban environment encourages it. If we remind ourselves of nudge theory, “seemingly small features of social situations can have massive effects on people’s behaviour” (Thaler & Sunstein, 2009).

Social communities now form online as well as offline (Pink) and so initiatives which connect people on a site on the internet can also be considered as social spaces and should be designed to maximise their community growth and development impact. This is particularly relevant for our later example of the community smart meter intranet.

It is important to consider what happens if social spaces do not form or begin to deteriorate. Here the social and the physical are linked - “the worse the social climate, the more dilapidated the setting becomes and vice versa. Before long, there are fewer symbols of the individual and group territoriality, from brightly lit doorways to clean sidewalks, that could help turn things around” (Gallagher). It is therefore important to consider the two together in the creation of spaces. If the physical space alone is considered and changed, it may undermine a thriving community. For example: “within what outsiders perceive as an unrelieved slum, convenient shops and services and the frequent crossing of residents’ paths to help shrink an impersonal city down to size, lower stress, promote socializing and provide a forum for attacking problems too big for individuals to handle” (Gallagher). We know that the scale, visual oversight and presence of community members every day in shared spaces can improve safety and quality of the urban environment (Jacobs, 1961).

In regeneration it is vital to consider the social paths that the area provides, regardless of the outsider's perceived quality of the urban environment. Better social practices could exist in that environment than should the urban realm be updated and the community bonds weakened, reducing the opportunities for social practices to spread. While in a new build site, the urban form has another purpose of community creation. It is important to get the urban design right from the start so that it enables strong communities to form. Taking crime rates as an example - "It's not the fixtures – the lights, the shrines, or the flowers – that prevent crime, but the social dynamics that drive and are driven by these environmental features" (Taylor in Gallagher, 1993).

In this study, social practice theory provides the community link between urban design and other influences on individual behaviour, and the realisation of a site-wide prevalence of such behaviours, with the result of energy and carbon savings.

2.5 Policy Framework

Introduction - policies and programmes

Policies and programmes may be created by national governments, local authorities, NGOs and charities, resident groups, campaign groups and educational initiatives amongst others and can range in formality and scale. The primary purpose of environmentally-friendly policies and programmes is often to achieve a certain energy or carbon outcome, through influencing a set of 'desirable' behaviours by the target group. There is a wide variety of policies and programmes which require instruments to be put in place on a site, with the designer or owner of the policy, time scale and content having varying success rates in terms of achieving their goals. Various factors will have an impact on resident engagement in the related instruments – e.g. regulation, cost, social status, time, routine, tradition, perceived or experienced effectiveness and demographic groups.

Policies and programmes create the backdrop to this study, being considered in the scenarios entered into the model. Instruments used in such policies (the part that engages people in changing behaviour) are used as inputs to the scenarios run through the model. Policy, programme and instrument recommendations can be put forward as a result of the project, tailored for scenario outcomes with the greatest energy and carbon-saving potential.

Example types of policy or programme:

- Information or awareness-raising projects
- Energy pricing or efficiency incentives related to accommodation
- National carbon reduction targets
- National schemes e.g. Green Deal (UK Government Green Deal)
- Environmental campaign group community challenges/commitments
- University-wide schemes e.g. Green Impact Awards
- Programmes related to the proposed community energy-monitoring intranet on the NWC development
- Schemes which act as determinants of transport mode choice

Government and policy makers have important roles in terms of what they choose to implement (or not) in terms of policies and programmes on new build sites. Policies can be financially driven, regulatory or voluntary to take part in. The nature of the specific policy, context that decisions about participation are made in (Barr et al.) as well as the specific demographic groups it applies to will affect the strength of the outcome.

As explored in the previous section, there is growing awareness that the techno-economic paradigm is simply not delivering the change that is needed to meet energy consumption targets (Guy & Shove, 2000) and so policies and practices targeting human behaviour must be implemented to have a chance of achieving carbon savings.

In 2008 DEFRA suggested that governments should "use the mandate for action: in terms of public understanding and attitudes, there is a mandate for government to take action – not to force radical changes into people's current lifestyles so much as to help "green" those lifestyles and reduce their overall negative impacts, for example in terms of investment in the provision of more sustainable energy and transport services or in the "choice editing" of products" (DEFRA, 2008).

In terms of practical implementation, policy makers and other actors, past and present, can and do influence:

a) The range of elements in circulation
b) The ways in which practices relate to each other
c) The careers and trajectories of practices and those who carry them
d) The circuits of reproduction (Shove et al., 2012)

Considering the above, policies and programmes should reflect this range of factors in influencing environmentally-friendly behaviours.

Urban environment planning falls under the remit of governments and decision-makers (such as planners, architects and developers). We have already explored the importance of the urban environment in influencing behaviour, as in terms of the subject area of this thesis, this is one of the key areas in which policies and programmes can have an impact on ultimate carbon outcomes. An example of this is that "planning needs to create an urban environment and a structure that supports major expansion of public transport, promotes walking and cycling and leads to only limited use of the car" (Stockholm City Plan, 2010) to reduce emissions from private vehicle use.

There is, however, still some debate over the popularity of environmentally-friendly measures. For example, "the fact that a group of energy-efficient homes failed to sell faster than similar 'conventional' properties confirms the view that energy-related features are generally ignored" (Guy & Shove, 2000) and cost considerations may come ahead of 'green' considerations.

However, in terms of developments themselves within the market, cities are starting to invest in 'people-friendly' infrastructure as a means of encouraging use of public space, to the advantage of the economy as well as the environment and social groups. One example comes from Stockholm's vision of becoming a walking city:

> *"in an increasingly internationalised world, a people-friendly urban environment, a rich variety of housing and workplaces, well-developed services and a broad range of culture and entertainment are becoming ever more important in gaining a competitive advantage"*[7].

The policies and programmes put in place also must reflect the particular political, social and geographical environment in which they will be implemented. For example, in Sweden there is a climatic house building season which requires flat pack parts for quick building. This means that there can be a direct influence on insulation levels across the sector – allowing for the flexibility in the climate (Guy & Shove, 2000).

As exemplified in the following and previous sections, there is clear consensus that to drive the most effective, long-term behaviour change, a package of instruments must be put in place which complement and support each other (Carbon CAP, 2015) while tackling the different barriers to uptake.

Points of intervention

There is a range of different points of policy intervention, as set out in the Carbon CAP reports:

1) "Government or private sector policies aimed directly at final consumer choices
2) Government or private sector policies aimed at intermediate consumption stages in the production chain – i.e. affecting corporate choices and the characteristics of products sold on through the supply chain
3) Policies and procedures – often by corporate or in support of corporate initiatives – that affect overall supply chain management, largely down to procurement policies of the large corporations which affects the range of offerings to final consumers in the consumer-facing organizations" (Carbon CAP, 2015)

In this project we are concerned mainly with those aimed directly at the consumer, although there may be certain instruments which could be considered to interact with the supply chain.

Combining instruments

There are different theories on what the best combinations of policies are for achieving the most behavioural change. Bocken (2014) suggests that a policy suite is "most impactful when it influences multiple facets (individual incentives, social normalization, availability/access and control) simultaneously". The Carbon CAP report concludes that "there is no one-size-fits-all approach and that instruments need to be appropriate to the consumer product and supply chain characteristics of the sector concerned" (Carbon CAP, 2015). Consideration should be taken to understand the interaction of different instruments in place, or influencing, the population of the same site, and how these could be targeted to maximise areas of impact of common interest.

An example from Bocken (2014) on the classification scheme for the programmes developed by M&S and other consumer-facing organizations (Carbon CAP, 2015) shows a combination of instruments used together to drive change:

- Informing[8]: providing information on implications of consumer choices but not directing
- Positively directing[6]: incentives for lower carbon products
- Negatively directing: dis-incentives for higher carbon products

[8] there is evidence that these are less effective, but are the methods used most often (Carbon CAP, 2015).

- Forcing: banning high carbon products.

The scenario approach allows for combinations of instruments to be put together and tested for ultimate carbon outcomes, so that we can investigate which combinations would work most effectively with a certain demographic make-up on a site.

In our study we will look to analyse the types of influence policies are likely to have on our sample population and therefore recommend combinations of programmes which encourage the type of interactions with green features which we need to see for energy and carbon reductions across the site.

Social practice through policies and programmes

Policies and programmes can be put in place which have an aim of establishing social practices which encourage a less resource-intensive way of life to take hold in a community (Shove & Spurling, 2013). An example of this is when the District Council in Aylsham, UK supplied a non-plastic bag to each household as part of the policy to make the town plastic-bag-free. By doing this and collecting plastic bags they took them out of the system and replaced them in the lifestyles of residents with the non-plastic bags (Pink, 2012).

The type of information available to users of a site and its sources will also impact on decisions taken and the type of practices that form. The importance of timing in implementing certain policies and programmes should not be underrated. Social practice theory sees norms and practices being established in communities. A programme implemented too long after a community starts to form may have a smaller impact than one initiated before the first residents moved in (in a similar way to the transport infrastructure examples given above).

2.6 Mixed methods research

The interdisciplinary nature of this study, as explored in this chapter, means that it is also well suited to a mixed methods research approach. An analysis of the background literature on mixed methods methodologies and the reasoning behind the decision to pursue this approach, and the specific methods used, are explored in the following chapter.

2.7 Chapter conclusions

Building upon the foundations

In this chapter we have explored the key literature of the fields at the core of our study. First analysing the various relevant influences on human behaviour, we then introduced nudge and social practice theory and how these are particularly applicable to this piece of research.

The foundations laid in each of the distinct fields of sociology, psychology, behavioural economics and urban design have provided a solid base upon which the next generation of interdisciplinary research can build. The strongest methods and findings from each of the fields can be brought together to have a combined approach to tackling the most pressing issues such as climate change mitigation.

Filling gaps in knowledge

From this review we have established that while this interdisciplinary approach has started, there remain gaps in the literature, some of which this study can contribute to closing. We expand on the work to bridge the gaps between literature of the different fields and go forward with an interdisciplinary approach.

The first identified gap which this study can contribute to, is the impact of planned visual signals in influencing use of green technologies and low-energy and carbon behaviour on new build sites. This has the potential to develop a new avenue of encouraging use of green technologies, through targeted use of urban design.

A second gap concerns the application of nudge theory to the built environment, in terms of how we can shape the physical urban spaces in which decisions are made, to encourage behaviours which contribute to lower energy and carbon use.

Thirdly, this study can explore the role of social practice theory in the way we design physical spaces between buildings and policies and programmes for environmentally-friendly behaviour on new build sites, harnessing the influence of social networks on the development and continuation of environmentally-beneficial practices.

In the following a chapters, we will bring together findings on psychological factors and external influences on behaviour and extend nudge and social practice theory to apply them to behaviour change in the context of reducing energy and carbon emissions on urban development sites through our study. Further literature is brought in to the relevant sections of the later chapters of the thesis.

3 Methodology

3.1 Introduction

This chapter sets out the methodology of the study. It uses a combination of qualitative and quantitative methods due to the nature of the crosscutting of the subject areas. In this study we use methods from sociological, psychological and urban design fields for our work on human behaviour and perceptions to the urban environment, followed by quantitative energy policy methods to calculate the resultant energy and carbon outcomes.

Choice of methods

The methodology is built upon the premise of mixed methods. The reasons for this are two-fold: the nature of the study requires a journey from qualitative to quantitative data, and therefore an approach which fits both types of data; and the fact that the study aims to bring theoretical fields together to approach the topic fully and in an interdisciplinary manner, and the methods also need to reflect this, combining the best from different fields to get the biggest impact from the study. Mixed methods approaches have the advantage of going beyond simply counteracting the weaknesses of qualitative or quantitative methods, to be able to select different methods to suit the various stages of an emerging study (Tashakkori and Teddlie, 2010). While there are some challenges in successfully combining different types of data analysis – in particular how to bridge between the qualitative and quantitative - it is also a strength of this study that it is possible to combine these different types of data and create a methodology which enables us to gain both qualitative and quantitative insights. While quantitative data is necessary for obtaining energy and carbon data through modelling, qualitative methods are able to provide the vital social phenomena context (Silverman, 2016) which is at the heart of our research questions. As a result, we can put forward recommendations with a fuller picture of this human interaction with technologies and our built environment.

The study is framed in the context of the North West Cambridge development as a case study. This was chosen as a current and unique example of a mixed-use, rural-urban fringe site being designed with low carbon objectives, with a university as the owner and developer. As previously discussed, having the thesis framed around this gives a real-life example upon which to test the other methods. It enables us to target a specific population sample (as we know roughly what the make up of the

North West Cambridge site will be) and specific green technologies against a set of scenarios around the parameters of the specific site. Telling this as a predictive analysis for something tangible bridges between the research theory and outcomes, closer to possible applications.

In this study three sources of primary research gave us the dataset for our study. Using a mixed method approach for gathering data can enable new insights into "the causes and consequences of beliefs and behaviour" (Axinn and Pearce, 2006) and provide a fuller understanding of the research problem than either qualitative or quantitative methods on their own (Creswell, 2014), which suits the context of this study. Fieldwork analysis of a range of low carbon community urban developments was undertaken to provide a set of additional case study examples to explore in comparison to our main case study site in terms of green technologies, programmes and urban design features. The specific methods for gathering the case study content (site visits, taking observation notes during exploration of the physical environment, green technologies and features; notes from discussion with local experts on site design and energy/carbon use trends; photographs; gathering marketing materials available on or about the site) were chosen on the basis of providing a fuller picture of the sites and a glimpse of what it is like to be in the spaces, experience visual signals and use transport features, which cannot be gained from literature alone. Photographs taken on the fieldwork were then taken forward to be used in the NWC population sample survey and follow-on interviews. A survey was completed by a sample population in Cambridge which reflected the population expected to live on the NWC site. Follow up interviews provided further insight to the study themes and provided the basis for behavioural grouping.

In addition to descriptive analysis of the survey data, an innovative mixed method has been used in the coding of the interview transcripts, establishing the behavioural groupings, creating synthetic variables and sorting the full survey data into groups. This process has allowed us to make full use of our data in a way that works with a dataset of this size and shape, where statistical grouping methods such as factor and cluster analysis were initially tested, as the tools typically used in grouping methods, but were not suitable. The variables in the survey exceeded the number of responses and so this method would not have guaranteed robust results. Q-methodology (Stephenson, 1953) was another technique which could have been used in this context. It is a method known for bridging the gap between quantitative and qualitative data, and can work, for example, by a ranking of various data and selecting a correlation and factor analysis method (Brown, 1996). However, due to the size and lower level of complexity of the dataset, It was decided to instead use the 'manual' behavioural grouping method due to the size and scale of the data – which,

although arguably increasing the chance of human error, additionally enabled a more nuanced approach to be taken to this process by understanding the individual responses qualitatively in relation to each other to find and test the most suitable groupings.

To give further depth to our behavioural groupings, we looked to external data sources (each explored in later sections) to create a bespoke dataset which enabled us to establish energy profiles for each of our groups which provided us with a bridge between our profiles and the required inputs to a quantitative model. This is a similar approach to that used by DEFRA in their attitudinal groupings methodology – where a survey provided the primary data for groupings, with external datasets them being linked through 'hooks' to elements of the groupings to add depth to the understanding of each group and the wider implications. A series of scenarios were created under differing behavioural patterns, to allow us to see the projected impact of applying the recommended tailored behavioural group measures to the first phase NWC population. This approach was chosen due to the predictive nature of the study, whereby scenarios provide a range of outcomes within which you would expect the future results to exist, depending on the key parameters. This gives a higher likelihood of correct estimation and a therefore a more reliable outcome than one single prediction.

The Cambridge Retrofit model (Cambridge Retrofit) was used in the final stage of the study to calculate the energy and carbon outcomes under the scenarios. This model was designed for use within the Cambridge city context to calculate energy savings as a result of retrofitting buildings with energy-saving features. The variables of the model are such that they can be set to be equally suitable for use in this new build context. Using this already tried and tested model provided a stable base for these calculations, to strengthen the robustness of the predictive calculations, more so than a new model could do. Comparison of scenario outputs from the model allowed calculation of percentage reduction rates under each of the scenarios and measurement of overall impact on residential and transport sector energy and carbon emissions, as set out in the Cambridge Retrofit model.

Having decided on the methods, below we set out the overall process of the study, followed by explanation of the specific methodology followed for data collection, analysis techniques, scenario exploration and energy and carbon calculations.

3.2 Process

The methodology of the study follows a four-step process, containing a range of qualitative and quantitative techniques.

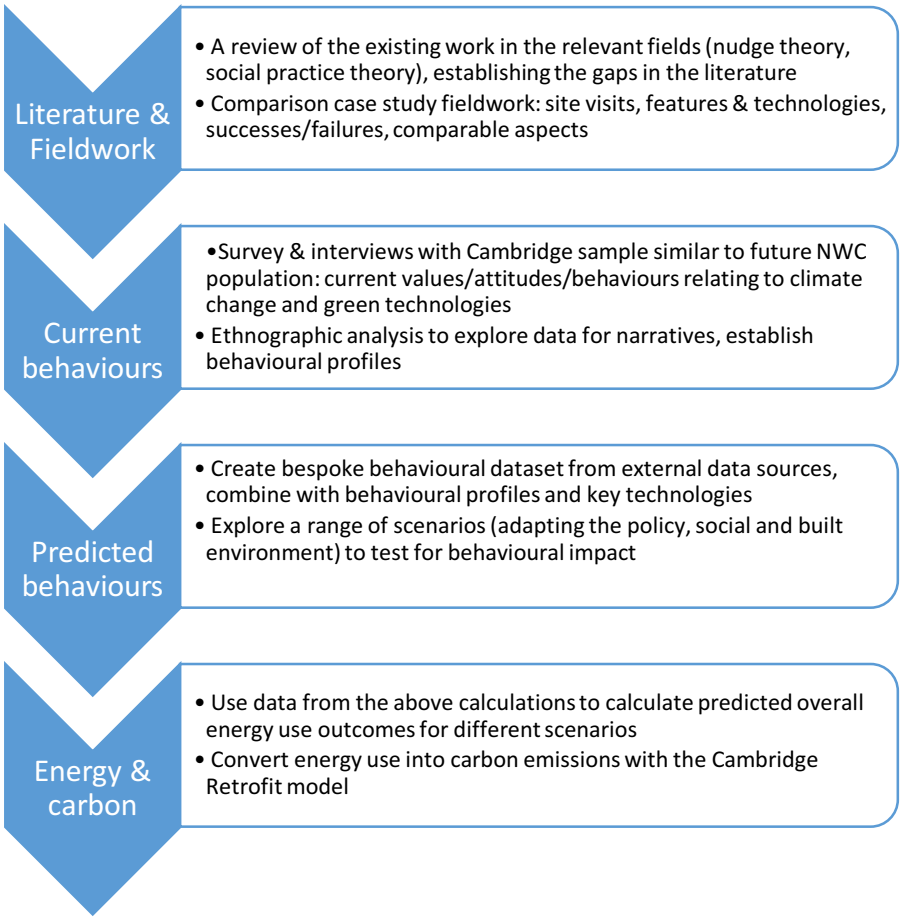


Figure 4: Process stages diagram

Literature and fieldwork

This first stage provides the groundwork for the study. A review of the existing work in the relevant fields gives both a platform on which to build our study and an idea of where the specific gaps are that could be explored in order to give significant contributions to the wider research field. Much of this work is explored in the literature review.

As this thesis has a main case study site, it is important to consider this site in comparison to others sharing one or more elements of similarity with the North West Cambridge site. Looking across

Europe, a set of twelve case study comparison sites was put together. Each site was visited with an exploration of both the physical environment, green technologies and features, as well as discussion with local experts on the merits of the site design and trends in energy and carbon outcomes as a result. Data was gathered in the form of photographic evidence of urban design features and visible green technologies; discussion observations; and materials related to the design and features of each site and how they are marketed.

Current behaviours

The data and literature findings collected in step one were used to shape the questionnaire. This survey was shared with populations in Cambridge which had some relevance to the North West Cambridge site – e.g. postdoctoral researchers (future resident demographic group), postgraduate students (future resident demographic group) and Trumpington Meadows residents (residents of a newly-constructed low carbon site on the opposite edge of Cambridge). Questions asked covered a range of aspects of human behaviour (e.g. values, attitudes, current behaviours, interaction with green technologies) and perceptions based on images from fieldwork sites.

Seventeen follow-up interviews were undertaken with survey participants. These explored the themes of the questionnaire in further detail, to build up a picture of the lifestyles and behaviours of the respondents. The second part of the interview consisted of documenting reactions to thirteen images showing particular aspects of the fieldwork sites, to gauge the impact of various visual signals in low carbon developments. This visual approach was taken to focus on visual signals and their impact on human behaviour, although it should be noted that an individual's 'image' of the city may be partially formed in their perception developed in their mind (Hansvick, 1977) rather than just through the senses.

Ethnographic analysis of the survey and interview data took the form of a combination of the following: descriptive statistics, cross-tabs, interview transcript coding, grouping of interviews via coding matrix and behavioural narratives established by in-depth analysis of grouped responses.

With the groups established, synthetic variables linking survey questions to behavioural groups were created and survey responses sorted into the best fit group. Demographic analysis was additionally carried out to find the profile of the average respondent and two key groups: postdoctoral researchers and postgraduate students. While there are also some market housing units planned for

phase one of the NWC site, the decision was taken to focus on these two more distinct demographic groups that sit at the heart of the site designed for the university community. Demographic data applied to the behavioural narratives created behavioural profiles for each of the behavioural groups, so that in total seven groups were established (three purely demographic, four behavioural) to be used in the next stages of the study.

Predicted behaviours

This section of the process linked the previously established qualitative research around behavioural groupings with a bespoke external dataset to match each group to an energy profile, ready for input into the Cambridge Retrofit model under different scenarios.

The bespoke dataset consisted of energy profile-related findings from a range of recent studies and datasets in this field. These were applied to the data in line with our groupings by linking with demographic characteristics of each group. From these came the quantitative inputs required to use the Cambridge retrofit model.

For the model a set of different scenarios was laid out, considering the different types of behaviour which could be seen from our site population based on the behavioural group findings and recommendations for engaging each of the groups in taking up and using the green technologies on the NWC site. Two green feature examples were used to give an indication of the type of possible scenarios.

Energy and Carbon

Using the inputs from stage three, in the last stage calculations for energy and carbon outputs of the NWC site were run using the Cambridge Retrofit model[9]. This model was set up to predict projected energy and carbon savings in the city of Cambridge by retrofitting a percentage floor area of buildings in various sectors and by transport modal shift from high to low carbon forms. In our study it is used to gain an understanding of the potential savings to be made on the NWC site between different scenarios, giving us an indication of the likely energy and carbon emission percent reductions under the tailored measures set out in line with our behavioural groups.

[9] The Cambridge Retrofit network of private and public sector organisations aimed to help Cambridge achieve the 80% carbon reduction target by 2020.

Exploring the methodology

The next sections explore each of the steps in the above process in further detail, looking at the reasons for the selected methods, process, data collected and analysis techniques used.

3.3 Data collection

This section sets out the various data sets collected and used for analysis in the thesis.

Data sets

Three sets of primary data have been collected, each fulfilling a different purpose in the study. An overview of the purpose of each set is explored below.

Fieldwork data

In exploring the various policies, programmes, technologies and urban design features which could be used on low carbon developments to encourage energy-saving behaviour and gain carbon savings, it was necessary to look beyond the main case study site to a range of similar sites across Europe.

Twelve case study comparison sites across Europe were identified – they exhibited different scales, types and ages of development but all with at least one common characteristic with NWC, to allow for a level of comparison. Site visits were conducted and primary and secondary data was collected at each site to build up a bank of examples of similar sites to use in the study.

Survey data

The population sample survey was created to gather information around the themed areas set out in the conceptual framework as key factors affecting behaviours, particularly in relation to green

technologies. The information from the survey was later used with synthetic variables to sort the population sample into behavioural groups.

There was a variety of question types; all closed apart from the questions concerning the built environment, where some responses had a more open style[10] to capture a different type of response to the visual signals present in the photographs.

Interview data

Follow-up interviews of twenty to thirty minutes were conducted with seventeen volunteering survey respondents. The interviews explored in further detail some of the answers given in the participant's survey response to build a more nuanced picture of the nature of various behavioural trends. The second part of the interview consisted of a round of thirteen images of scenes from the fieldwork shown to participants to hear their reactions to a range of low carbon site urban realm features, using a photo elicitation method. The interview transcripts were then coded, grouped and used as the basis of the behavioural groups.

External data

A bespoke forth dataset, created from external sources, was used to provide a quantitative backdrop to the qualitative analysis of the primary data. This also enabled us to create a more in-depth understanding of the behavioural groups through the matching of energy profiles to the groups. These could then be used in order to find numeric inputs to use in the energy and carbon calculation stage.

Collection process

Below we set out the collection process for each of the four data sets and the specific data which was collected.

[10] One set of questions asked for participants to click on parts of an image they liked or disliked. No open-text questions were used – this level of detail was explored in the interviews

Fieldwork data

Collection process

The twelve case study comparison sites were visited in-person in February 2015. The sites were in varying stages of construction. Some had been built for decades (e.g. Hammarby Sjöstad and Vauban) whereas others were in the initial construction stages, similar to the NWC development. Sites were reached by public transport and exploration of the sites was by foot. There was an effort to explore the different types of zone in each development – quiet residential streets as well as key central meeting spaces. This enabled a feeling for the different types of spaces across each site and the sense of place created in general throughout the development, as well as the bridging between different types of space. The best way to understand a space and how people might feel living in it and using it is to spend time in the space. While it was not possible to spend time living on each site, being there in-person was a good basic indication.

In addition, where available, information on the presentation of the site and notes on the development itself were gathered from visitor or community centres. Meetings were arranged with academics at local universities in the relevant fields, who were able to provide further local context to the sites and information on the sustainable design elements and in meeting the energy and carbon targets of the sites. They were additionally able to provide insight on the demographic profile of residents and any specific behavioural patterns observed.

Data collected

Throughout site visits, notes and photographs were taken concerning elements such as: the sense of the spaces, presence and incorporation of nature, urban realm layout, visible green technologies, travel methods given priority, urban art, building materials and innovative streetscape design.

Site information was collected on features such as green technologies, the marketing of the site, accommodation units and services available. For the North West Cambridge community, we were able to clearly identify the expected demographic of the future residents of the first stage of the development through an analysis of the number of accommodation units provided for different groups. For example, we know how many rooms will be available for postgraduate students. The key worker demographic is also possible to predict through unit size and number of bedrooms. All of this

information allows us to build up a profile of what the site community may look like and the surveying of such demographic groups within the city allows us to add behavioural information to the demographic trends to build up weightings of behavioural groupings for the scenarios.

Notes were taken in interviews with local academics studying the sites and key stakeholders.

Survey data

Collection process

The survey data collection followed the process set out below.

The survey questions were based on the conceptual framework and the data that we would need to create and sort the population sample into behavioural groups. Questions were adapted to the Cambridge context where possible (e.g. including 'university-owned rental' in tenure options) and kept closed with the exception of the image section which followed a different format, based loosely on the principles of photo elicitation (this method is explored in further detail in the interview data section below).

Consideration was taken to follow good practice in survey design and take steps to gain a good response rate and output data which would be in a format which we could easily use in the study. Care was taken to ensure that the survey was not so long that participants would not complete it. In the end ten out of eighty-eight respondents did not complete enough of the survey to be sorted into a behavioural group, which was a low enough level that there were still a good number of responses with which to conduct the analysis. Respondents did not have to give their name and contact details unless they wanted to be entered into a prize draw (as a motivation for taking part) or were willing to be contacted for a follow-up interview.

The survey was created using the Qualtrics platform[11]. This was chosen as it is a popular tool used in social science research due to its easy-to-use interface, range of adaptable tools and functions and ability to store response data. It offers a wide range of flexible question types including a key ability for this study – the possibility of several types of image-based questions. There is also the option to

[11] Accessed throughout project using the academic login at www.qualtrics.com

customise the layout and structure of the survey. For data analysis purposes, it has high functionality including advanced filtering options, report creation and a range of visualisation and data download options. Other online survey options considered did not provide this combination of functions and flexibility required for the study.

The draft survey was created on Qualtrics and a pilot test was done with a small sample group. Here participants filled in the survey with a range of different response types. This enabled a final check of the functionality and coherence of the survey, as well as addressing any issues of clarity around wording, option choices etc. Feedback in this stage resulted in some small changes which were incorporated into the final questionnaire.

The survey was sent to key target groups. These groups matched the sorts of residents likely to live in accommodation on the first phase of the NWC development. These target groups included residents of the recently constructed Trumpington Meadows development on the South Cambridge rural-urban fringe. They were introduced to the survey with paper slips with the survey link handed to residents met during a community nature walk on the site and a community site meeting. Additionally, posts were placed on the community social media page and website. This site's population was targeted as they are living on a site which shares a lot of elements with the NWC site. It is on the rural-urban fringe of Cambridge, is designed to high sustainability standards, includes natural areas and a mixture of residential tenures. The majority of the respondents from this population were retired and so while their responses are not matched to the key demographic groups of the NWC site, their experiences as a population of a similar site are relevant to the survey and behavioural elements of analysis. The postdoctoral researcher demographic group was targeted by an item in the Cambridge Postdoctoral Society postdoc email newsletter containing information and a link to the survey. Through this many postdoctoral researcher responses were obtained. University of Cambridge postgraduate students were targeted by links to the survey in graduate email mailing lists (e.g. College Middle Combination Room/Graduate Body emails). Live monitoring of the survey allowed further targeting to be pursued to ensure adequate responses from the key groups.

Initially a target survey response rate of fifty to sixty participants was put forward, targeting a wider group of two hundred and fifty to three hundred, based on a thirty percent response rate. In the end, eighty-eight useable responses were collected, exceeding the target set and providing a dataset with which significant analysis would be performed.

With the responses collected, the data was cleaned up on the Qualtrics platform (e.g. excluding blank responses) and downloaded for safekeeping. The platform then allowed responses to be filtered and basic descriptive analysis to be performed using the Qualtrics tools and reporting functions. The platform continued to be used throughout the analysis process.

Data collected

The survey data was collected in the form of the responses to the questions in the online form. This was available to access on the secure Qualtrics account and on the downloaded spreadsheets.

The full set of survey questions for which answer data was collected can be seen in Appendix 1. The general topics covered were: demographics and background; norms, values and attitudes; information sources; community and peers; routine and lifestyle (including interaction with green technologies); participation in policies and programmes and urban environment scenes.

The survey used a variety of question types including tick boxes, multiple choice, answer scales and ranking questions. Each was chosen to reflect the type of output data that was required on the question theme e.g. personal values were ranked to reflect importance, others such as lifestyle questions were on a five-point scale from 'strongly disagree' to 'strongly agree'.

Interview data

Collection process

All participants who in their survey responses stated a willingness to be interviewed were contacted and as a result seventeen face-to-face interviews were arranged.

A range of elements of good interview practice was considered and incorporated in the design. Interviews were twenty to thirty minutes long and held in meeting rooms convenient to the participants. Participant permission was obtained to take audio recordings of all interviews. At the beginning of the meeting interviewees were introduced to the interviewer, the study and what to expect in the structure of the interview.

As participants had previously filled in the questionnaire, the structure of the interview was to go through the participant's questionnaire answers, picking up on answers where their responses were

particularly strong and/or deviated from the mode response. This was in order to explore the depth of responses and extremes of reasoning for answering in certain ways. Questions also picked up survey questions where responses were of a more qualitative nature, as further understanding of the response could be garnered from words rather than closed question responses in the form (e.g. on personal values).

For the final part of the interview there was a visual picture round to gather responses to photographs of the case study comparison sites. The photo elicitation method was chosen for the purpose of gathering information related to the visual signals element of this study. It is a process whereby participants in an interview are shown photographs and encouraged to share responses in relation to those, which Harper suggests not only enlarges the possibilities of research, but additionally produces different kinds of information, commonly in the form of memories, feelings and information related to the image the participant is shown (Harper, 2002). As a method it can be beneficially combined with other methods (such as ethnographic) in a study (Clark-Ibáñez, 2004).

In our study, the aim of this section was to show participants a series of photographs one by one and hear their response without any spoken introduction to any scene. Ahead of the first image participants had the exercise explained and were asked to give their immediate reaction to the space shown – what they did/did not like about the scene, anything that particularly stood out to them and how they might feel in the space. Minimal responses to comments were given by the interviewer, although it was necessary to show some sort of reaction to help the interviewee feel comfortable in what was an unusual scenario – the rest of the interview was more of a discussion, whereas they were not given obvious verbal or other cues in this section.

Through this we gained data on reactions to types of urban design, features, visual signals and how this might make participants feel in each of the spaces. Participants had only seen a couple of the images in the series of thirteen before, as these were included in the survey questions. These were included to provide crossover and gain more in-depth responses to the images, which would help us in the analysis of the survey images and what particular responses might mean in terms of a fuller participant description.

Data collected

The data collected from the interviews was initially in the form of audio recordings. Full transcriptions of the interviews were then produced. These stayed as true as possible to the audio recorded and as such included text which was as spoken (e.g. often not in full sentences), with non-speech reactions included in order to gauge responses to the images in particular (e.g. laughter).

External data

Collection process

Additional external sources of data related to resident energy behaviour were identified for use as a bespoke dataset to add depth to and create energy profiles for the behavioural groups created from the primary data.

The sources of external data this piece of work were:

- Marcus Pelenur and Heather Cruickshank's barriers and motivations research (Pelenur & Cruickshank, 2012 & 2014)
- Passivhaus comparative behavioural studies (various – see below)
- National Energy Efficiency Data-Framework (NEED)
- Home Energy Efficiency Database (HEED)
- Carbon Cap reports 5 and 6 (2015)
- Department for Transport cycling and walking statistics

This data is either publicly available for download and use where appropriately referenced, or available upon request for academic purposes.

Data collected

The particulars of each of the external datasets is explored in a later section of this chapter. In general, this data was either data relating to behavioural profiles or quantitative energy and carbon data, for use in creation of energy profiles and Cambridge Retrofit model inputs.

Data processing

The data obtained for the survey was processed using a variety of methods to prepare it for the analysis stages.

Fieldwork data

Fieldwork data in its various forms was documented throughout the fieldwork trip (as notes, photographs and documentation) and afterwards catalogued and synthesized into a Fieldwork Report. Themes were drawn out of the notes, meeting notes written in full and photographs sorted (but not edited, to preserve a realistic impression of light levels and colours in the spaces).

Survey data

Survey responses on the Qualtrics platform were cleaned (null and pilot questionnaires removed) and the full dataset downloaded in various formats. The Qualtrics platform also provided some of the descriptive analysis of the survey data and cross tabs.

Interview data

The audio recordings from the interviews were fully transcribed. Common themes were then picked out through coding for each question/type of response. This was recorded in a coding matrix spreadsheet. Further detail on this process is provided in a later section of this chapter.

External data

Relevant variables from the above sources were extracted to be combined to create a unique dataset matching the needs of this particular study. Further exploration of the sources is given in a later section of this chapter.

3.4 Analysis techniques

This section explores the methods used to analyse the datasets collected.

Primary data analysis

The initial stage of the analysis concerned the primary datasets collected. This section explores the analysis techniques and processes used, from survey responses and interview recordings to behavioural groupings.

Descriptive Analysis of survey

Survey responses were cleaned and compiled into a dataset with which descriptive analysis could be carried out, to understand the broad shape of the data.

Qualtrics descriptive statistics

The Qualtrics software on which the survey was hosted has a number of descriptive data functions, allowing descriptive reports to be downloaded. This provided a good initial view of the shape of the data and broad trends. The first grouping we looked at was that of the average respondent within our sample, based on the mode responses to each survey question.

Filters were also used on the occupation and education questions to complete descriptive analysis of the key demographic groups of postgraduate students and postdoctoral researchers. The resulting profiles are explored in a later section.

Cross-tabs

Qualtrics was able to create cross-tabs for key survey questions which were used in the process of creating synthetic variables from the interview behavioural groups combined with survey questions. They allow you to see the relationship between respondents' answers to one question against another and how many people answered each combination.

Thematic notes on interview transcripts

Once the audio recordings of the seventeen interviews had been transcribed, we were able to pick up on themes throughout the various conversations. Reading and analysing responses we started to draw out key topics, themes and types of answers, broadly within the overarching themes of the study.

A list was compiled of the range of topics and themes and a detailed coding system was created. For each survey question discussed in at least one interview, a set of responses was written down. Each type of answer was given a code.

Each interview asked about a different set of questions, as the questions chosen for follow-up were those where interviewees had a strong answer which may have been different to the general trend. This method was chosen to get to the heart of the matters people felt strongly about and get a sense of the extremes of each group of respondents. Overall, there was enough spread over the questions and establish response codes and there were key questions which all participants were asked to expand upon, e.g. why they ranked the personal values in the way they did.

With the general themes in mind, we were able to create a defined set of the various specific types responses to each question asked, in order to attach codes to each response. For example, for question twenty-two on motivations, the following codes were established from the themes running through interview responses to follow-up discussion on the interviewees' answers to this question.

Question 22: "My main motivators in my decision-making are:"

*For each of **'personal benefit', 'benefit for my family', 'benefit for others (locally), 'benefit for others (globally)'** and **'benefit for the planet'** survey participants were asked to answer on five-point scale from 'strongly disagree' to 'strongly agree'.*

Code	Description
24A	Priority is self
24B	Not close to family/if had own family would be different
24C	Unsure about impact actions have
24D	Willingness to be part of bigger picture/make sacrifices
24E	Local is closer to life
24F	Would like to but don't (benefit of planet)
24G	Wouldn't do something if had negative impact on group care about

Figure 5: Coding example

In total 125 codes were established and allocated to the text in the interview transcripts. It was felt that this number covered the key distinct aspects mentioned in the interviews and gave enough scope for subsequent grouping. After each transcript was coded, a list was made of the codes attributed to it. The next step was to record the codes in a spreadsheet for the seventeen interviews.

Themes from coding of interview transcripts

With the codes for each interview inputted into a spreadsheet, we were then able to work through trends in the response data and pick out key themes and groupings. This was done through a series of matching interview responses to see how many codes they had in common and then comparing highly-similar pairs to other pairs to find groupings. This was done by hand on the spreadsheet as the shape and size of the dataset did not allow for statistical factor or cluster analysis to be undertaken.

Consideration took into account both the number of transcripts sharing particular codes and the strength of the correlation of responses between pairs and small groups of transcripts. One of the groups was smaller than the others but that small number of transcripts shared a clear set of separately coded responses. The key common factors within each grouping allowed us to start to establish the behavioural groupings.

Creation of behavioural groupings

With the common factors from each of the small groups from the coding, through ethnographic analysis, we were able to explore the main groups of respondents we were finding in our survey and interview participants.

Coding groups were finessed and cross-checked with trends in the survey data through cross-tabs (mapping of the correlation of responses to two different survey questions) and careful reading of a range of question responses in interview transcripts. While the cross tabs did not always match the coding perfectly, through the combined detail of survey and interviews, a small number of responses provides a small, but nonetheless distinct, behavioural grouping.

The key codes and trends in responses were brought into a set of main descriptors of each of four behavioural groups, which were given names based on their defining characteristics. The names are written to reflect the voice we could expect to hear from an individual in each group.

Creation of synthetic variables

The four behavioural groupings from the interviews each included a set of transcript codes, many of which correlated with survey questions and specific responses to those questions. We took these for each behavioural group and linked them with the relevant part of the survey to create a defined set of responses to survey questions, which would most closely correlate with the behavioural grouping (some codes were from more open discussions and so did not match directly with the survey questions). From this we created a list of relevant responses for a survey response to be put in each behavioural group – synthetic variables.

Sorting of responses based on synthetic variables

With a set of synthetic variables attached to each of the behavioural groups, we were then able to sort each survey response into the closest match behavioural group. Sorting the responses in this way allowed us to see the pattern of behavioural groups across the full population sample. We could also gain a greater insight into how we might expect each of the groups to interact with green technologies, based on a greater number of responses to the relevant questions.

The sorting of responses into behavioural groups was done by checking each individual survey response against the full set of synthetic variables across the four groups. We looked to see if the participant's answer to a relevant question matched that of one of the behavioural groups. If it did (e.g. they answered 'disagree' to Q9C, matching the synthetic variable of group C), then 'C' (representing an answer in line with behavioural group C) was entered into the spreadsheet under that question. Sometimes the response would not match any particular behavioural group and so was left blank.

Example survey response group allocation *(second line of table shows the input of an example individual survey response)*:

Codes: ***Group allocations:***

9B	9C	10	11B	12B	12C	18A	18B	18D	22B	22C	22D	24A	24E	25A	25B	B. Group	Final group	% Group	**A %**	**B %**	**C %**	**D %**
C	C	B			D	D								D	D	D	D	D	0	50	33	80

Figure 6: Group allocation example

When all questions had been checked, a closest fit behavioural group for the survey response was suggested. Normally this would be the behavioural group with the most matched answers. However, as there were different numbers of synthetic variables associated with each behavioural group, it was necessary to use some weighting e.g. if there were equal numbers of 'D's and any other behavioural group, the suggested group should be given to the non-D group as it had two variables associated with it which were very similar and so could skew the data.

Occasionally a survey was not completed for all questions. If some of the questions assigned as synthetic variables were answered, a grouping was assigned based on the given answers. If none of the synthetic variable questions were answered, the response was marked as "DNC" (Did Not Complete) and not assigned to a group. There were ten survey responses which fell into this category, leaving seventy-eight for sorting into the four behavioural groups.

A secondary test was applied using purely numerical weightings (labelled as "% group" in above table example). Here the percentage match to each behavioural group was calculated (the number of matching responses divided by the number of synthetic variables for that behavioural group) and the group with the highest percentage assigned to the survey response. These were then compared to the originally assigned group and those where there was a difference were assessed for a second time – taking into consideration the relative importance of the matched variables as above. As a result, some of the original suggested group allocations were changed to those suggested purely numerically.

The numbers of responses allocated to each behavioural group were then totalled up and found as a percentage of the survey population sample, excluding those 'did not complete' responses.

As a final step, we were then able to find the precise demographic information for the sets of responses under each of the behavioural groups. We did this by noting the answers to the survey questions on demographic variables (age, occupation, dependents, where from, tenure and education) for each individual response and totalling these up for each group.

Secondary data analysis

Following analysis of the primary datasets, a clearer picture was available of the specific behavioural groups within our population sample. It could be seen in which areas external data could help to strengthen our understanding of these groups and give us quantitative data with which to build energy profiles for our groups, as input for the Cambridge Retrofit mode, in order to gain energy and carbon outcomes for the site.

Bespoke data set

With the main case study site still under construction, in this study it was not possible to get actual green technology use and energy data from the site residents. While it was possible to gather information on a range of factors affecting behaviour and on participants' perceptions of how they behave and might behave, this is unlikely to directly translate into those stated actions in practice due to the value-action gap.

External studies have been able to collect some data of the nature that we would otherwise aim to collect from the North West Cambridge site, though. By finding the relevant parts of these findings that match with our findings on our site behavioural groups, we are able to build upon the external research by applying it to our data from the survey of similar populations to the North West Cambridge site. The components of the external sources illustrate the type of real-time research that could happen on the site when completed, to build upon and compare with this predictive analysis.

In this section of the methodology, each of the external sources is explored. We focus on the findings or data of key relevance to our dataset and look at what role the external data can play when applied to our primary data.

Barriers and Motivations to adopting energy efficient measures – Pelenur and Cruickshank

Pelenur and Cruickshank's research on the energy efficiency gap addressed the barriers and motivations to adoption of energy efficiency measures in residential settings. When combined, the findings from the two papers below build a picture of two energy behaviour profiles which can be compared to our behavioural groups. Their additional findings in this study can also be applied to our groups and scenarios.

Barriers

In their paper on barriers to adopting energy efficient measures (2012), Pelenur and Cruickshank used the chi-square test of association and an odds-ratio test on data from short interviews to find correlations between demographics and barriers to adopting energy efficiency measures in the domestic setting. The analysis process involved was similar to our method in that it used coding and identification of trends in responses to questions asked of a population sample.

There were several key findings of relevance to this study. Occupant age, household income and no. of bedrooms were found to be "not significantly associated with any energy efficiency barrier". Strong associations were found between female respondents and internal barriers, such as beliefs and information and family, partner or household factors. On the other hand, male participants were found to have a strong association with external barriers such as: institutional factors; and landlord, tenant or housing association barriers.

As could be expected, owner occupiers were associated with property-related barriers and tenanted households more so with landlord-tenant split barriers.

These findings are then taken forward as part of the bespoke external dataset to be applied to our group, especially in terms of policy and programme recommendations.

Motivations

Pelenur and Cruickshank's second paper on motivations (2014) looks again at the trends between demographics and adoption of energy efficiency measures, this time in terms of motivations. This

research is combined with that of the previous study to create behavioural profiles, which are of particular interest in our study.

Key findings are that the top motivations for adoption of measures in the home were: to save money; environmental or emissions-based; resource efficiency; none (noted that this category "touched on the feelings of helplessness, apathy and shifting personal responsibility"); and warmth and comfort ("does not necessarily align with the government energy demand reduction targets").

The specific barrier of saving money associated with those respondents who had >£40,000 income and were married individuals, living in semi/detached homes. On the contrary, resource efficiency associated with those with <£40,000 income, single individuals and those living in flats/terraced homes.

Some other notable findings were that: Sex, age and education had no strong association with particular motivations; household income was associated with motivations but number of bedrooms was not; and gender was associated with barriers but not particular motivations.

Two consistent profiles were identified across the two studies:

1. Currently single individuals, earning <£40,000/year, living in apartments/flats
- Motivations: to save resources, be more efficient out of general principle
- Barriers: landlord-tenant/housing association
2. Married/common-law individuals, income >£40,000/year, living in semi/detached homes
- Motivations: to save money
- Barriers: physical property

If profiles can be compared to the demographic profiles of our behavioural groups, closest match groups could then be assumed to show similar trends in terms of motivations and barriers. This comparison and depth of information could help to build our recommendations for use in the scenarios.

Passivhaus studies

As explored in the literature review, there have been a number of studies of occupant behaviour and resultant energy use, several of which are focused on passive houses.

Most of the studies are focused on space heat demand, which can provide us with helpful insight into occupant behaviour in relation to gas and electricity use. Below we observe the main findings of relevance for our study and how these can be used alongside our primary dataset.

Blight and Coley conducted a study into the effect of occupant behaviour on energy consumption in passive houses (2013). In their work around the relationship between space heating load and behavioural variables, they found that "in general passive houses are less sensitive to behaviour than anticipated" (2013). This is good news in terms of the technical construction of the buildings and shows that in homes constructed to higher sustainability levels we may need worry less about behaviour than in older homes.

However, a study in 2014 gave us an insight into behaviour in passive houses through a side-by-side comparison. Over two years, Ridley et al. monitored the energy performance of two Welsh houses (2014) and found some interesting outcomes for our study. In comparison to the study above, they found that "although not high by average UK standards, the electricity consumption of both houses is clearly excessive compared to passive house philosophy and expectations". While the technical performance of the buildings was good, they found electrical appliance use to be the biggest contributor to CO_2 emissions – a factor directly influenced by occupant behaviour.

Additionally, other behavioural patterns such as opening of windows in winter and summer ventilation practices impacted negatively on summer overheating risk and overall space heat energy consumption. They projected that accommodation units under 100m^2 with more than four adult occupants may face challenges reaching energy targets if appliance use is not carefully considered.

These findings are useful for our study as they provide us with helpful behavioural context from actual studies of energy use in residential accommodation with a similar type of built-in sustainable design. This allows us to establish in which areas our population may use most energy and which sorts of behaviours contribute to significant energy use above targets. We can use this in calculating projected reductions for different residential energy uses.

NEED dataset

The National Energy Efficiency Data-Framework (NEED) provides UK data on gas and electricity use which can be viewed for a range of variables using the spreadsheet tool. Variables available are: property age, property type, number of bedrooms, floor Area (m2), tenure, income, number of adults, Fuel Poverty Quintile, Index of Multiple Deprivation Quintile and region. These can be viewed for electricity or gas, by Median, Mean or Number of Observations. Data is available for the years 2005-2015.

This dataset gives us comparison energy use figures for different types of occupants living in otherwise similar accommodation – showing us the variances which relate to demographic groups. While keeping one variable constant, we can change the second variable to measure percentage changes in occupant energy use according to changes in the accommodation.

We can use this tool to build energy profiles for our behavioural groups according to the variables which match the demographic information from our survey. With this we can establish which groups are likely to have the highest energy consumption levels and carry out comparison work.

HEED dataset

The Home Energy Efficiency Database (HEED) provides data on installations of energy efficiency measures in UK homes. Various sheets are available to explore different types of data.

HEED Area Report

Data is collected from across the UK and categorized by Country, Government Office Region, Parliamentary Constituency Code and Parliamentary Constituency Name.

Data collected:

- Property type
- Property tenure
- Property age
- Loft insulation
- Wall construction & insulation

- Main fuel type
- Main heating system
- Glazing type

On the summary page percentages for each category are found for each parliamentary constituency.

Of note from the Cambridge data:

- 18% of data on flats (3314 count)
- 0% data is on properties built post-2006
- For 92% gas is the main fuel type, with 6% electric
- 0% of data on properties with community heating as main heating source
- 34% had full double glazing

HEED Installations by Data Source

This sheet shows data on numbers of installations of different energy-efficiency technologies, grouped by the source.

Sources:

- Energy supplier
- Fuel poverty scheme
- Local authority
- NI schemes
- Other sources
- Scottish schemes
- Welsh schemes

Types of installations:

- Appliances
- Heating
- Insulation
- Lighting
- Microgeneration
- Other

Of note from the Cambridge data (2016 & 2017):

- The data shows no installations in Cambridge in 2016 or 2017.
- There are pockets of installations in previous years – but before the period of our survey and interviews.
- There is no record of any community heating systems being installed in Cambridge for the available years of HEED records (1993-2017).
- There are some individual installations of solar PV or heating in earlier years – nothing on a large scale.
- There is evidence of larger-scale installations of long lifetime RTDs (resistance temperature detectors) and visual display units in previous years.

HEED installations by property tenure

This sheet shows the same data on installations as in the previous sheet, but this time categorized by tenure type.

Of note from the Cambridge data (2016 & 2017):

- The data shows no installations in Cambridge in 2016 or 2017.
- There are pockets of installations in previous years – but before the period of our survey and interviews.

HEED installations by property type

Here we see the same categories of installation as in the previous sheets, this time categorized by property type.

Again, there are no installations recorded for Cambridge in 2016 or 2017.

While this dataset has the potential to be of great interest to this study, there is little in the way of installations for Cambridge in the years we are studying. This, however, does show us that the types of technologies in our case study site are a relatively novel addition to the city and so potentially have a greater impact on emission levels due to residents finding them new and interesting.

Carbon CAP Reports

As previously discussed, the Carbon CAP reports (2015) explore the various behavioural factors influencing engagement with green technologies. A set of policy, programme and urban environment design feature instruments is used in our study to emulate a range of scenarios in our model. These do not represent what is planned for a specific site, but the types of instrument which are available and may deliver overall carbon reductions.

To select the instruments for use in the model scenarios, a long-list of options was created from those rated highly in terms of scope and effectiveness in the Carbon CAP WP 5.1 report (2015). This long-list was shortened according to viability on a new build, mixed-use development. The short-list appears in the table below. Each instrument is then rated in terms of applicability to the selected green technologies in this project. Those instruments highlighted in green are compatible with three or more of the technologies, while those in orange apply to two technologies. While the green instruments would be most applicable across a range of technologies, the final list takes into account the need to have a range of instruments which cover the main aspects of carbon footprints and applicability across the range of technologies.

The built environment design feature instruments are taken from fieldwork findings and are, again, matched against the range of green technologies. These instruments are less obviously linked to the technologies e.g. human scale may impact on energy meter use if it allows for stronger community formation, which in turn encourages greater use of community intranet and energy meter output comparison. This is taken into account in the selection of instruments.

The instruments in bold are those which have been selected for use in the creation of scenarios for the model (six in each category), although it is possible that other instruments could be brought back in at a later stage if a specific scenario arises that requires it.

INSTRUMENT OPTIONS	Instrument	Technology					
		Solar PV	Energy meters	District heating	Natural ventilation/cooling	Site-wide travel plan	Electric car charging points
Policy/programme	**Information campaign**	*	*	*	*	*	*
	Consumer/personal carbon budget/allowance	*	*	*	*	*	*
	Subsidy		*			*	*
	Product user fees					*	
	Licenses					*	
	Refund mechanism	*	*			*	*
	Recycling requirements						
	Product ban					*	*
	Shop product choice						
	Waste targets/requirements						
	Deposits on purchased goods					*	*
	Minimum price limits					*	
	Limits on % ownership or use					*	
	Enabling recycling						
	Extension of product lifetime	*	*	*	*	*	*
	Enabling product sharing					*	*
	Mandatory metering	*	*	*	*		
	Infrastructure improvements					*	*
		Solar PV	Energy meters	District heating	Natural ventilation/cooling	Site-wide travel plan	Electric car charging points
Built environment design feature	**Visible green technologies**	*	*	*	*		*
	Public art	*	*			*	*
	Human scale		*			*	
	Priority to pedestrian/cycles		*			*	
	Multi-level access to public space					*	
	Pocket parks		*			*	
	Visual corridors to nature		*			*	

Figure 7: Table of green technologies and instrument options (based on Carbon CAP, 2015 findings)

Each green technology has a level of "stand-alone" performance – meaning the output it can generate without need for human interaction. An example of a technology with a high stand-alone performance is a solar panel – the panel itself requires minimal maintenance to operate effectively.

Other green technologies, however, require a specific human action or actions to operate at all – for example an electric car requires decision-making on the part of the owner in terms of use patterns and will not operate unless plugged in and charged up. When we think about the efficiency of green technologies, we must be clear about how much of the output relies on a certain type of human behaviour.

There are therefore three different ways in which we might describe a green technology:

1) **Stand-alone technology** – where for the most part, the technology is unaffected in its energy performance by any human interaction. There is likely to be either no, or very minimal, human interaction required for the technology to operate.
2) **Combination technology** – where a technology relies on both stand-alone performance and human interaction to meet its performance targets. The human interaction component could be in terms of take up of the technology (decision to use) and/or take up of a type of behaviour in relation to the technology.
3) **Behaviour-dependent technology** – where the technology relies, for the most part, on a preferred set of human behaviour interactions with the technology for its optimum operation

The range of technologies in the table above were selected from the site plans for potential study in this thesis to cover a mixture of stand-alone or occupant operated and occupant or building based technologies, across the range of plug-load, heat and transport. Each has a different method of take up or use and operation. Further analysis on “take up” rates of technologies and behaviours and definitions of the different characteristics of green technologies is explored in the literature review.

The Carbon CAP analysis contributed to the decision to focus on two technologies for this study. The selected green features of a community smart meter system and site-wide active travel plan have been chosen to cross-cut the different combinations of stand-alone/self-standing and occupant/building based technologies (shown in the tables below) as they are both categorised as combination technologies. This means that we can explore the range of different aspects through these two examples. Exploring a wider range of technologies could form a follow-on study to this piece of work.

Potential green technologies for the study:

Plug-load:

Technology	Behaviour-dependent	Self-standing	Combination	Occupant-based	Building-based	Combination
Photovoltaic arrays*		Y			Y	
Energy meters connected to community intranet			Y			Y

*Solar panels are a way of providing the power needed to meet plug-load – not an example of plug-load themselves.

Heat:

Technology	Behaviour-dependent	Self-standing	Combination	Occupant-based	Building-based	Combination
District heating (CHP source)		Y			Y	
Natural ventilation/cooling			Y			Y

Transport:

Technology	Behaviour-dependent	Self-standing	Combination	Occupant-based	Building-based	Combination
Site-wide travel plan			Y			Y
Electric car charging points	Y			Y		

Figure 8: Green technology categories

For the purpose of our analysis, we assume the features of each technology to be as below. These are based on a combination of what we know is planned for NWC, what we have seen in other developments and what is possible with this sort of feature.

Community smart meter system	Site-wide active travel plan
Aim: reduction in domestic energy use through live information and comparison with other households	Aim: site-wide strategy to increase active travel modes of transport on the site, encouraging walking, cycling and other person-powered forms of movement where possible
Features: live energy use data – sources, quantity and cost, community intranet allowing members to compare energy use with neighbours and see community totals	Features: streetscape features – separated bike lanes, pedestrian zones in centre of site, visible and regular bike racks on streets, secure bike storage, bike hire available through accommodation
Practicalities: provided in accommodation, monitor in accommodation, intranet available on any connected device (e.g. laptop, smartphone)	Practicalities: access to secure bike parking through accommodation, signposts and use of variety of materials to differentiate space for active travel
Information: induction given on arrival at accommodation, instructions, online system	Information: site travel map provided to residents, signage in urban realm encouraging active travel

Figure 9: Technology information

Department for Transport cycling and walking statistics

The UK Department for Transport publishes figures on cycling and walking within the population, by local authority.

On looking at the statistics for Cambridge, we can see the following statistics on active travel in the population:

Proportion of adults who do any walking or cycling, for any purpose in Cambridge:

- Once per month: 91.1
- Once per week: 86.8
- Three times per week: 72.6
- Five times per week: 60.6[12]

This information is useful for our study as it allows us to compare what our survey participants said about using walking or cycling as a main mode of transport with this government data. We can use these figures as a basis for model input estimations on transport modal shift.

Site transport energy use is then calculated from the National Travel Survey data (2016). This allows us to find number of miles travelled by mode, per person, for the East of England[13]:

Car/van passenger: 2,043 miles per person per year
Car/van driver: 3,958
Local bus: 162
Bicycle: 45
Walk: 180
Walks of over a mile: 98[15]

In the results section we use this to calculate the transport inputs to the Cambridge Retrofit model.

[12] Department for Transport cycling and walking statistics 2015-2016 (from table CW0301)
[13] Department for Transport – National Travel Survey (2016) Nts9904: "Average distance travelled by mode, region and rural-urban classification, England, 2015/16"

3.5 Scenario exploration

Matching behavioural categories to energy use profiles

In setting up the scenarios we first match each of our behavioural groups to a unique energy profile which is created using the data from our bespoke external dataset.

In the results we see this matching process undertaken step by step to give us predicted energy profiles for the demographic groups found within our behavioural groups.

Scenarios

We use scenarios in our study as a means of undertaking predictive analysis of the energy and carbon outcomes of our site population given a range of behavioural circumstances around two example green technologies.

This method was chosen as the main case study was still under construction and so actual energy use could not be monitored, but as accurate as possible predictions could be made based on current survey information paired with data from similar projects. In order to get the closest fit energy and carbon data, it was decided to use the Cambridge Retrofit model for the final stage calculations as it was designed for use in the Cambridge urban area.

To gain results from this model, we need a set of inputs tailored to our site population. In order to explore the range of energy and carbon outcomes possible under different situations, we set out to run the model several times with different inputs.

To establish these inputs, we set out different policy and built environment scenarios to influence the data inputted and show the impact of different combinations of measures on the energy and carbon outcomes.

The scenarios are the result of a combination of our behavioural groups, matched with their energy profiles (from the external dataset) and interacting with a set of policies, programmes and built environment features to take up and use the example green technologies.

The full scenario environments are explored in the results chapter.

3.6 Energy and carbon outcomes

The final step of the methodology is to calculate predicted energy and carbon outcomes under the various scenarios for the NWC site.

The Cambridge Retrofit community model for Cambridge was chosen to undertake these calculations as it is a model which was designed for the Cambridge city areas specifically, under the so-named project which looked at the impact of retrofitting buildings in the urban area on the city reaching its overall energy and carbon outcomes.

The model is set up with data from the DECC 2009 subnational electricity and gas figures and takes inputs per section (e.g. residential) of floor area retrofitted, population and the percentage energy reduction per sector category for electricity and gas. These reduction levels are the variables which we edit according to the scenario.

The model gives us automatic outputs for energy and carbon savings achieved by a range of years. We chose to look at the 2020 figures as a good timeframe for analysing the potential impact of the first phase of the NWC site as the first residents will have been on site for a few years at that point and so the energy and carbon impact will start to be felt as the first phase reaches capacity.

In the results chapter we analyse the model output figures and compare the potential savings between the different scenarios.

3.7 Chapter conclusions

This chapter has set out the methodology process by which the research for this study was undertaken. We have explored the reasons for the choice of techniques, the processes, analyses and calculations undertaken and the steps to ensure that the process provides the most robust data possible for the type of study.

The results of the process are set out, analysed and explored in the Results chapter.

4 Visual Signals

4.1 Introduction

"The city shapes our decisions. It always has." (Montgomery, 2013)

Building on chapter 3, in this chapter we turn our focus to the impact of visual signals in the urban environment on human behaviour.

We can kit a new site out with all of the most advanced technologies, replications of the most successful policies and tailored bespoke programmes, but without a built environment which supports its users to take part in initiatives and use the technologies, we risk actively decreasing their influence on the population.

The way in which we design spaces is known to have direct and indirect impacts on the behaviours of those passing through them. In this chapter we will explore the impact that each element of our urban design can have on the way in which users of that space will behave, through visual signals. Our exploration of the combination of the theories of social practice, nudge, urban design and psychogeography explored in the literature review sets out a context for understanding the following research.

We will first look at the method for gathering data, followed by the primary data which we have collected from field site visits across Europe, survey and interviews to create a dataset which reflects the types of urban design features in use in a range of developments aiming for environmental sustainability and then the NWC sample population's responses to them.

From the above, we present three themes in the data from which we can provide a set of recommendations in terms of urban design features which are likely to help increase environmentally-sustainable behaviour on a site. These will be combined with the results of the other research strands to build a set of recommendations for new low carbon urban developments.

4.2 Fieldwork analysis

An exploration of the physical environments created in case study comparison sites.

Overview and purpose of fieldwork

Fieldwork research allowed us to explore the ways in which various design features embedded in sustainable development design can influence people to adopt behaviours which, through interaction with green features, can result in energy and carbon savings across mixed-use urban developments.

Purpose

The purpose of the fieldwork was to investigate several developments which are similar in one or more characteristic (sustainability, university presence, scale, mixed-use, location etc.) to the North West Cambridge (NWC) site, to: investigate behaviour in relation to green technologies there, get a feel for the urban environment, connect with academics working on similar research in the localities to discuss local behaviour trends and to find and photograph a range of design elements on each site, for use in the survey and interviews to follow.

Aims

- To research which services each site provides and through which green technologies
- To visit each site to see how the urban structure and environment works in practice
- To investigate signals in the urban design which may encourage environmentally-friendly behaviour of residents
- To take lessons from each site in terms of how site design may influence residents' behaviours

The methodology established for the fieldwork is set out in Chapter 3.

Influencing behaviour in low carbon communities

Over the last couple of decades, we have seen a rise in the number of developments being created with a specific "sustainability" vision. To start to look at how effectively these sites are living up to their sustainability goals, we can first look at which services they provide to residents and other

users of the site. We then investigate if and how these services are being produced by technologies which allow them to occur at low carbon and finally progress to look at what human behaviour is required to operate the technologies in the most energy-efficient manner.

We take clues on the likelihood of this behaviour being achieved by looking at the design of the site, as it is suggested that "energy-efficient action takes place within, not outside, localized, culturally and temporally specific settings" (Guy and Shove, 2000) and so the physical space and demographic make-up of the population are of key importance. As many as "80 per cent of the factors influencing behaviour do not result from knowledge or awareness" (Fliegenschnee & Schelakovsky, 1998) and so experts suggest that "instead of trying to change people's minds we should focus on the environment within which we make our decisions" (Global Awareness in Action).

Throughout we refer to how each case study exhibits examples of different techniques to encourage environmentally-friendly behaviour – whether it be through policies and programmes or the design of the built environment itself. Where mentioned, "nudging" (Thaler & Sunstein, 2009) refers to "effecting desired behaviours through subtle changes to the context in which the decision is made", within a framework of "libertarian paternalism", where certain behaviours are encouraged for the greater good, but which does not impinge upon anyone's individual options (Davis).

Our main case study is the North West Cambridge development in Cambridge (NWC), but as it is still under construction we look to other sites which share one or more characteristic that will be present at NWC, to investigate factors contributing to behaviour which gives green technologies the best chance of meeting carbon emission targets.

The methodology for these field visits is set out in the methodology chapter. Each of the sites visited had at least one shared characteristic with what is planned for the NWC site (e.g. urban-rural fringe location, academic institution central to development, similar city context, similar building scale, next to natural area etc.), was mixed-use and had elements of sustainable development in its design (e.g. strategy based on low carbon living, emphasis on public transport, prioritisation of active travel, green technologies, renewable energy sources etc.).

We have analysed the fieldwork observations to come up with a set of features which we think may be relevant in terms of assessing which features have an impact on behaviour of site residents. A selection of photographs of such features on the field work sites is used in the image section of the population sample interviews.

Itinerary

Date (2015)	Location	Case Studies
11th February	London, UK	BedZED
12th February	Brighton, UK	One Brighton
17th-18th February	Freiburg, Germany	Vauban, Freiburg
		Rieselfeld, Freiburg
19th - 21st February	Copenhagen	Western Harbour, Malmö
		Nordhavn, Copenhagen
		Ørestad, Copenhagen
		IT University Campus, Copenhagen
22nd-25th February	Stockholm	Hammarby Sjöstad, Stockholm
		Royal Seaport, Stockholm

Figure 10: Fieldwork itinerary

Activities

Location	Meetings	Site visits
London, UK		BedZED
Brighton, UK		One Brighton
Freiburg, Germany	**Samuel Mössner, Freiburg University**	Vauban
		Rieselfeld
Copenhagen	**Patrick Driscoll, Aalborg University**	Western Harbour, Malmö
	Nordhavn Exhibition Centre	Nordhavn, Copenhagen
	Danish Architecture Centre	Ørestad, Copenhagen
		IT University Campus, Copenhagen
Stockholm	**Ulrika Gunnarsson Östling, KTH**	Hammarby Sjöstad, Stockholm
	Maria Håkansson, KTH	Royal Seaport, Stockholm
	Sofie Iverooth, KTH	
	Royal Seaport Development Office	
	GlasshusEtt Community Centre	
	Stockholm Planning Office	

Figure 11: Fieldwork schedule

Case study sites

Overview

The case study sites span a range of countries, planning systems and societies. These will all naturally have an effect on lifestyles on the site and thus the energy and carbon outcomes. However, there are certain common threads running through them, which we will explore in more detail in the analysis section. Below is an overview of each individual site.

List of case study sites:

- **BedZED**, London, UK
- **One Brighton**, Brighton, UK
- **Vauban**, Freiburg, Germany
- **Rieselfeld**, Freiburg, Germany
- **Nordhavn**, Copenhagen, Denmark
- **Ørestad**, Copenhagen, Denmark
- **IT University Campus**, Copenhagen, Denmark
- **Western Harbour**, Malmö, Sweden
- **Royal Seaport**, Stockholm, Sweden
- **Hammarby Sjöstad**, Stockholm, Sweden

United Kingdom

BedZED

Site Overview

BedZED was the UK's first substantial development with an environmental vision central to its design. Located to the South of London, the development is on a smaller scale than some of the other case studies, but was built under the UK planning system and behavioural culture.

Main Features

100 homes	Office space	FE College
Community facilities	Open air gym	Perimeter parking

Figure 12: BedZED main features

Services provided by the site and any green technologies which enable them to be provided at low carbon

Electricity	Solar PV panels, window solar
Heating	Solar thermal, thermal heating/cooling
Accommodation	Good insulation
Outdoor space	Parks, grass roofs
Community space	Short journeys to facilities
Business space	
Waste disposal facilities	Recycling
Walkways	Pedestrianised lanes
Bike racks	Good cycling infrastructure

Figure 13: BedZED services

What behaviour is required to make people to use these technologies and how does the design of the site influence these behaviours?

On a practical level there is a need for understanding of the technologies to ensure that they are working correctly and a willingness of the residents to sort their waste and engage in physical modes of transport.

Solar panel windows and brightly coloured roof vents highlight the presence of the green technologies in accommodation blocks. However vehicular transport options are more visible in the streetscape and given priority over physical modes in the main thoroughfare around the outside of the site. This may create a subconscious information flow about the continued presence of e.g. private cars even in an ‘eco’ development.

Findings

Example signals:

Cars present on site	Open area not well maintained (not invitingly green)
Perimeter road traps green area within	Solar panel windows
No bridging with external surroundings	Birdsong
Lack of real privacy	Lots of paving
Greenery at different levels	Human scale passages
Different levels bridged to street	Different shapes and angles in residential design
Grass roofs mud/moss	Unused bike racks (could be time of day) & lack of connection to cycle infrastructure
Vents on roofs make development look 'futuristic'	Solar panels

Figure 14: BedZED signals

Take away lessons

While BedZED was ahead of its time in the UK and does boast some efficient, impressive green technologies, its small scale means that the impact of its surroundings is higher than in a bigger development. The variety of services available to residents of the site is limited (e.g. there are not shops or a school on site) so, outside of their homes, people are likely to spend a lower percentage of their time on the site compared to larger sites in which most everyday facilities could be accessed, so the level of impact on their individual carbon footprints may be lower. While green technologies are present, the visual signals could be somewhat detrimental – 'hard' construction materials dominate and public green spaces are lacking and poorly maintained. An interpretation is that the road circling the boundary of the site sends a message that private vehicle use is inevitable. Bridging with the external environment is important to see such developments as ones blending with and influencing their surrounding areas rather than as green 'islands' in isolation.

One Brighton

Site Overview

Developed by the same company as BedZED, One Brighton is a newer take on green communities within the UK. The site itself is very limited – consisting only of two apartment buildings on the edge of a larger new residential regeneration development.

Main Features

Two residential buildings	Courtyard
Community facility	Brown roofs
Sustainable water consumption targets	Rooftop allotments
No private car parking, car club	Bike parking
On site food composter	Zero carbon

Figure 15: One Brighton main features

Services provided by the site and any green technologies which enable them to be provided at low carbon

Electricity	PV solar panels
Accommodation	Good insulation
Community (roof) gardens	Green spaces
Business space	Low carbon construction materials
Community space	
Waste disposal facilities	Recycling infrastructure
Cycle racks	Linked into cycle infrastructure

Figure 16: One Brighton services

What behaviour is required to make people to use these technologies and how does the design of the site influence these behaviours?

Education needs to be provided to the residents for them to have an understanding of the green technologies that they will be coming into contact with. Gardening skills, but more importantly, a level of community social integration will be key to the success of the community garden space, as "community gardens are less about gardening than they are about community" (Glover in Pink, 2012).

There needs to be willingness on the part of residents to sort waste for recycling and make the choice to travel by bike or walking, although to a certain extent this is already enforced or self-selecting as the site is car-free by design.

The site design influences the strength of these behaviour types in various ways. The community spaces are not particularly welcoming – outside areas are cold and concrete and the garden areas are so high up as to be hidden from view, although the community centre does serve as a hub or information point for the development. The recycling points look tired and unprofessional (despite

the site being relatively recent) and notices actively ban cycling in the central public thoroughfare of the site.

Findings

Example signals:

Community centre (cafe, adult education centre and ethical property centre)	Signs saying "cyclists dismount" and "no skateboarding" – negative signal for enjoying the public realm.
Scale of buildings is beyond human scale	Allotments and green roofs beyond human vision
Recycling station looks tired and unprofessional	Unclear local transport links

Figure 17: One Brighton signals

Take away lessons

One Brighton has been built in an area experiencing a high level of regeneration next to the central train station. The buildings in themselves boast impressive technologies and features, but these are hidden or too high up to be visible on a human scale. There is a general issue with small-scale green developments, in that their scale offers little potential for real influence in people's lives, or spill over into bordering developments.

There is an abundance of concrete and the areas between the buildings offer little greenery. In fact, there are signals discouraging residents and visitors from using the space – such as written notices banning cycling and skateboarding. Being discouraged from using shared space does little to encourage community spirit, which could perceivably have an impact on environmental efforts – if social practices have little opportunity to develop and each resident sees their part in the development as their private individual space and nothing beyond.

However, there is an example of the design creating a "green by default" (Global Awareness in Action) situation by there being a conscious decision to include no car parking spaces in the development. If having a private car becomes the more difficult option, there is a much increased chance of residents cycling, walking or using public transport to get about and that becoming a norm.

Germany

Vauban

Site Overview

Vauban is built close to the centre of Freiburg in Germany, on the site of a former army barracks. It was a joint development between the local council and small housing cooperatives, each building apartment blocks around the existing natural landscape, featuring a wide variety of green technologies. It is a popular place for environmentally-conscious families to settle.

Main Features

Low energy building mandatory	170 units passivhaus
70 energy-plus homes	Green spaces between houses
Community facilities	Tram and bus links
Car-free side streets	Fees to own a car on site
Natural green spaces between buildings	Solar panels
Bike presence	

Figure 18: Vauban main features

Services provided by the site and any green technologies which enable them to be provided at low carbon

Electricity	Renewables (solar PV and wind turbines)
Heating	Solar thermal
Accommodation	Low carbon construction materials (to Passivhaus and energy-plus standards), good insulation
Outdoor space	Green spaces
Social space	
Community gardens	
Community space	
Shops	
School	
Nursery	
Business space	
Healthcare facilities	
Transport links	Public transport infrastructure, cycle and pedestrian zones and infrastructure
Waste disposal facilities	Recycling facilities

Figure 19: Vauban services

What behaviour is required to make people to use these technologies and how does the design of the site influence these behaviours?

There is a need for an understanding of the green technologies by the residents to ensure that they are operating efficiently. There needs to be an awareness of public spaces and a willingness to use and maintain them. The community needs to integrate to share these spaces. People have some active decisions to make on whether to sort waste for recycling, use public transport or walk or cycle.

The design of the site by its nature influences these behaviours. The high presence of nature on the site means that buildings are integrated into nature rather than the other way round, with pedestrianised streets providing access. The public transport links are found in the central artery of the site and the recycling facilities are prominent. There are notice boards on the site which provide information to help form a sense of community and many visual signals across the site and the attitudes of residents combine to create community behaviour norms that strengthen the level of green technology use.

Findings

Example signals:

Buildings integrated into nature	Local services and activities
Birdsong	Gardening
Public transport links	Bridging
Murals/street art	People priority
Heterogeneous building styles	Street layout
Recycling prominent	

Figure 20: Vauban signals

Take away lessons

At a first glance, Vauban seems like the ideal eco-community space. The area is overwhelmingly green – with buildings seemingly carefully placed in between trees and natural areas rather than the other way around. This feeling of humans in harmony with nature rather than above it working to manage it pervades throughout the site. This ties in with the idea of connecting people to nature as a means to "increase people's motivation to act and live sustainable lives by strengthening their connection to nature" (Global Awareness in Action).

There has been a conscious decision to make vehicles seem, to residents and space users, like imposters in the pedestrianised zone. The heterogeneity of the buildings and structures ties in with the natural ethos and the safe space is maintained for children to grow up outdoors. However, digging deeper into the non-visual aspects of the site, it is clear that Vauban is not quite as it seems. Demographically, the area is very homogenous, middle class and white and large percentage of residents are academics and families[14]. This group holds status and power through its networks with decision-makers in the city of Freiburg. The influence of this factor on the site should not be underestimated, how did the tram line make its way into the heart of the site? Why is it that the tallest homes next to the railway are the only affordable ones? This aspect of the development might skew the behaviour of residents, depending on the level of influence by peers versus the visual signals apparent on the site. If there is a strong group dynamic, though, establishing a common set of behavioural norms can raise the baseline of environmentally-friendly behaviour.

Rieselfeld

Site Overview

Rieselfeld is almost like Vauban mark two, set in the same city, sharing similar building types (and occupier builders), an urban-rural fringe position and local political environment. However, it presents itself as more of a typical modern mixed-use development than the nature-centred Vauban: there are few fully-pedestrianised streets, a greater commercialisation of public spaces and it is altogether on a much larger scale, incorporating many more services.

Main Features

Borders 250-hectare nature reserve	3700 Low-energy houses
Photovoltaics & solar thermal	District heat from CHP and renewables
Water supply plan	Importance of green spaces
Cycle paths	Pedestrianised streets

Figure 21: Rieselfeld main features

[14] From discussion with Samuel Mössner, Freiburg University

Services provided by the site and any green technologies which enable them to be provided at low carbon

Electricity	Solar PV panels
Heating	Solar thermal and CHP
Accommodation	Insulation, low carbon construction materials
Water system	Efficient water supply systems
Sports facilities	
Outdoor space	
Social spaces	
Emergency services	
Community space	
Shops	
Schools	
Nursery	
Business space	
Public services	
Healthcare facilities	
Transport links	Low carbon public transport infrastructure, pedestrian and cycling infrastructure
Waste disposal facilities – recycling facilities	

Figure 22: Rieselfeld services

What behaviour is required to make people to use these technologies and how does the design of the site influence these behaviours?

Education on the operation of green technologies will aid in achieving maximum carbon savings. There are active choices to be made by residents and visitors to the site in terms of willingness to use public transport, cycle or walk places and whether to sort waste for recycling.

The shape and design of the urban environment suggests certain behaviour patterns to residents. There are also some visual signals like bike racks, pavements in residential areas which are separated from vehicle lanes by trees and green spaces are found throughout. Recycling is prominent in the streetscape, a central artery route gives priority to the tram route and pedestrian and cycle routes have priority elsewhere, with no kerbs disrupting smooth movement.

Findings

Example signals:

Visible recycling	Bike racks
Central tram artery road	Pavements separated from roads and trees on streets
Natural green spaces	Street layout – no kerbs

Figure 23: Rieselfeld signals

Take away lessons

While Rieselfeld might make it seem like a half-way house between a truly sustainable eco-community and your average modern development, it perhaps presents a realistic compromise going forwards. Instead of being a somewhat environmentally-exclusive community, it draws people in to use its space by providing public services and amenities such as medical facilities, schools and shops[15]. This could be one means of using its visual signals to impact on behaviour beyond its own boundaries. There are several clear visual signals – green spaces, recycling, public transport domination, accessible pedestrian areas, vegetation separating pedestrians from traffic. Although subtler, it is probable that these consciously or subconsciously remind people of the importance of remembering our impact on the natural environment in our lives in new developments.

Rieselfeld in its 'middle ground' might be an example of trying to "avoid denial" of climate change by "avoid[ing] spreading information that triggers negative attitudes towards sustainability" (Global Awareness in Action), for example extreme and dire messages which reduce people's willingness to believe that climate change is happening. Here it could be put into action by sending a message of 'you can have a smaller impact on the environment but still live a normal life' rather than suggesting that everyone must make significant personal sacrifices to their lifestyle.

Denmark

Nordhavn

Site Overview

[15] From discussion with Samuel Mössner, Freiburg University

Nordhavn, a port and reclaimed land development in the North East of Copenhagen, is still overwhelmingly in its construction phase. It is nonetheless still useful to study its planned urban structure and design for clues to how its future residents may behave.

Main features

First phase accommodation for 3000 people	Workplaces for 6-7000
'Green and blue city' structure	5-minute city transport system

Figure 23: Nordhavn main features

Services provided by the site and any green technologies which enable them to be provided at low carbon[16]

Accommodation	Insulation, low carbon construction materials
Business space	
Electricity	Renewables (wind turbines, solar PV)
Water purification	rainwater harvesting
Sports facilities	
Social spaces	
Community space	
Shops	
Schools	
Public services	
Transport links	Electric car charging points, cycle and pedestrian infrastructure, public transportation infrastructure
Waste disposal facilities	
Heating	District heating system

Figure 23: Nordhavn services

What behaviour is required to make people to use these technologies and how does the design of the site influence these behaviours?

Several technologies included in the plans will depend on active decisions by residents e.g. to purchase an electric car, to ride on public transport or to cycle or walk to their destinations, as well as sorting their waste appropriately and recycling it.

The design of the site influences these decisions in various ways. The innovative "green and blue city" idea runs through the master plan, ensuring a constant presence of water and green spaces

[16] Information based upon future of the site on completion, based on the masterplan

throughout the urban realm, with visual proximity having an impact on actions. Rocks next to the silo have been extended into the water to create an "archipelago-like swimming area" (Nordhavn) and there will be green roofs to fulfil a number of purposes: absorbing rainwater, counteracting temperature increases, abating noise and insulating buildings(Nordhavn).

The infrastructure is also designed along a "5 minute city" structure, having accessibility to public transport as a key priority within the development. The streetscape itself will be designed to be flexible and human-focused, with "flexible zones ...that can be used for lounging, outdoor cafes and restaurants, planting or car and bicycle parking" (Nordhavn). The ideas is that the layout will be "causing a natural slow-down of traffic, or they may be laid out linearly to allow attractive views of water or green urban spaces" (Nordhavn).

There are plans for an intelligent grid system to create an information flow to residents when on site, but the way in which life on the site is marketed to future residents in advance of the site being occupied is also key.

Findings

Take away lessons

Nordhavn is still very much in the construction phase. However, it makes an ambitious claim to be "a district that makes it easy to have a green conscience" (Nordhavn). Here we can see an example of a development consciously choosing a strategy of using the urban layout and design as a means of creating new habits "to seek ways that encourage people to make a promise about changing their behaviour" (Global Awareness in Action). If this new lifestyle is what has been marketed to people ahead of their living on the site, they know what to expect of life there. "The natural choice for people should be to walk, cycle or use public transport rather than to travel by car" (Nordhavn).

Here its man-made position in a natural setting is a key part of the theme chosen to expand and develop the site. It is a regeneration and expansion of an old port area of reclaimed land out in the sea. While reclaiming more land (partially to expand the size of the site, partially as a way of reusing material dug up in the construction of the city's new metro line) they have made an active decision to build more water channels and spaces in between land plots "...with water as the all-pervading element that frames the public life of the district" (Nordhavn). They are making big efforts to increase leisure and recreation opportunities linked to the water and are working on urban design

that bridges the land/water boundary. Perhaps here the blue will be a substitute for the green influences and signals that are discuss elsewhere in relation to other sites.

Ørestad

Site Overview

This district to the south of Central Copenhagen, near the airport, is being developed into a commercial and residential area. The scale of buildings is somewhat larger to that found commonly in the city.

Main Features

Large indoor shopping centre	Large apartment blocks
Large office buildings	Main artery road with prominent raised train lines and metro

Figure 24: Ørestad main features

Services provided by the site and any green technologies which enable them to be provided at low carbon

Electricity	PV solar panels
Accommodation	Insulation, low carbon construction materials
Sports facilities	
Outdoor space	
Social spaces	
Shops	
School	
Business space	
Transport links	Low carbon public transport infrastructure, pedestrian and cycling provision
Waste disposal facilities	Recycling facilities

Figure 25: Ørestad services

What behaviour is required to make people to use these technologies and how does the design of the site influence these behaviours?

As it is a common theme, there is a need for an understanding of the workings of the green technologies to ensure proper use and a need for residents to be willing to make decisions about

taking public transport, using a bike or walking and recycling waste a part of their everyday routines. The design positively influences this sort of behaviour through physical and visual features. These include: raised public transport corridors on the main street, natural looking recreation space, pockets of bike racks and prominent water features. However, it can also influence it negatively, for example by allowing cars to be prominent in residential areas, using lots of concrete in construction and creating buildings on a scale which is larger than human scale.

Findings

Example signals:

Water features prominent in the urban environment	Water in canals and trees buffer large buildings
Cars still prominent in residential areas	Curved road mirrors natural patterns
Raised public transport corridors	Lots of concrete
Boulders in park area bring nature back in	Pockets of bike racks
Views through to green areas	Picnic tables encourage use of green space

Figure 26: Ørestad findings

Take away lessons

Ørestad is not similar to the NWC development in terms of location or land use, or even demographic, but some of the visual signals make for a relevant study. There is a heavy presence of water in the site, but its formations are not natural in shape. The dominant position of its key public transport infrastructure raised in the middle of the main street may reinforce the importance of public transport options, but also reminds us of the power that humankind can exert over natural form, scale and environment. The materials here are strong, industrial types and the building and streetscape scale is large.

There are pedestrian areas, but it is not until you are in between apartment blocks that these are obvious in the large and fairly natural park area. There are regular small bike racks, to be seen as an everyday choice and the very large shopping complex is cleverly hidden, but all in all green signals are lacking. The identity of the area is not obvious, which may hold back the journey to a local eco-community behaviour.

IT University Campus

Site Overview

The area is being developed into a joint campus between University of Copenhagen and the new IT University. The architecture (from 2000s) has modern aspirations and scale is quite large.

Main Features

Academic and residential facilities	Water very prominent
Some areas still under construction	Large-scale cycle racks

Figure 26: IT University Campus main features

Services provided by the site and any green technologies which enable them to be provided at low carbon[17]

Research facilities	
Student accommodation	
Outdoor space	
Social spaces	
Community space	
Shops	
Business space	
Transport links	
Waste disposal facilities	

Figure 27: IT University Campus services

What behaviour is required to make people to use these technologies and how does the design of the site influence these behaviours?

Though there is little information on the exact green technologies on the site, it is possible to make some observations on how the design of the site might influence behaviour of the residents and users.

The student accommodation building (acclaimed by architects) central courtyard has trees in it – acting as a visual reminder of the natural world around us. The site in general has a high presence of

[17] We were unable to get much information on green technology used in this development

water on it, both in natural and man-made forms. The buildings have a very (2000s) modern style which probably reminds residents and users about humankind's use of materials and ability to shape the world.

Findings

Example signals:

Water presence	Modern buildings, 'screen' building
Layers, patterns	Trees
Well-received student accommodation block has inner courtyard and balconies with trees	Several bike trailers were parked under balconies – intentional? Or residents moulding their environs?
Glass reflects the water	Tree in walkway between buildings
Meandering river (man-made?) ensures water presence throughout	Large area of bike parking next to faculty buildings

Figure 28: IT University Campus signals

Take away lessons

The IT campus has similarities to NWC in terms of its purpose, land use and partnerships. Some of the water form resembles that in nature, but the dominant large-scale buildings minimise the impact of the smaller green signals. It raises a question about the role of modern architecture (and construction materials) as part of creating urban environments that inspire 'green' behaviour.

Sweden

Western Harbour

Site Overview

The Western Harbour site with its Bo01 development is an impressive example of how to incorporate sustainable living into a large scale, mixed-use urban fringe development. Transformed from a coastal industrial zone to a showcase of environmentally-friendly living, the site has incorporated many different urban design and green technology features within its urban realm. It also plays host to a university and business park within its boundaries.

Main Features

Mixed-use site	Different zones
Residential, retail, commercial, industry, academic presence	Bo01 Housing development

Figure 29: Western Harbour main features

Services provided by the site and any green technologies which enable them to be provided at low carbon

Electricity	Solar PV
Heating	Solar thermal, district heating and cooling system
Accommodation	Insulation, low carbon construction materials, smart meters
Water purification	Rainwater collection, SUDs system
Sports facilities	
Outdoor space	Green roofs, parks
Social spaces	
Emergency services	
Community gardens	
Community space	
Shops	
Schools	
Nursery	
Business space	
Public services	
Healthcare facilities	
Transport links	Bike and pedestrian facilities, public transportation links
Waste disposal facilities	Recycling facilities

Figure 30: Western Harbour services

What behaviour is required to make people to use these technologies and how does the design of the site influence these behaviours?

Residents need to have a basic understanding of green technologies which they use in order to ensure that they are operating effectively. Understanding of and use of smart meter technology is also key in this example. Active choices will need to be made in regards to the successes of public transport links, cycle and pedestrian routes and waste recycling. The greater the amount of time residents spend familiarising themselves with their environment, the larger the effect the design may have on their behaviour.

The design of the site influences this behaviour in various ways. Much care and attention has been put into the urban design and structure, as evidenced by the fact that the Head Architect envisioned "a network of street[s] with a broken-up character, much like that of the inner-city of medieval towns. This was to have a dual purpose, partly it would break up the urban environment allowing for a more pleasant experience, partly it was to break up the harsh sea winds"[18]. The built environment itself presents shapes and colours which could be seen to be reminiscent of nature, complemented by regular green spaces. "Nature is present throughout the city district thanks to conscious planning. Rich and varied greenery in parks, yards, along streets and in squares has a positive effect on the health of residents and visitors" (Malmö Stad).

Pedestrianised zones give people clear priority over vehicles. The presence of water throughout the site and visual corridors out to the sea also provide an important visual reminder of what we need to preserve. There is access to the public realm on many levels across buildings, emphasising the shared nature of the space. Some green technologies are deliberately visual in the streetscape e.g. the SUDs draining system. Public artwork (e.g. taps, eye watching over residents) complements the environmentally-friendly design with similar messages.

The replication of a historic street pattern – winding and narrow – reflects back to a time before our cities and towns were designed primarily for cars.

There are certain information flows causing people to make behavioural decisions. In this example these could be the eye artwork, the marketing around the project and accommodations and the visual signals throughout.

Findings

Example signals:

Wavy lines – sea and nature, slow traffic	Wooden street furniture – nature, enjoy the space
Ship's prow balcony – history of site	Steps down to water – edge zone connections
Open space, buildings, tower overseeing	Wooden decking – people space, connection to water edge
Marina – transport, leisure, water connection	Walkway – edge connections, walking space, NWC parallel
Boulders at water edge – bridging, climate adaptation	Levels and materials

[18] http://en.wikipedia.org/wiki/Bo01

Water feature – natural stream reminder	Combination of natural and man-made into a space
Nature pockets – never far, constant reminders, individual	Water and park area – space for people to enjoy and relax
Large natural park area and sustainable play park	Road system prioritises bikes
Integrating water and buildings	Courtyard natural spaces throughout
Bridging – access to public realm from different levels	Waterway and reeds, view out to sea
Pocket parks and continual yellow paving – pedestrian zone	Individual houses, jetties onto river
Shared space – children, bikes, vehicles – colour coding	Visual corridors out to sea edges, visible drainage systems
Pedestrian space – vehicles limited and hidden	Mix of building styles and colours
Artwork – taps water-themed display	Artwork depicting children playing near skate park
Car parking in 'tree cage'	Innovative bike racks around trees
Larger 'industrial' buildings for university and business	Marina area – gateway to sea
Public artwork – eye, watching over?	

Figure 31: Western Harbour signals

Take away lessons

The Western Harbour development combines different building structures and scales for different purposes, but ultimately creates a sustainable living atmosphere throughout. How does it do this? Anyone strolling through the Bo01 housing area will understand. This area forms natural (historic) street patterns, heterogeneous building styles, colours and heights, a truly pedestrian dominance – it seems wrong to find a car there. The green technologies are open and visible – a built-in part of the urban realm. Pocket parks, vegetation and waterways are a constant but blended reminder of what we strive to protect with our actions.

Visual signals of various types and scales are all important for creating an environment where 'green' behaviour is the benchmark norm. The importance of social community spaces is clear - "it has to be possible to interact with other people and to participate in cultural activities" (Malmö Stad), providing "an example of social sustainability in the area" (Malmö Stad).

The eye artwork is a possible example of exploring "new and creative ways to reward people and show them why their actions matter" (Global Awareness in Action) for example if it changed colour according to how well the community jointly was doing in terms of reaching energy targets. The famous example of this technique is Schultz et al. using happy faces on comparative home energy bills to encourage sustained low energy consumption (Schultz, 2007).

Royal Seaport

Site Overview

The Royal Seaport development is being created building upon lessons from Hammarby Sjöstad. The area is challenging because of industrial contamination, proximity to a nature reserve and port operations and so the decision was taken to develop it to very high environmental standards. Unfortunately, these were only put in place after the first two phases were already given the go-ahead.

Main Features

Mixed-use site in various bundles	Water-edge at parts and inland at others

Figure 32: Royal Seaport main features

Services provided by the site and any green technologies which enable them to be provided at low carbon

Electricity	Solar PV
Heating	Solar thermal
Accommodation	Insulation, low carbon construction materials
Shops	
Office space	
Outdoor space	
Social spaces	
Transport links	Pedestrian and cycle infrastructure, public transport infrastructure
Waste disposal facilities	Recycling facilities

Figure 33: Royal Seaport services

What behaviour is required to make people to use these technologies and how does the design of the site influence these behaviours?

As in other developments on a basic level, residents will need to understand the green technologies to check their proper operation. They will need a willingness to walk, cycle or use public transportation, although the level of ability of private vehicle parking on the site will affect this. There will need to be a willingness to sort waste for recycling.

The design of the site will influence this behaviour in various ways. For example: the presence of nature on and surrounding the site, a street-facing screen educating residents and visitors on green technologies and facilities, variety in building designs reflecting nature, recycling features in the streetscape, regular bike parks positioned in "attractive nodes", charging stations for electric vehicles in parking spaces (Yin, 2014) and pedestrianised areas.

Findings

Example Signals (based on the Norra 1 section):

Natural edge to site – trees and waterway	Decking bridges gap between people and water, different levels
Planning office has model of full-scale development	Screen onto street highlights eco-features of the site
Green spaces between buildings	Development will extend to regenerate docklands
Different colours and designs of buildings	Recycling features in streetscape
Small-scale bike parks, greenery surrounding	Gas cylinders remind of history of area
Curved path of road – slows traffic, natural lines	

Figure 34: Royal Seaport signals

Take away lessons

Royal Seaport is still developing but the first stage is promising in terms of signals and environmental indicators. The border with the forest natural park area and river provides a convenient bridge to the natural world, but this has been developed and complimented throughout the site with visible technologies and reminders (e.g. screen explaining processes), as examples of initiatives to attract attention and remind people of desired behaviour (Global Awareness in Action). It will be interesting to see how this is developed through the later stages which have higher sustainability requirements due to newer planning regulations.

It has been noted that "one of the most important lessons learned from Hammarby Sjöstad was that a lack of follow-up and monitoring hindered the realization of objectives"[19], so it will be interesting to see if more monitoring here will affect residents' actions in relation to green technologies.

Visual information flows may help bridge the technology-human gap. Another question is raised about to what extent proximity to a (protected) natural area can change people's attitudes towards environmentally-friendly behaviours.

[19] Pandis and Brandt, (2009), in City of Stockholm, 1998, in Ying Yin (2014)

Hammarby Sjöstad

Site Overview

Hammarby Sjöstad was originally the plan for an eco-friendly athletes' village in Stockholm's bid for the 2004 Olympics. The bid was unsuccessful but the vision for the area lived on and the previous industrial site was decontaminated and transformed into a popular mixed-use area which extends and develops the centre of Stockholm, based on "a political consensus in the City of Stockholm regarding the use of Hammarby Sjöstad as a pilot project for experimenting with environmentally friendly planning and construction for residential areas" (Yin, 2014).

Main Features

Mixed-use area	Family-friendly
Commercial space and community facilities	Suction waste system
Hammarby model shows cycles of resources in and around the site	Pedestrianised areas and bike paths
SUDS drainage system	Solar panels
Green areas & water presence	Salmon ladder
Wildlife green bridges to nature reserve	

Figure 35: Hammarby Sjöstad main features

Services provided by the site and any green technologies which enable them to be provided at low carbon

Electricity	Solar PV
Heating	Solar thermal
Accommodation	Insulation, low carbon construction materials
Water purification	SUDs system
Sports facilities	
Outdoor space	
Social spaces	
Emergency services	
Community spaces	
Shops	
Schools	
Nursery	
Business space	
Public services	
Healthcare facilities	
Transport links	Cycle and pedestrian infrastructure, public transport infrastructure
Waste disposal facilities	

Figure 35: Hammarby Sjöstad services

What behaviour is required to make people to use these technologies and how does the design of the site influence these behaviours?

As with the other case studies, there is a certain knowledge base and willingness to adopt a certain routine that will be required of residents to make meaningful use of the green technologies.

The design of the site influences this behaviour in various ways, including the presence of: pedestrianised areas and bike paths, water across and through the site, green areas and links to bigger natural areas, salmon ladder, visual corridors to water or nature, trees, the GlassHusEtt building and accessible step design.

There is an information flow from the GlassHusEtt information and community centre encouraging certain behaviours and the urban design acquaints residents with an environment free from vehicles, reducing their perceived need.

There were some issues as the first batch of residents moved onto the site, who were "resistant to some of the environmental objectives" (Yin, 2014) such as parking restrictions, experiments with urine separation (later scrapped) and biogas cookers.

Findings

Example Signals:

Nature

Nature integrated with residential streets	Visual corridors to natural lake area
Dam with salmon ladder – increasing ecology	Natural woodland park in middle of development

Leisure

Bridge zone between waterways and buildings becomes leisure zone	Space for kayaks in public realm – leisure and active lifestyles in nature
Decking and seating areas bridge built-up and natural zones	Artificial ski slope/bike track built on waste hill - visual reminder

Streetscape

GlasshusEtt model shows flows of energy/water/waste	Steps include provision for bikes/prams/wheelchairs – inclusivity & access
Recycling suction system takes waste to edge of site for processing	Pedestrianised major street offers park/waterway/paths/seating
Separated public transport/car/bike/pedestrian zones of street	Car looks out of place in pedestrianised zone

Figure 36: Hammarby Sjöstad signals

Take away lessons

Hammarby is the go-to example of a sustainable urban development project and it is obvious why – the green areas and waterways seamlessly connect to the built-up areas and green lines run throughout. Certain green technologies are visible and the history of the site itself tells a tale of environmental regeneration. However here, as with Vauban, there is another side to the story, based on a dominant demographic, lack of true social integration and a dominant value set which might not quite line up with the basis of the site's development – leading to lower than target energy and carbon savings[20].

Demographics play an important part in reaching targets of CO2 on a site. The dominant group of middle-class families on this site may have a perception that if they 1) do recycling 2) keep the area tidy and 3) enjoy nature, that they are the ideal 'green' residents, when in fact the site demands more to reach its targets[21].

It is also important to consider 'externalities' of a site e.g. consumption levels and carbon footprint of building the development.

Summary of the key lessons learned

The table below provides a summary of the key take away lessons from each case study site.

BedZED
- Small scale means that the impact of surroundings is higher than in a bigger development - Limited variety of services means people are likely to spend a lower percentage of their time on the site so the level of impact on their individual carbon footprints may be lower - 'Hard' construction materials dominate and public green spaces are lacking and poorly maintained – negative visual signals - Road circling the boundary of the site sends a message that private vehicle use is inevitable - Bridging with the external environment is important to blend with and influence surrounding areas rather than existing as green 'islands' in isolation
One Brighton
- Technologies and features are hidden or too high up to be visible on a human scale. - Scale of site offers little potential for real influence in people's lives, or spill over into bordering developments - Concrete, little greenery and signals discouraging residents and visitors from using the common space e.g. written notices banning cycling and skateboarding

[20] Discussions with Ulrika Gunnarsson Östling, KTH
[21] Discussions with Ulrika Gunnarsson Östling, KTH

- No car parking spaces in the development - increased chance of residents cycling, walking or using public transport to get about

Vauban

- Buildings carefully placed in between trees and natural areas rather than the other way around - feeling of humans in harmony with nature rather than above it
- Vehicles seem like imposters in the pedestrianised zone.
- Heterogeneity of the buildings and structures ties in with the natural ethos and the safe space is maintained for children to grow up outdoors
- Demographically very homogenous, with privilege which made aspects of site easier to implement e.g. tram connection, affordable homes next to railway

Rieselfeld

- Half-way house between a truly sustainable eco-community and your average modern development - a realistic compromise going forwards?
- Draws people in to use its space by providing public services and amenities
- Several clear visual signals – consciously or subconsciously remind people of the importance of remembering our impact on the natural environment in our lives in new developments
- Sends a message of 'you can have a smaller impact on the environment but still live a normal life' rather than suggesting that everyone must make significant personal sacrifices to their lifestyle

Nordhavn

- Development consciously chose a strategy of using the urban layout and design as a means of creating new habits
- New lifestyle has been marketed to people ahead of their living on the site - they know what to expect of life there
- Reclaimed land but with active decision to build more water channels and spaces in between land plots
- Efforts to increase leisure and recreation opportunities linked to the water and urban design that bridges the land/water boundary

Ørestad

- Heavy presence of water in the site, but its formations are not natural in shape
- Key public transport infrastructure dominant - reinforces importance of public transport, but also reminds us of the power that humankind can exert over natural form, scale and environment
- Materials used are strong, industrial types and the building and streetscape scale is large
- Pedestrian areas, but not obvious
- Regular small bike racks - seen as an everyday choice
- Large shopping complex is hidden
- Identity of area not obvious

IT University Campus

- Some of the water form resembles that in nature
- Dominant large-scale buildings minimise the impact of the smaller green signals
- Raises a question about the role of modern architecture (and construction materials) as part of creating urban environments that inspire 'green' behaviour

Western Harbour

- Combines different building structures and scales for different purposes, but ultimately creates a sustainable living atmosphere throughout
- Bo01 housing area forms historic street patterns, heterogeneous building styles, colours and heights, truly pedestrian dominance
- Green technologies are open and visible – a built-in part of the urban realm
- Pocket parks, vegetation and waterways are a constant but blended reminder of ultimate aims
- Visual signals of various types and scales
- Focus on social community spaces

- Examples of public art encouraging engagement in public realm
Royal Seaport
- Border with the forest natural park area and river provides a convenient bridge to the natural world - Visual information flows about the site may help bridge the technology-human gap - Proximity to a (protected) natural area – can this change people's attitudes towards environmentally-friendly behaviours?
Hammarby Sjöstad
- Green areas and waterways seamlessly connect to the built-up areas and green lines run throughout - Certain green technologies are visible and the history of the site itself tells a tale of environmental regeneration - 'Externalities' of a site e.g. consumption levels and carbon footprint of building the development must be considered

Figure 37: Fieldwork key lessons

General analysis and overall lessons

While we can take lessons from each of the case studies, some common themes are explored in more detail below.

We have seen that the development of a community is a key strategy aim of many of the case study sites and so ties in with the evidence of social practice theory in terms of influencing longer-term community behaviour trends. Massey suggests "space as 'a simultaneity of stories-so-far' and suggests that 'places are collections of these stories, articulations of the wider power-geometries of space' (2005:130)" (in Pink, 2012). For the social element of sustainability to work (and thus the economic and environmental aspects be able to be a success too) certain practices must start to exist and for their continued existence, "the density and character of social bonds is important for how practices travel and for the populations they encounter and attract" (Shove et al., 2012). So whatever the planners can create in terms of an urban environment which encourages residents and visitors to interact and form strong communities has to be a positive, as "practices cannot be understood as being performed in isolation from the wider environments of which they are a part" (Pink, 2012) and indeed our research takes this further in terms of the key role that urban design features can play in encouraging sustainable behaviours.

It has become clear that nudges are key to encouraging environmentally-friendly behaviour. Although to some they may seem "ridiculously inadequate – a bit like an effort to capture a lion with a mousetrap" (Thaler & Sunstein, 2009), they do definitely start to have an impact on changing the

'human' part of behaviour in relation to green technologies. "The underlying problem is that energy is invisible" (Thaler & Sunstein, 2009) and human behaviour is at least in part irrational, but what aspect we can influence could make key differences when applied to use of green technologies. Choice architecture greatly affects our decisions (Thaler & Sunstein, 2009) and so if we can use urban design in our new developments to additionally construct environmentally-friendly behaviour, we may be on to a winner.

4.3 Scene interpretation

A picture is worth a thousand words

Introduction

During the fieldwork explorations, we took a number of photographs of different scenes and elements of each site – some focusing on specific green features, others showing standard streetscape scenes. On return, a selection of these cross-cutting the range of environments, urban design and types of features were chosen for inclusion in either the survey or to be explored in the picture round of the interviews. We use the fieldwork examples to look for attitudes in the NWC population sample and associated anticipated behaviours.

We wanted to gather impressions from respondents as if they were in each scene – what stood out to them? Which features or combinations of elements gave a positive reaction and which a negative? Two types of question were used in the survey – side-by-side comparison of two images with a set of three questions and image area questions – where images were split into smaller pieces in advance and respondents were asked to click on parts of the photograph that stood out to them, indicating whether this was in a negative or positive way by the number of clicks.

In the follow-up interviews, we went through a set of 13 images with participants. Some of these they had seen previously in the survey; others were new. They were asked to comment on the following aspects of each image, with minimal prompts from the interviewer: what stood out to them initially; any aspects of the scene which they liked; any aspects of the scene that they did not like; how they think they might feel in the scene. There were occasional follow-up questions asked, for example around reactions to the eye artwork in one image, to get a range of responses on a key aspect.

The photographs were taken in the late winter when some would say that the developments are looking at their worst. This was a deliberate choice in order to gauge responses to the environments without the benefit of sunlight and plants in full bloom. In this way we avoid any 'rose-tinted' responses and get reactions on the core structure of the spaces. After all, these developments will be lived in year-round, not just in the best weather and so we are looking to find out what makes a good place to live, which gives year-round energy and carbon savings.

Image data

In this section we explore the results to the image questions in the survey and corresponding interview themes and comments.

We looked at trends picked up from the survey respondents' answers and interviewees' reactions to a range of images of the case study sites and the influence that these might have on people's behaviour.

Comparison questions

Methodology: In the first part of the 'picture round' of the population sample survey, we asked participants to look at two pictures at a time, then answer three questions on the images.

"For the first 3 questions you will be looking at pairs of photographs of urban areas and answering questions based on your impressions. Let your immediate reactions to the scenes guide your answers."

Happy spaces

Pair 1:


Scene 1 – Vauban, Germany **Scene 2 – Orestad, Denmark**

Question	Scene 1	Scene 2
I would be likely to walk or cycle there	82% yes	48% yes
This environment makes me feel happy	47% yes	54% no
I think I would live a 'green' lifestyle there	50% maybe (+42% yes)	59% maybe (+26% no)

Figure 38: Happy spaces data

These two scenes were juxtaposed as both show a pedestrian/cycling area next to a natural area, next to a main transport route (road in scene 1, raised railway in scene 2 with a road behind). While the respondents were likely to walk or cycle in both, the preference for this in scene 1 was 34% higher than in scene 2. When we combine this result with the answers to the second question we see a contrast in answers – almost as many people think that scene 1 makes them feel happy as the number that do *not* think scene 2 makes them feel happy. From this we can consider that while putting active travel infrastructure in place will encourage people to cycle or walk, to make the leap to majority use, we also need to create a space in which people will feel happy. They are much more likely to want to walk or cycle in a space which they find pleasant. In terms of whether participants think they would live a 'green' lifestyle there, we see the majority unsure in both cases, but with a positive skew in scene 1 and a negative skew in scene 2. This correlates again with the happiness ratings of the scenes. Perhaps the three tie in – creating a space in which people feel happy means that they will cycle or walk more, which will be part of them living a 'greener' lifestyle.

These questionnaire findings above are backed up by feedback from participants in the interview picture round:

- *"So the thing I really like about this photo is that you can see all of these trees, so it's clearly a kind of mountainous, wooded area which is my favourite type of place" (scene 1)*
- *"I like this one because it looks like they have a segregated cycle path that's away from the main road, erm and I really like that, especially living here and cycling every day" (scene 1)*
- *"It's very pedestrian/cycle-friendly, safe, it's got nice greenery bits, separated from the road. Looks very nice" (scene 1)*
- *"Well water, good thing, raised concrete structures, not so good" (scene 2)*

- *"I don't really like this… it just feels like a motorway bridge. It feels like it'd be noisy and polluted… water looks green, it looks dirty" (scene 2)*
- *"If that's a railway and someone lives near it, that's going to be a nightmare, oh the noise, the noise is going to be so bad!" (scene 2)*
- *"Ooh no. Ooh no I don't like that one! Horrible underpass and sort of dingy green water and an ugly bin in the foreground erm yeah, no I don't like that one at all." (scene 2)*

Space to share

Pair 2:

Scene 3 – Orestad, Denmark

Scene 4 – Western Harbour, Sweden

Question	Scene 3	Scene 4
I can imagine being part of an active community there	47% maybe (+30% no)	54% yes
I think I would live a 'green' lifestyle there	51% maybe (+28% yes)	49% maybe (+46% yes)
I would like to spend time in this space	41% maybe (+31% no)	67% yes

Figure 39: Space to share data

These images were compared as they both show open public spaces in the centre of a built-up area. Both have bodies of water, trees and paved areas with buildings around the edge (scene 3 is commercial, scene 4 mixed/mainly residential).

Our comparison shows a clear indication that most people would like to spend time in scene 4 but not in scene 3. Another big area of contrast is in whether people could imagine being part of an active community in the space. While we must bear in mind that scene 3 looks more obviously commercial *("looks very much a business place rather than somewhere you'd want to live"* scene 3), there are clearly elements of scene 4 which make people think they would be more socially active in that space. The comments from interviews give us a feel for why this is:

- *"So it seems that the trees are kind of blocked off, you can't go and read a book underneath them or something like that" (scene 3)*
- *"It doesn't look like there's anywhere to sit or anything there just I guess you'd sort of pass through that area and it's quite angular and severe so meh" (scene 3)*
- *"It was too big… the passages were too long and okay it was nice to explore but this wouldn't be the place I would spend my afternoon" (scene 3)*
- *"The water just feels like it got put there because, to try and soften it, but I'm not sure it works. Not enough trees." (scene 3)*
- *"There is space for the families, there is space for children and there is space to actually go and have a picnic on the grass" (scene 4)*
- *"Oh I really like this space. I think it looks really relaxed and give you the sense of eh community also a little bit, I feel like there could be lots of people here at some point and there is enough space to accommodate a lot of people" (scene 4)*
- *"I like the hammock especially, oh yeah, it's very um, free, open" (scene 4)*

General themes for what makes a good community space are open space that is well thought-out to provide what people need for a social space – places to sit, nature to enjoy, places for children and adults alike to enjoy.

The two scenes have similar scores for how likely people think they would be to live a 'green' lifestyle there. Perhaps they can see the merits of both spaces, or are unclear in both cases. For us the interesting aspect to examine is in relation to community–building. If we are to rely on social networks to spread energy- and carbon-saving behaviours, we must create spaces which foster community creation and growth.

Overall scene 4 had the highest combined 'maybe' and 'yes' score for whether respondents thought they would live a 'green' lifestyle in the space (although this was only asked of four scenes).

Inspire me

Pair 3:

Scene 5 – Hammarby Sjostad, Sweden

Scene 6 – Western Harbour, Sweden

Question	Scene 5	Scene 6
I would feel comfortable in this space	39% yes	61% yes
I can see myself taking part in leisure activities there	43% yes	52% yes
This space would encourage me to look after my local area	54% maybe (+24% yes)	49% maybe (+36% yes)

Figure 40: Inspire me data

The third pair of images were picked because the scenes both include something a bit quirky to find in an urban environment – the first a collection of kayaks tucked under a walkway, the second a large eye public art piece. Those are the main focus of the photographs, but both also feature residential buildings in the background and pedestrian spaces with changes in ground levels.

Both spaces score highly on the perception of being good for leisure activities – most likely influenced by the obvious kayaks and bikes present in each photograph respectively. This fits with the idea that you are more likely to take part in certain activities if they are perceived as 'normal' – you can see evidence of the activity right in front of you on the street. Normally this occurs when we see parked cars, telling us that it is a done thing to drive in a place, but this result shows us that this equally applies with active travel equipment stored visibly. If we incorporate visible storage of active travel equipment into our urban design – bikes, kayaks, even push scooters and skateboards perhaps – we can change perceptions of what the 'normal' means of getting around are and start to shift habits. These also bring colour and interest to otherwise fairly plain spaces. Our interviewees confirm these ideas:

- *"It's one of the environments where you feel like you can do things" (scene 5)*

- *"It seems like people are quite active who live in the neighbourhood… if I was to choose an apartment there, I would feel like oh my neighbours are active… so, this would give me actually a good message" (scene 5)*
- *"It's kind of making me imagine more" (scene 5)*
- *"If I was walking by there I'd be like oh wow how do I get involved in that?" (scene 5)*
- *"I like that there's lots of bikes there, it's like obvious that people are using it and that it's safe enough to do that" (scene 6)*
- *"Of course I love that there are cycle racks" (scene 6)*

Both photographs also scored highly for feeling comfortable in the space. This is somewhat surprising for scene 6, which shows the eye art work. Views on this piece of art were mixed, but the interviewer prompted the question so all interviewees gave a response. We see that if we want to draw attention to something we can do it through art, which also has the potential to be used as a tool to encourage certain behaviours. Thoughts and feelings associated with the eye were explored in the interviews:

- *"The artwork's kind of cool but it does seem very big brother is watching you kind of visual effect" (scene 6)*
- *"I love the art… I don't feel watched!" (scene 6)*
- *"I like quirky things, that's good" (scene 6)*
- *"Maybe it's like for the thieves to stop them" (scene 6)*

Most survey respondents were unsure about whether the spaces would encourage them to look after their local area, but with a positive skew. Perhaps it is hard to link this idea with the space in their heads. There might be ways in which spaces with a high level of active travel and comfort levels in a space give an incentive for users to look after the space – you do not want litter in the way of your cycle route, or pollution in the water you are paddling down, of course.

Like/dislike features

Methodology: We asked survey participants to study two separate images and pinpoint visual areas of like or dislike.

"In the image below, as you scroll over the picture, boxes will appear over different areas. Select the parts of the scene which stand out to you. Click once on an area if you like it. Click twice if you dislike it."

Scene 7 (Western Harbour, Malmo, Sweden)

Figure 41: Scene 7

Most liked features:

- Sea 77% (lower centre box)
- Trees 70% (upper centre box)

Most disliked features:

- SUDs 73.3% (left lower centre box)
- Terrace 35% (+ 53.3% neutral) (left upper centre box)

This scene is from Malmo's Western Harbour port regeneration development. With the overarching aim of sustainable living, the designers have gone for a combination of high density while retaining human scale where possible. A conscious decision has been made to make visible green technologies used on the site to reduce energy use and carbon emissions. The aim is that having these

technologies form a part of the urban environment will acquaint residents and site users with them and encourage greater use of them in line with the overall sustainable behaviour aims.

Our response to the image above shows that this may not quite have the desired effect. The sustainable urban drainage system pipes visible in the photograph ranked as the most disliked element of the photograph (73.3% dislike). This was backed up by interviewee feedback which on the whole found the pipes aesthetically displeasing or unnecessary in the space. No one mentioned sustainable behaviours in relation to these:

- *"Erm, are those drains?... I dunno aesthetically it's not great"*
- *"Perhaps diverting these, what are they, overflow pipes, or extract pipes?"*
- *"Really industrial…all those pipes and things, like you just need to have them for disposal and stuff."*

By contrast, the most favoured features were the views to nature in the centre of the image, where the passageway leads out to trees (77% like) and the sea beyond (77% like). This is clear evidence of the relationship between nature and human happiness. Even having a view of nature in the distance is proven to have positive effects on health and wellbeing (as shown in Roger Ulrich's study on hospital patients where those with a view of nature recovered more quickly).

Scene 8 (One Brighton, Brighton, UK)

Figure 42: Scene 8

Most liked features:

- Bush 58% (lower centre)
- Balconies 2 53% (centre left)
- Balconies 1 52% (centre right)

Most disliked features:

- Grit bins 40% (bottom left corner)
- No smoking poster 30% (centre right)

The second image in this section was looking outwards from the community centre in the One Brighton development in the UK. This photograph shows the area of the site which developers designed to bring people together.

The most liked feature in this scene was the bush (58% like) – one of a few sparse pieces of evidence of nature in the photograph. Respondents also appreciated the two sets of balconies (53 and 52% like) on the apartments looking onto the courtyard, showing an appreciation of individual outside space, but in a zone which is communal.

The balconies encourage people to use the outside space, whereas one of the disliked features – the 'no smoking' poster in the window (30% dislike) – is an obvious attempt to control what people are able to do in the space. Also unpopular were the grit bins (40% dislike). With both of these elements, it could be that participants are more put off by the aesthetic of these features. In the wider courtyard area there were various unsightly bins and signs and labels in temporary-type materials rather than having these elements hidden or imbedded into the design. The presence of lots of signs telling users of the space that they must behave in certain ways e.g. "no ball games" gives a sense of corporate power over the space, rather than community ownership. This could contribute to residents feeling less like it is a space for them to share and shape as a community. When people feel ownership of a space they are more likely to want to look after and improve it.

Interview picture round

Methodology: Interviewees were asked to take part in a picture round at the end of the interview. In this they were shown a series of 13 images and asked to give their impressions on the scene e.g. what stood out to them, elements they liked or disliked and if they thought they would feel a certain way in the space. Some of the 13 images were those included in the survey (apart from scene 8) and

so interview comments on those scenes are included above. Additional scenes and findings are below.

Seventeen individuals took part in interviews and each had a chance to comment on the following images. While this is not as large a population sample as the survey provides, it allows us to gain depth in understanding some of the survey responses on the images and how people interact with their surroundings. We can use this data as one element of our identification of behavioural traits in our groups established in the following chapter.

Some key comments are included for each image below, to highlight the main trends in responses (a full set of responses is not included due to repetition and space).

Scene 9 – a pocket community

Figure 43: Scene 9

On the whole, this image got a positive response. Participants liked the intimate communal space created by the small-scale buildings and the opportunities that this little garden space with water and plants could provide for the community to sit and enjoy a little bit of nature.

The main criticisms came in the form of the plants looking dead (which could be attributed to the season rather than maintenance!) or the space seeming artificial or just not that exciting.

This tells us that people like the idea of little pocket community spaces as well as those larger communal areas. They like the idea of having a space where chance encounters or socialising could happen just outside their door. However, these need to be visually appealing or people will start to think of them as neglected and lose the positive effects that pocket parks can give.

- *"Looks like a bit of effort has been made and it's not just a paved courtyard, they've sort of put in bit of a water feature of some sort that's nice"*
- *"I would love to live there!... The thing that each corner, each part of the place is so different, it's the variety of, of buildings, lots of little niches, lots of public space" (interviewee had been there)*
- *"In the summer, it'd be a nice place to sit"*
- *"Oh, this one is beautiful! …oh, I like the little bench where people can sit and relax and have kind of like some rest, I like water as well"*
- *"The pond is maybe a little bit on the drab side but erm it's better than not having one I suppose"*
- *"Oh that looks really nice, that's really peaceful… looks like a nice place that people could go to chat or think about the world"*

Scene 10 - function is not enough

Figure 44: Scene 10

In this scene there were elements that participants identified as something they would like to have in a place they lived - e.g. cycle lanes, a café, open space – but on the whole the scene didn't gain much enthusiasm from the interviewees. Main stated reasons were that the design wasn't aesthetically-pleasing, with no greenery and that the lack of evidence of people made them think they wouldn't want to hang around there.

- *"Lot of grey in this picture… it looks quite quiet so I dunno what it would be like to actually live there"*
- *"A bit bare really"*
- *"So I like that the traffic is slowed down by the arrangement of the junction"*
- *"I love cycle lanes so I would really enjoy that"*

- *"There are no signs which is quite good, if this was Britain it would have lots of signs everywhere"*
- *"Otherwise that looks a bit bleak to me"*
- *"There is almost like no transition between eh your home and the street. So it just goes like **bam** go into a car. There is something missing here."*

Scene 11 – big is overwhelming

Figure 45: Scene 11

Participants liked the green space that this scene offered, but felt that this was overshadowed by the large buildings which they found overpowering. They impression was that the designers had tried to create a nice space to sit, but that in some ways this was not quite as functional as perhaps aimed. Some commented that the weather on the day that the picture was taken perhaps impacted on their impression.

- *"Am I supposed to enjoy the grass for walking on or am I supposed just to stay off it?"*
- *"Loads of green space and again people can sit and maybe, yeah children can play around, yeah, they can go with a dog"*
- *"Quite nice and green"*
- *"Looks quite overshadowed by those buildings, they're quite high rise"*
- *"The buildings are… too big, basically they overwhelm the neighbourhood"*
- *"I guess that could be a nice place to go and sit, I like the decking, I like the grass but I dunno what the view is particularly nice these buildings are not particularly attractive"*
- *"If it's taken on a rainy day it's not as impressive"*

Scene 12 - give us nice spaces to walk

Figure 46: Scene 12

Most responses to this scene were fairly positive – interviewees liked the benches and balconies providing space to relax. Some of the negatives were to do with the season, others unsure about whether they would actually like using the space as it was not as interesting as they would like. They really liked that the space was pedestrianised.

- *"The buildings are kinda samey and not particularly pretty but at least there's some gardens and maybe fountains to look at there"*
- *"This is a nice place… because again it's more for the pedestrians"*
- *"I like the big trees… I feel like in summer this would be quite a nice place"*
- *"Kind of half and half whether I'd be like to walk around there"*
- *"The canal is quite a nice feature"*
- *"I think anything without traffic is pleasant. To live in and walk around in"*
- *"I also just like how pedestrian oriented it is"*

Scene 13 – immersed in nature

Figure 47: Scene 13

While some participants were confused about the purpose of the space, on the whole people were intrigued by the boardwalks out on the water and felt it invited exploration. This shows us that we

can adapt our traditional notion of what a natural leisure area is in an urban area, making use of space which would otherwise be wasted to benefit the users of the space by immersing them in nature in a new way.

- *"I don't really understand what the space is for, if it's kind of recreational space or to get to another place. But it looks like it'd be nice in summer"*
- *"I like those walkways I think it would be nice to walk over the water"*
- *"That's a bit more wild"*
- *"It's attractive space, it's like inviting you to actually explore and things"*
- *"You've got a nice expanse of water to go look over"*
- *"It's very interesting, it's kind of like a place you'd like to explore!"*
- *"I hope there's loads of lights!"*
- *"I want to make sure that we have enough distance to the wildlife so that you don't disturb them too much"*

Scene 14 – don't exclude me

Figure 48: Scene 14

The key impressions on this image were that it was a fairly standard style of architecture, but that it was nice to have views of the water and to soften the transition between housing and street. There were some concerns about the steps in terms of accessibility – these effectively exclude wheelchair users, pushchairs and those with limited mobility from using this route. To create true community spaces we must consider how we can make routes in accessible for the whole range of users.

- *"I wonder how people cycle around when they have to go down stairs"*
- *"It looks more car friendly than cycle friendly"*
- *"A lot of concrete"*
- *"I don't like the steps… I wouldn't feel comfortable, especially, I mean, having a bike or pram or"*

- *"Looking out across the water"*
- *"Separation in level between perhaps a pedestrian area and the traffic"*
- *"It just feels a bit closed in"*
- *"Very safe, I feel like you're on the sidewalk, but you're a step removed so that you're not, you're not just like living in front of someone"*

4.4 Visual signals for sustainable behaviours

In this section we combine the findings from the three primary data sources to analyse the impact of the range of identified visual signals on human behaviour in urban developments with sustainable development aims.

Combining the findings

In the table below we have sorted visual signals evidence into those providing positive and negative encouragement. Within those groups we have categorised the examples and set out our evidence in the following columns: urban design feature, survey/interview evidence and fieldwork evidence.

We then go on to draw together features into three main categories and analyse these in line with the aims of the study.

Categorisation of visual signals evidence

The numbers in brackets refer to the relevant image.

Positive encouragement for people to adopt low energy & carbon behaviours		
Urban design feature	**Survey/Interview evidence**	**Fieldwork evidence**
Spaces for people to gather/communities to come together	"In summer, it'd be a nice place to sit" (3) "There's space for people" (9)	Central community centre (One Brighton) Notice boards create sense of community (Vauban) Public services and amenities (medical facilities, schools and shops) draw people together[22] (Rieselfeld) Picnic tables encourage use of green space in between buildings (Ørestad)

[22] From discussion with Samuel Mössner, Freiburg University

		Wooden street furniture (Western Harbour) Water and park area (Western Harbour)
Spaces that allow people to consider their connection to the wider world	"Oh, I like the little bench where people can sit and relax and have kind of like some rest, I like water as well" (3) "Looks like a place that people could go to chat or think about the world" (3) "I want to make sure that we have enough distance to the wildlife so that you don't disturb them too much" (11)	Birdsong (BedZED, Vauban) Buildings integrated into existing nature, rather than the other way around (Vauban) "archipelago-like swimming area" (Nordhavn)
Nature – on site and views to beyond	Most liked features (2): - Sea 77% - Trees 70% "It's just kind of intimate and and actually incorporation of the wild nature" (3) "My eyes drawn to like the nature bit of this picture and I just want to go out into the bit beyond this tunnel and I don't really want to be in this space" (2) "That's great, I love trees" (1) "Quite nice and green" (8) "I think it would be nice to walk over the water" (11)	Greenery at different levels, green roofs (BedZED, Nordhavn) Birdsong (BedZED) Buildings integrated into existing nature, rather than the other way around (Vauban) Gardening opportunities (One Brighton, Vauban) Green spaces found throughout the site (Rieselfeld, Western Harbour) "Green and blue city" idea runs through masterplan – constant presence of water and green spaces throughout urban realm (Nordhavn, Western Harbour, Hammarby Sjöstad) "archipelago-like swimming area" boulders (Nordhavn, Western Harbour) Boulders in park area (Ørestad) Addition of extra water channels and open spaces to the site (Nordhavn) Prominent water features (Ørestad, IT University Campus, Hammarby Sjöstad) Views through to green areas (Ørestad) Central courtyard and balconies with trees (IT University Campus) Meandering river ensures water presence throughout (IT University Campus) Water feature – like a natural stream (Western Harbour)

		Nature pockets – never far, constant reminders, individual (Western Harbour) Views out to sea – visual corridors (Western Harbour, Hammarby Sjöstad) Natural edge to the site – trees and waterway (Royal Seaport) Salmon ladder (Hammarby Sjöstad) Natural woodland park in middle of development (Hammarby Sjöstad)
Aesthetically-pleasing design	"free, open" (4) "It's a fairly narrow street that would be fairly comfortable to occupy, not in a sort of causing obstruction sense!" (12)	Curved road mirrors natural patterns, slows traffic (Ørestad, Royal Seaport) Glass reflects the water (IT University Campus) Wavy lines – sea and nature, slow traffic (Western Harbour)
People and evidence of human activities	Image 13: - 39% would feel comfortable in this space - 40% can see themselves taking part in leisure activities there - 54% think the space might encourage them to look after their local area (+24% yes) "If I was to choose an apartment there, I would feel like oh my neighbours are active" (13) "Sounds like a space that I could live in definitely" (13)	Evidence of people out walking/cycling/rollerblading, children playing, people gardening, chatting (Vauban) Recycling prominent, suction system (Rieselfeld, Royal Seaport, Hammarby Sjöstad) Leisure and recreation opportunities linked to the water (Nordhavn, Hammarby Sjöstad) Several bike trailers parked under balconies (IT University Campus) Kayaks (Hammarby Sjöstad) Artificial ski slope/bike track built on waste hill (Hammarby Sjöstad)
Bright, colourful materials; range of materials and textures	"Different colours, you know, not a… great slab of buildings, bit more individualism there" (13)	Solar panel windows (BedZED) Brightly coloured roof vents (BedZED) Different shapes and angles in residential design (BedZED, Royal Seaport) Heterogeneous building styles (Vauban) Layers, patterns (IT University Campus) Yellow paving for active travel priority areas (Western Harbour)
Separation from cars	Image 1: - 82% likely to walk or cycle there - 47% think this environment makes them feel happy	No car parking in the development (One Brighton) Pedestrianisation (Vauban, Western Harbour, Royal Seaport, Hammarby Sjöstad)

	- 50% might live a green lifestyle here (+42% yes) "It's more for the pedestrians" (10) "I think anything without traffic is pleasant… to live in and walk around in" (10) "It's nice and non-motorised and the people walking around, that's nice" (6) "I feel like this would be a nice place to cross as opposed to a really busy, crammed junction" (5)	People priority – vehicles imposters (Vauban) Street layout designed to slow people down (Vauban) Pavements separated from roads by trees (Rieselfeld) Pedestrian and cycle routes given priority in the street design – no kerbs (Rieselfeld) Vehicles hidden from view (Western Harbour) Car parking in 'tree cage' (Western Harbour) Separated public transport/car/bike/pedestrian zones of street (Hammarby Sjöstad)
Easy access to active travel and public transport		Central artery of site provides public transport (Vauban, Rieselfeld, Ørestad) Bike racks, interesting designs, nodes (Vauban, Rieselfeld, Ørestad, IT University Campus, Royal Seaport) "5 minute city" infrastructure "archipelago-like swimming area" (Nordhavn) Marina – transport, leisure, water connection (Western Harbour) Road system prioritises bikes (Western Harbour) Charging stations for electric vehicles (Royal Seaport)
Public art – points of interest	Image 6: - 61% would feel comfortable in space - 51% can see themselves taking part in leisure activities there - 49% maybe would encourage to look after local area (+36% yes) "I like quirky things, that's good" (6)	Brightly coloured roof vents – make development look 'futuristic' (BedZED) Murals/street art (Vauban) Tree in walkway between buildings (IT University Campus) Ship's prow balcony, gas cylinders – history of site (Western Harbour, Royal Seaport) Taps water feature (Western Harbour) Artwork depicting children playing near skate park (Western Harbour)
Space for different users – accessibility	Image 4: - 54% can imagine being part of an active community there	"flexible zones… that can be used for lounging, outdoor cafes and restaurants, planting or car and bicycle parking" (Nordhavn)

	- 49% maybe think they would live a 'green' lifestyle there (+45.9% yes) - 67% would like to spend time in this space "There is space for families, there is space for children and there is space to actually go and have a picnic on the grass" (4) "They've got nice ground surfaces obviously this is for blind people and people of impaired sight" (5)	Shared space – children, bikes, vehicles – colour coding (Western Harbour) Accessible step design – incorporation of ramps (Hammarby Sjöstad)
Mixed uses and types of space (natural and human-made)		Grass roofs (BedZED) Bridging between different types of space, access to public realm (Vauban, Western Harbour, Hammarby Sjöstad) Water in canals and trees buffer large buildings (Ørestad) Steps down to water & walkway – edge zone connections, decking, becomes leisure zone (Western Harbour, Royal Seaport, Hammarby Sjöstad) Integration of man-made and natural elements of a space (Western Harbour, Royal Seaport)
Sense of purpose of space	"If this was Britain it would have lots of signs everywhere" (5) "Maybe it's like for thieves to stop them" (6) "I feel like the people who designed it thought about it" (6) "I like how structured and kind of squared off everything is"(9)	Plans for an intelligent grid system to create an information flow to residents (Nordhavn) Colour-coding of street zones (Western Harbour) GlasHusEtt building – community environment centre (Hammarby Sjöstad)
Good lighting	"There is lighting" (9) "Maybe not as safe at night although there are lights" (7) "I hope there's loads of lights!" (11)	
Invitation to explore and be active	"I love cycle lanes so I would really enjoy that" (5) "Looks like there's more people walking and roller-blading than there are actually driving" (1) "I'd be keen to go" (9) "Inviting you to actually explore and things" (11) "If I was walking by there I'd be like oh wow how do I get involved in that" (13)	Different levels bridged to street (BedZED) Meandering lanes (Western Harbour) Visual corridors to the beyond (Western Harbour) Information board and site map with features (Royal Seaport)

Human scale		Human scale passages (BedZED) Human scale Bo01 development, medieval style (Western Harbour)

Figure 49: Positive encouragement evidence

Negative encouragement for people to adopt low energy & carbon behaviours		
Urban design feature	**Survey/Interview evidence**	**Fieldwork evidence**
Badly maintained spaces and gardens	"When the trees are all barren, it looks a bit boring" (10) "The water looks green, it looks dirty" (7)	Grass roofs turned to mud & moss (BedZED) Open area not well maintained (not invitingly green) (BedZED)
Green technologies that are not aesthetically pleasant	Most disliked features (2): - SUDS 73.3% - Terrace 35% (+53.3% neutral)	Recycling points look tired and unprofessional (One Brighton)
Closed, dark spaces, unused spaces		Unused bike racks & lack of connection to cycle infrastructure (BedZED) Community spaces unwelcoming (One Brighton)
Brutal transition between 'zones' e.g. personal to public and beyond development	"This is the sort of place where I'd be happy to walk through it on my way to work but perhaps not live there" (7) "Intermediate phase between the two" (12) "I feel like you're on the sidewalk, but you're a step removed" (12)	No bridging with external surroundings or active travel infrastructure (BedZED) Lack of real privacy (BedZED) Unclear local transport links (One Brighton)
Visible cars	"I believe if you don't see any cars in sight, that that can make you much more nice" (1)	Cars present on site (BedZED) Perimeter road traps green area within (BedZED) Cars still prominent in residential areas (Ørestad)
Main material concrete, lack of variety and nature	Image 7: - 47.5% people would be likely to walk or cycle there - 54% think the environment does not make them feel happy - 59% think they would maybe live a green lifestyle there (+26% no) "This is a bit eh, eh… grim…" (5)	Lots of paving (BedZED) Outside communal space cold, concrete (One Brighton) Allotments and green roofs beyond human vision (One Brighton) Lots of concrete (Ørestad)

	"The trees are kind of blocked off" (9) "I don't really see why you want to cover this surface when you don't have to" (8) "Well water, good thing, raised concrete structures, not so good" (7)	
Buildings at too large a scale	"I wouldn't choose to go there if I didn't have to go to the concert" (9) "Imposing… modernistic building" (9) "They overwhelm the neighbourhood" (8) "Seems to be like how the whole world is going" (12)	Scale of buildings beyond human scale (One Brighton, Ørestad) Larger 'industrial' buildings for university and business (Western Harbour)
Confusing design	"Kind of half and half whether I'd be likely to walk around there" (10) "I'm not entirely sure what the point of the water feature is" (9) "It's sort of a bit unclear" (8) "I don't really understand what the space is for" (11)	Lack of identity of the area (Ørestad)
Design that looks wasteful in terms of resources e.g. water use	"I feel like this is one of those add on spaces where they build new flats" (4) "Um I just hope the water's recycled" (7)	
Noise	"Oh the noise, the noise is going to be bad!" (7)	
Materials that do not age well	"You always think well what's it gonna look like in a few years' time" (7) "How it will look however in many years' time I don't quite know" (9) "I wonder what it will look like in a few years or season's time" (3)	
Design that has too many sharp edges	Image 9: - 47% can maybe imagine being part of an active community there (+30% no) - 50% maybe think they would live a green lifestyle there (+27% yes) - 40.9% would maybe like to spend time in this space (+31% no)	

	"Too dry and too square like and too artificial" (7)	
Elements which do not blend in well	"I just don't really know why it's there" (6) "That eye looks really freaky and like it keeps watching you" (6) "It makes me feel like I'm being watched" (6) "Kind of looks like you had this nice space and put a concrete ramp in it" (13)	
Heavily regulated use of space		Notices saying "cyclists dismount" and "no skateboarding" in central public thoroughfare (One Brighton) Public art eye – watching over (Western Harbour)

Figure 50: Negative encouragement evidence

Themes in the data

Our data categories can be grouped into three themes which in turn answer three key questions we must ask ourselves when attempting to design a development for community living with sustainable outcomes.

Broadly, our data tells us that there are three key attributes of our urban environment examples which give people a positive impression. These are:

- **Connection to nature** - a space which gives us the opportunity to experience being in or seeing nature
- **Connection to people** - a space which enables us to see, be with and form relationships with other people
- **Sense of purpose** - a space which guides and encourages its users in its use

Thinking in terms of how these attributes contribute to low energy and carbon behaviour, we see that each links in with a key question:

- **What** are we trying to achieve? **Nature** reminds us of the end goal of environmental protection and sustainability.

- **Who** are we trying to influence to adopt low energy and carbon behaviours? A focus on creating spaces for **people** enables the creation and strengthening of key community units which social practice theory shows are key to the enduring adoption of behaviours.
- **How** will the space help us to achieve these behaviours? A space which helps guide users towards desired behaviours and gives users an indication of the **purpose** of the space will give users clarity and ease decision-making.

We will now analyse each of the key themes in more detail, focusing on the associated urban design aims and things to avoid when designing urban environments where there is an aim for low carbon living.

Nature

A space which gives us the opportunity to experience being in or seeing nature

Overview

Something as simple as hearing a bird sing can remind us of the wider world beyond our own individual day-to-day existence. We have already explored the significant benefits of seeing or being in natural environments on individuals' physical and mental wellbeing in the literature review. From our primary research, we can see physical design elements which enable people to have this experience of connection to nature on a developed site. This helps raise awareness and interest in the end goal of environmental protection and sustainability.

What are we aiming for?

Nature – on site and views to beyond

Nothing can beat the physical presence of natural areas – plants, trees, rocks and bodies of water – on a development. We consistently saw that some of the best liked features in our images of sites were natural features – visual corridors to the sea, trees, grassy areas and pocket parks. Our various case study sites have employed a range of techniques to enable this green presence to a varying degree, as part of an urban site. Examples range from the impression that the buildings have been built around the existing natural environment (e.g. Vauban) to man-made installations to mimic natural scenes (e.g. stream water installation, Western Harbour). Some sites have tried to add

natural elements to building design (e.g. roof gardens, BedZED) while others have incorporated regular small-scale green spaces into the masterplans for a site (e.g. "green and blue city" idea, Nordhavn). Here we look to establish the types of features which can build the sort of environment that encourages users to be in tune with the natural environment and therefore more likely to engage in low carbon behaviours.

Mixed uses and types of space (natural and human-made)

Water is increasingly being used in sites in a similar way to green spaces. As several of the sites studied bordered large bodies of water, there the design of the edge zones was important and sites used building techniques to draw people to the water to benefit from its presence (e.g. swimming areas in Nordhavn and Western Harbour, steps down to water's edge and decking in Western Harbour, Royal Seaport and Hammarby Sjöstad), often setting spaces out as leisure zones for walking, swimming or paddling.

The quality of bridging between different uses of space (private to public) and types of space (natural to man-made) is also a key feature in how people use a mixed-use site. The more that people see nature incorporated, the more they are in tune with the natural environment and see it as a key part of modern life. Attempts have been made to ease this through multi-level access from buildings to public spaces (e.g. Vauban, Western Harbour and Hammarby Sjöstad) and integration of nature into man-made zones and vice versa (Western Harbour and Royal Seaport).
"I think it would be nice to walk over the water" (11)

Spaces that allow people to consider their connection to the wider world

"Looks like a place that people could go to chat or think about the world" (3)
Giving people the space to be in nature and start to feel that connection to the natural world around them is key to building up a relationship between residents and the natural environment. When people value nature and its influence on their personal life, they may be more sympathetic to adapting their behaviour towards aims to protect the environment. Studies have shown the benefits on physical and mental wellbeing from spending time in nature[23].

[23] Found in experiments by Francine Kuo and William Sullivan

What should we avoid?

Badly maintained spaces and gardens

"When the trees are all barren, it looks a bit boring" (10)

From our research we heard that people felt negatively towards spaces that they felt were badly maintained. Even sites which had considered careful incorporation of natural and man-made elements faced criticism where the plants did not look cared for. We should note that many of these comments may have been due to the site visits taking place in February, when vegetation is at its least green. However, this gave us a specific opportunity to see what people thought of sites away from the sunshine and happy summer street life. As people live on sites year round, we need to design them to look nice and to be able to be maintained throughout the year.

Main material concrete, lack of variety and nature

"This is a bit eh, eh… grim…" (5)

Of our survey respondents looking at the site image containing arguably the most concrete (Ørestad), 54% thought that the environment did not make them feel happy. In the interviews there were additional negative comments relating to the use of a lot of concrete in the scene. Part of this could be to do with the material itself, but there is also the issue of the quantity of one material – it creates a more monotonous environment which is less likely to lift spirits or provide interest (Gehl, 2006, Ellard, 2015 & Montgomery, 2013). While paving may be practical, it can make spaces feel cold and clinical, where the presence of some natural elements can soften an environment.

Design that looks wasteful in terms of resources e.g. water use

"I just hope the water's recycled" (7)

Regardless of whether the water feature does or does not recycle water, in the example above, the fact that a participant is concerned about whether the water is recycled points to a reaction which could unintentionally undermine elements of sustainable design on a site. It looks like something is wasteful in terms of resources, residents may question the energy and carbon-saving potential of the site and indeed their own ability to make reductions when elements they have no control over could be wasteful. Careful design which considers perceptions as well as actual resource use can avoid reactions like the above.

Design that has too many sharp edges

"Too dry and too square like and too artificial" (7)

Human beings have evolved from the times of living primarily in natural environments, but with us stays an unconscious bias towards things which 'look' natural. That is to say that we are likely to feel more comfortable in environments which mimic the curves, scales and textures found in nature (Montgomery, 2013). While modern and eye-catching design has its place in providing interest and excitement on a site, we should be careful to consider the scale of this type of design in one area and how removed that makes the users feel from nature.

People

A space which enables us to see, be with and form relationships with other people

Overview

In designing low carbon developments, ultimately we are creating places primarily for the people who will live there, work there and use the space. The aim of any architect or planner should be that the final users will enjoy being in a space which fulfils their needs and wants. When we look at this from an environmental sustainability perspective, we also want these developments to foster environmentally beneficial behaviours. For those behaviours to be adopted and endure, social practice theory tells us that we need strong social communities. In this section we look at the design elements of sites which provide spaces which encourage people to come together, do things together and live their lives as a community.

What are we aiming for?

Spaces for people to gather/communities to come together

"There's space for people" (9)

Above all, there needs to be space built into the design that can accommodate people, in different sized groups – ranging from neighbours sharing news to community markets or events. Without adequate communal space, residents are more likely to spend time inside their individual houses and travel further afield for social spaces – diluting the strength of the local community. Examples range from indoor community centres (One Brighton, Hammarby Sjöstad) to street furniture

(Ørestad and Western Harbour), leisure facilities and amenities (Rieselfeld, Western Harbour) to large open squares and grassy areas (Western Harbour, Vauban).

Aesthetically-pleasing design

People are more likely to spend longer in a place that they find aesthetically pleasant. When we are designing functional spaces, it is also important to think about the perception of the space and how that will make people feel in the space. If they like it they are more likely to come back. Busy spaces make for thriving communities. Some examples include using curved lines for structures and roads – these provide interest, slow people and traffic down and mirror natural patterns (Ørestad, Royal Seaport, Western Harbour), or clever use of reflective materials to create interesting patterns (IT University Campus).

Bright, colourful materials; range of materials and textures

The more variety we can incorporate into the design codes for a development, the more interesting the streetscape becomes. Users of a space are more likely to take their time and enjoy a space which provides them with a variety of colours, shapes and textures, reminiscent of heterogeneous medieval streets. Across the case study sites we saw examples of this – quirky colours used to highlight design features (BedZED vents), shapes and angles used in building design (Royal Seaport) and yellow paving to mark pedestrian spaces (Western Harbour). Interviewees noted colourful elements as parts of a photograph which stood out to them.

Public art – points of interest

Public art has long been a mechanism for increasing interest in urban spaces (Lippard, 1997). In the photographic rounds of the interviews, the eye artwork in Western Harbour stood out in both negative and positive ways to participants, who were asked their views on it. Some found it to be a negative influence (e.g. watching over them) while others liked it - “I like quirky things, that’s good” (6), but overall 67% of survey respondents would like to spend time in the space. This illustrates that careful use of artwork can enhance and provide interest and a focal point in a public space. There are many examples of this across the case study sites. Some in particular also support a sustainable development vision – murals including animals (Vauban), taps water feature (Western Harbour), encourage particular activities – artwork depicting children playing near skate park (Western

Harbour), or provide reminders of the site's history – ship's prow balcony (Western Harbour) and incorporation of gas cylinder structures (Royal Seaport).

Space for different users – accessibility

"There is space for families, there is space for children and there is space to actually go and have a picnic on the grass" (4)

In several of the interviews, participants picked up on how accessible certain spaces might be for different users – children, those with limited mobility or people of impaired sight. Diversity helps create strong communities and so we should aim to make developments accessible for all. Examples of this from the sites include accessible steps incorporating ramps (Hammarby Sjöstad) and ground surface textures which explain the street layout (Western Harbour). Having spaces which provide elements which appeal to different groups bring people together and encourage mixing of different demographic groups – for example shared space for children, bikes and vehicles and open spaces with play equipment and seating areas (Western Harbour).

People and evidence of human activities

"If I was to choose an apartment there, I would feel like oh my neighbours are active" (13)

People like to be where other people are. Studies have shown that we have an instinct to want to be where things are happening (Gehl, 2006). There is of course a fine line between crowding and a healthy number of people enjoying a space, but if we can get this right, communities can benefit from having lively streets where activity is the norm, drawing together people from all backgrounds. There were some comments in the interviews about spaces looking used. A particular example is that of the image containing kayaks lined up under a walkway. 40% of survey respondents could see themselves taking part in leisure activities there. In turn this may have contributed to a positive skew on whether people thought the space would encourage them to look after their local area (54% maybe, 24% yes). Other examples of visual signals of this activity included people out engaging in active travel e.g. rollerblading and cycling (Vauban), bike trailers parked under balconies (IT University Campus) and children carrying balloons in a residential courtyard (Hammarby Sjöstad).

Good lighting

"I hope there's loads of lights!" (11)

Safety and the feeling of safety, are key factors in how long someone will spend in a space and indeed whether they will use or pass through a space. Lighting is a key element in making a space feel safer. There were a few comments in interviews about whether a space looked like it had lights or not, even though all photographs were taken during the day, both for personal and physical safety reasons (e.g. not falling off boardwalks in Hammarby Sjöstad).

What should we avoid?

Green technologies that are not aesthetically pleasant

The most disliked feature of one of the area-select images was the area showing the pipes for the sustainable urban drainage system (SUDs) – 73.3% disliked them. Additionally, recycling points at the One Brighton site looked tired and unprofessional. Where green technologies and features are visible, it is important that they are also visually pleasant, otherwise they risk leaving people with a negative perception of both the technology (and less likely to use the technology if they do not like it aesthetically) and the space (and less likely to go there).

Closed, dark spaces, unused spaces

Interviewees commented on spaces looking empty or unwelcoming and wondered whether people used them. This indicates that people judge places based on how they see others using them. If a place doesn't seem used, it may indicate that there is a reason that people avoid it and encourage that individual to avoid it too.

Visible cars

What we see regularly happening in an urban environment gives us ideas as to how we should be using the space too. If we see cars parked along streets, we see that driving a car is normal here and that they are given priority over other forms of travel in the streetscape. If we want to lower emissions by encouraging active travel, we must endeavour to at least hide personal cars from sight, as one of the easiest ways to change perceptions of the travel practice norms of a development. Even where a site boasts a lot of green technology, when road and parking space takes precedence,

it threatens to undermine other carbon-reducing measures by its very placement (e.g. perimeter road at BedZED).

Buildings at too large a scale

"They overwhelm the neighbourhood" (8)

Several interviewees commented along the lines of finding larger buildings imposing or overwhelming in some of the images shown (e.g. One Brighton, Ørestad). Having the majority of buildings on a site beyond human scale may increase feelings of overwhelm in the environment or powerlessness over the way of life in the development, which could reduce incentive to spend time in overlooked spaces.

Noise

"Oh the noise, the noise is going to be bad!" (7)

Constant background noise (e.g. from train lines in Ørestad) can be very distracting and even distressing for people who experience it every day where they live, work or commute. Reducing noise in an urban environment has benefits for communities as well as for physical and mental wellbeing, as people are more likely to spend a longer period of time in a space that is calming and relaxing as opposed to loud and frantic.

Materials that do not age well

"You always think well what's it gonna look like in a few years' time" (7)

Interviewees had concerns about how some of the relatively new developments might look in a few years' time. If buildings and landscaping are not built to last and able to be well maintained, they risk falling into one of the categories above where people no longer want to spend time in a space, which could lead to wider divisions and issues within the community.

Heavily regulated use of space

For a community to thrive, the built environment plays a role in providing them with spaces that they can feel ownership over. Allowing a community to shape and develop the heart of their urban

realm will help to foster longer-term community spirit which in turn will help to ensure environmentally-friendly behaviours prevail. Where it seems like an external force has control over the space (as often is the case in pseudo public spaces on private developments), there is a risk of residents feeling like the space is not theirs to use or experiment with (e.g. notices at One Brighton saying "no skateboarding" and "cyclists dismount")

Purpose

A space which guides and encourages its users in its use

Overview

Nudge theory explores how we can design decision-making spaces to encourage certain outcomes. Here we expand on this theory to explore the idea that the urban realm is a key space in people's lives, so we can use design as a tool to encourage behaviours that help towards a site's sustainable development goals. Our fieldwork sites have shown a range of visual features which are likely to encourage or discourage environmentally beneficial behaviours.

What are we aiming for?

Separation from cars

"I think anything without traffic is pleasant… to live in and walk around in" (10)

In an image showing people using a separated pedestrian/cycle zone (Vauban), 82% of survey respondents said they would be likely to walk or cycle there and that 94% might, or would live a green lifestyle there (50% maybe, 42% yes). If we provide safe, aesthetically-pleasant spaces for cycling and walking, people are more likely to choose active modes of transport[46]. Having to share space with cars often puts especially cyclists off using that route, or cycling at all. In the same vein that when bigger roads are built, more cars appear, if we build the cycling and pedestrian infrastructure to exceed current demand, we will see demand increase (Montgomery, 2013). There are examples of this sort of design throughout the case study sites from extremes of no cars on site (One Brighton and Vauban) to street design which prioritises pedestrians and cycles (Rieselfeld), to completely vehicle-free active travel zones (Vauban, Western Harbour, Royal Seaport, Hammarby Sjöstad).

Easy access to active travel and public transport

Reducing barriers to using public transport makes the choice to use those lower-carbon options rather than using a high-carbon personal vehicle easier. Examples include having public transport options available in a central artery through the site (Vauban, Rieselfeld, Ørestad), providing regular bike racks in interesting designs and nodes (Vauban, Rieselfeld, Ørestad, IT University Campus, Royal Seaport) and even planning a site around the innovative "5 minute city" vision – where no one should be further than a 5 minute walk from a transport connection at any part of the site (Nordhavn). To encourage lower-carbon personal transport, electric car charging points can be made easily available (Royal Seaport).

Sense of purpose of space

"I feel like the people who designed it thought about it" (6)

Creating spaces that give users a clear sense of the purpose of the space can help residents to feel guided through the streetscape and comfortable in knowing how their local area works. This avoids disorientation and helps ensure that a space lives up to its potential without enforcing certain activities. Examples include careful use of signs – either literal with words, or careful use of materials, shapes and paving e.g. at junctions, colour coded paving of zones and availability of information through intelligent grid systems (Nordhavn) or community environment centres (Hammarby Sjöstad).

Invitation to explore and be active

"If I was walking by there I'd be like oh wow how do I get involved in that" (13)

Some of the most enthusiastic responses to site images were where interviewees could see something in an image that they would like to take part in or explore. Examples included cycle lanes, roller-blading, natural spaces to explore and kayaks. Aside from having activities outside and accessible, features which can encourage people to take part in active and community-building activities are: bridging different levels of buildings to street level (BedZED), meandering lanes (Western Harbour), visual corridors to the beyond (Western Harbour), information boards and site map with features (Royal Seaport).

Human scale

Creating an urban environment at human scale makes users feel more comfortable and feel like the space is designed for humans rather than large vehicles. Completing tasks within such a space may seem easier to achieve than when surrounded by daunting buildings. Examples of designing in this way include human scale passages (BedZED) and the Bo01 medieval streets style development (Western Harbour).

What should we avoid?

Brutal transition between 'zones' e.g. personal to public and beyond development

"This is the sort of place where I'd be happy to walk through it on my way to work but perhaps not live there" (7)

We want to create a development where mixed uses blend together for the continuity of the space and active streets throughout the working day. While zoning does benefit from clear uses of each set of spaces, there is a risk that certain behaviours are perceived to only apply in certain zones and that to travel between zones is more of a step (perhaps involving high-carbon transport). Mixed use spaces will help to better integrate all activities of a community and allow for behaviours to exist inside and outside of a working day context as the space is used for both work and leisure.

Confusing design

"I don't really understand what the space is for" (11)

If we want a space to encourage certain behaviours, it must be clear in its purpose. Any confusion caused by design of an environment will weaken any attempts to nudge users into behaving in specific ways. Spaces should be designed with end uses in mind. If there is a perceived lack of identity of an area (e.g. Ørestad), people are less likely to associate it with a particular environmentally beneficial behaviour.

Elements which do not blend in well

"Kind of looks like you had this nice space and put a concrete ramp in it" (13)

When we are trying to design a space to lead to a certain type of use, any elements which do not fit in with that design narrative threaten to derail it. These are likely to catch attention if they stick out visually and distract the subconscious from the original purpose of the space. An example could be if you are trying to encourage recycling with innovative underground systems, then place additional large surface-level general waste bins ahead of the recycling units.

4.5 Chapter conclusions

The urban realm is the space in which many key decisions are made which influence the success of energy and carbon-saving aspirations of a development. It is therefore important to create an environment which visually reflects our ambitions, provides a place for communities to thrive and in turn ushers users of the space towards making decisions which benefit the environmental sustainability of the site.

In this chapter we have brought together the findings from our three sets of data around the impact of visual signals in the built environment, creating a set of recommendations for space design to encourage sustainable behaviours on low carbon sites. Even subtle changes to the way we present a streetscape can have a big impact on how people use and enjoy the space. The happier the users of the site are, the more likely they are to spend time in the space, forming closer relationships with their neighbours – the ideal environment for positive social norms to develop. These social norms in turn could embed environmentally beneficial behaviours which are necessary for such sites to reach their energy and carbon-saving targets.

If we therefore consider the ways in which we incorporate elements of nature, spaces for people to form communities and design spaces which tell users of their purpose through their design, we are likely to have happier and healthier communities and more sustainable urban environments as a result. These findings, combined with those from the other strands of this study, build a picture of the type of factors we need to influence, and in which way, to encourage communities to develop more environmentally sustainable behaviours in low carbon urban developments.

5 Results

5.1 Introduction

In this chapter we set out the results of the study, following the process outlined in the methodology. We present this in sections with each set of results building on the previous findings.

We first explore the behavioural groupings created from the population sample. We look at the characteristics of each group before analysing the barriers, motivations and potential policy, programme and urban design solutions for each group. We rate each group on three axes of action, impact and priority to aid this analysis.

We then move on to explore the external data sources used to build up our picture of the energy use profiles of our behavioural groups. We find the key data and findings from each of the external sources and what these tell us about how our behavioural groups are likely to behave in relation to green technologies on our NWC case study site.

Using some of the external data we were able to build energy profiles for our behavioural groups which allowed us to create the necessary inputs for the Cambridge Retrofit model. We created a series of scenarios to see the impact of the two green technologies on the NWC being implemented in line with the measures suggested for each behavioural group.

Finally, the scenarios were run on the Cambridge Retrofit model and resultant energy and carbon savings presented. While at every stage attempts have been made to use the most robust methods and data, this study remains a predictive by nature of the stage of the main case study development, and so results are inferred as indicative of what we might expect rather than based on current or previous data from the site. This remains of benefit to the sector as a predicted range of energy and carbon savings give an indication of the impact that might be expected, should the environment (policy, programmes, urban design features, green technologies etc.) be created as presented in the scenario in question.

5.2 Behavioural groupings

This section presents the behavioural groupings taken from the survey and interview data gathered.

Introduction

Following the data analysis, coding and sorting process set out in the methodology, we have seven groupings of the sample population:

From questionnaire (*purely demographic*):

1) **The average respondent** (average group A)
2) **The average Postdoc** (average group B)
3) **The average postgraduate student** (average group C)

From interviews (*behavioural, mixed demographic*):

4) **"Practicalities first"** (behavioural group A)
5) **"We are keen, bring it to us"** (behavioural group B)
6) **"Doing what I think is right"** (behavioural group C)
7) **"Preserve the beauty"** (behavioural group D)

Each set (demographic and behavioural) followed a different methodology. We explore the methodologies and resultant individual groupings below.

While the groups help us to understand the likely behaviour in our main case study site, in terms of likely reactions to certain influences, this is of course only one set of groupings through a particular lens. This only sets out where we might expect people to sit in groups given the current study context, but further research could investigate how people might move between such groups, and how they may change over time.

Groupings from the questionnaire

The questionnaire response groupings were established from descriptive analysis of the results. Here we explore the picture we get from the general trends in responses, to build up a behavioural profile of the attitudes and (perceived) previous behaviours of the surveyed population as a whole.

We additionally found trends two key sub-categories of respondents: postgraduate students and postdoctoral researchers, by using the Qualtrics filtering mechanism to sort responses into these groups.

To find the overall behavioural picture for the latter two categories, filters were applied to the dataset which allowed us to analyse the results from that group independently. We could then compare against the overall behavioural profile to find the key variances. These key variances help us to see what is different about the two key groups, which in turn help us find the best way to design programmes, technologies and environments to match with their behaviours to get the best carbon savings.

The overall average respondent

Below we have set out the survey question outcome for the average respondent – showing the mode answer for each question.

Age group	26-35
Current occupation	Postgraduate student
Ages of any dependents	No dependents
From	UK
Current tenure type	Private rental
Level of highest qualification	Master's degree
"Taking part in hobbies and interests is an important part of my life"	Strongly agree
"I have a good relationship with my colleagues"	Agree
"I identify strongly with a particular culture"	Neither agree nor disagree
"Money is often the most important factor in my decision-making"	Neither agree nor disagree
Been abroad on non-work trip more than once in past 12 months	Yes
"Fitting in and having a similar lifestyle to those around me is important to me"	Agree
"I like to follow socially-established norms"	Neither agree nor disagree
"I feel an active part of one or more social/community groups"	Agree
Personal values (this was a ranking question – the mode for each rank is presented here)	1 = Fairness 2 = Community 3 = Community 4 = Community 5 = Tradition/Aesthetics 6 = Tradition 7 = Spiritual growth
"It is important to stay true to your values"	Agree

"My personal values always guide me in my decision-making"	Agree
"Religious beliefs form an important part of my life"	Strongly disagree
"I believe that I make decisions that are environmentally-friendly"	Agree
"I think it is important for individuals to make environmentally-friendly decisions"	Agree
How often use information source mediums	Never = tabloid newspapers Sometimes = TV documentaries Regularly = talking to others
What is important in an information source	Not important = interactive Neutral = local focus Important = quality of content
"I know my neighbours well"	Disagree
"I like to take part in activities that make me feel part of the community"	Neither agree nor disagree/agree
"I am strongly influenced in my decision-making by my peers"	Neither agree nor disagree
"I am more likely to take part in something if key members of my community are involved"	Agree
Green tech - actively	Pay attention to energy and water use
Have used/currently use	Cycling as a main mode of transport
Barriers to using more green technologies	Practicalities
Life priorities (this was a ranking question – the mode for each rank is presented here)	1 = Career 2 = Leisure 3 = Family
"I regularly participate in a variety of leisure activities"	Agree
"I spend my average day between three or more geographically diverse locations"	Agree
Transport options used every day	Walking
Main motivators in decision-making	Personal benefit = agree Family = agree Others locally = agree Others globally = neither agree nor disagree/agree Planet = agree
Previous participation in programmes	None of the above
Likely to participate if	It requires minimal effort = agree Low/no cost = strongly agree Fits into my existing lifestyle = agree It will have a big impact = agree Other people I know are participating = agree
"I often notice my physical surroundings"	Agree
"My surroundings have an impact on how I feel"	Strongly agree
"My surroundings noticeably affect my decision-making"	Agree

Figure 51: Average respondent responses

Looking at the descriptive statistics of the questionnaire results we have built up an initial picture of our average respondent, as shown in the table above. While picking out the most popular answer for each question obviously misses out on some of the nuances of the data, it does give us an overall impression.

Our average respondent would fit within the highly-educated millennial+ group that you would expect to see well-represented within the Cambridge population (and indeed as targeted in our questionnaire). Overall our respondents were focused on their career aspirations as well as leisure, rather than family life at this point. The values of fairness and community were strongly valued, though on average respondents were not prioritising developing their relationship with local communities. Religion was (with a couple of exceptions) not at all a part of our respondents' lifestyles. Our respondents were strongly of the opinion that their surroundings affect how they feel, noting what is around them and the impact on their decision-making.

Below we take the responses from the table above explore each themed area of responses in more detail, presenting a picture of the average respondent according to our descriptive data. Those aspects in bold highlight key point from the data.

Demographics and Background:

Demographics:

The average respondent is a **postgraduate student** aged **26-35**. They have a **Master's degree** and come from the **UK**, with **no dependents**. They live in **private rental** accommodation.

Background:

The average respondent has a **Master's degree** and has been **abroad on a non-work trip** more than once in the past 12 months. They have a **good relationship with their colleagues** but **taking part in hobbies and interests is very important** to them. They feel **neutral** about whether they **identify with a particular culture** and whether **money** is the most important factor in decision-making for them.

Norms, values and attitudes:

Norms:

Fitting in and having a **similar lifestyle to those around them is important** and they feel an **active part of one or more social/community groups**, but they feel **neutral** about **following socially-established norms**.

Values:

Fairness is the top-ranked personal value for our average respondent. Community dominates the rest of the top-half slots, with **tradition, Aesthetics and Spiritual Growth coming in in the lowest-ranked slots**. They think that it is important to stay true to their values and find that their personal values guide them in their decision-making.

Attitudes:

Religious beliefs are very much not an important part of the average respondent's life. They do, however, believe that it is **important for individuals to make environmentally-friendly decisions** and that **they do this** themselves.

Information sources:

The average respondent's **most regular source of information is talking to others**. They **sometimes watch TV documentaries** but **never read tabloid newspapers**.

For them the **most important aspect of an information source is the quality of the content**. They are **neutral about it having a local focus** and **do not find it important for a source to be interactive**.

Community and peers:

Community:

Our average respondent **does not know their neighbours well,** however they are on the **positive side of neutral about whether they like to take part in activities which make them feel part of the community**.

Peers:

They are **neutral about whether they are influenced in their decision-making by their peers**, but agree that **they are more likely to take part in something if key members of their community are involved**.

Routine and Lifestyle:

Green technologies:

The average respondent **pays attention to their energy and water use** and **uses cycling as a main form of transport**. For them the **key barrier** to using more green technologies is **practicalities**.

Lifestyle choices:

For our average respondent, **career is top life priority** in the next five years, followed by **leisure and then family**. They **regularly take part in a variety of leisure activities** and **spend their average day between three or more geographically diverse locations**. Every day they use **walking** as a form of transport.

Their main motivators in decision-making are **personal benefit, family, others locally and the planet**. They feel **neutral about benefit for others globally being a motivator for them**.

Policies and Programmes:

The average respondent **has not participated in any of the programmes** listed. They **strongly agree** that they are likely to participate if a programme is **low or no cost** and would be **likely to participate if it requires minimal effort, fits into their existing lifestyle, will have a big impact and others that they know are participating**.

Urban Environment:

The average respondent **often notices their physical surroundings** and believe that **surroundings noticeably affect their decision-making**. They **strongly agree that their surroundings have an impact on how they feel**.

The average postdoctoral researcher

Below we explore the first of two key demographic groups in our sample – the average postdoctoral researcher. The table below only shows variances from the overall average respondent profile. The characteristics which were used for filtering are highlighted. Again, the mode answer for each question (from this group) is presented. Answers in brackets are unchanged from the average response.

Current occupation	Employed by the University of Cambridge
From	EU/other international country
Level of highest qualification	PhD

"Money is often the most important factor in my decision-making"	Disagree
"Fitting in and having a similar lifestyle to those around me is important to me"	Neither agree nor disagree
"I like to follow socially-established norms"	Agree
Personal values (this was a ranking question – the mode for each rank is presented here)	(1 = Fairness) 2 = Environment 3 = Community/Environment (4 = Community) 5 = Tradition (6 = Tradition) 7 = Aesthetics
How often use information source mediums	(Never = tabloid newspapers) Sometimes = books (Regularly = talking to others)
What is important in an information source	(Not important = interactive) Neutral = cost Important = type of content/quality of content/ease of access
Life priorities (this was a ranking question – the mode for each rank is presented here)	(1 = Career) 2 = Leisure/Family 3 = Leisure/Family
"I regularly participate in a variety of leisure activities"	Agree/strongly agree
Main motivators in decision-making	(Personal benefit = agree) (Family = agree) Others locally = neither agree nor disagree Others globally = agree (Planet = agree)
Likely to participate if	(It requires minimal effort = agree) (Low/no cost = agree) (Fits into my existing lifestyle = agree) (It will have a big impact = agree) Other people I know are participating = neither agree nor disagree
"My surroundings have an impact on how I feel"	Agree/strongly agree

Figure 52: Average postdoctoral researcher responses

The postdoctoral researcher group shows some key variances from the overall respondent trends. The answers suggest that this group feels more comfortable about money and places a higher importance on the environment, above community. For them leisure and family are of comparable importance but career is top priority. They feel more of a responsibility to care about impacts of their actions on the global population and are less motivated by whether someone they know is participating or not. They are slightly less clear on the impact of their surroundings on how they feel. Here we have a notable exploration of a key group in the future of universities – the mobile millennial+ postdoc group. These individuals are the next generation of academics. Highly mobile, they move between cities with universities for academic research positions. This lifestyle has impacts on the way they behave in their everyday life, which we explore further in later sections.

Below we take the responses from the table above explore each themed are of responses in more detail, presenting a picture of the average postdoctoral researcher according to our descriptive data.

Filters applied to find answers for this demographic group only:

Current occupation = Employed by the University of Cambridge

Level of highest qualification = PhD

Demographics and Background:

Demographics:

Most Postdoctoral researchers were from the EU or another international country.

Background:

This group **disagree** that **money is often the most important factor** in their decision-making.

Norms, values and attitudes:

Norms:

Postdoctoral researchers **neither agree nor disagree** about **fitting in and having a similar lifestyle** to those around you being important.

They **agree** that they **like to follow socially-established norms**.

Values:

Below fairness, for the Postdoc group **environment and community** are the **next highest-ranking** values. **Tradition and Aesthetics** come in the **lowest** rankings.

Information sources:

Postdoctoral researchers **sometimes use books** as an information source. They are **neutral about cost** but **type and quality of content and ease of access are important** in information sources.

Lifestyle choices:

For postdoctoral researchers, career is also top priority for the next five years, but **leisure and family are equal below** that. They very much participate in a variety of **leisure activities**.

In terms of motivators, Postdoctoral researchers feel **neutral about impact on others locally**, but agree that **others globally are a motivator**.

Policies and Programmes:

Postdoctoral researchers feel **neutral** about **whether people they know participating will make them likely to partake** in a programme.

Urban Environment:

The average Postdoc **agrees/strongly agrees that their surroundings have an impact on how they feel**.

No. responses: 20

The average postgraduate student

This section explores the second key demographic group for our case study site – postgraduate students. Again, this only shows variances from the overall average. Characteristics for filtering have been highlighted and the mode answer for each question is displayed. Answers in brackets are unchanged from the average response.

Age	18-25
Current occupation	Postgraduate student
Current tenure type	University-owned rental
"Money is often the most important factor in my decision-making"	Agree
Personal values (this was a ranking question – the mode for each rank is presented here)	(1 = Fairness) 2 = Fairness 3 = Advancement (4 = Community) 5 = Aesthetics (6 = Tradition) (7 = Spiritual growth)
Life priorities (this was a ranking question – the mode for each rank is presented here)	(1 = Career) 2 = Family 3 = Leisure
Likely to participate if	(It requires minimal effort = agree) (Low/no cost = agree) (Fits into my existing lifestyle = agree) It will have a big impact = strongly agree (Other people I know are participating = agree)

Figure 53: Average postgraduate student responses

Most of our postgraduate student respondents live in university-owned rental rather than private rental, but many of the challenges of this in terms of implementing green features remain the same. This group is concerned by money in a way that the postdoctoral researchers are not. They value advancement above community and environment and family above leisure (perhaps as a generally younger cohort they still have a closer relationship to close family where they may not be fully independent yet or have their own families). For the postgraduate students a programme having a big impact is an important motivator to participation.

Below we take the responses from the table above explore each themed are of responses in more detail, presenting a picture of the average postgraduate student according to our descriptive data.

Filters applied to find answers for this demographic group only:

Current occupation = Postgraduate student

Demographics and Background:

Demographics:

Current **tenure type** for the average postgraduate is **university-owned rental**.

Background:

Postgraduates agree that **money is often the most important factor in their decision-making**.

Norms, values and attitudes:

Values:

For postgraduates, **fairness also comes in at rank two** as well as one and **advancement** completes the **top rankings**. **Aesthetics comes in at rank five**.

Routine and Lifestyle:

Lifestyle choices:

For the postgraduate student group, **after career, family is most important, followed by leisure**.

Policies and Programmes:

This group are **very likely to participate in a programme if it will have a big impact**.

No. responses: 38

General analysis of the population sample

We must remember that we are working within the Cambridge population, which already has its own trends and characteristics. There is definitely a university focus within the sample. A large percentage of the population are studying at university, employed by the university as academics or support staff or by a spin-off company. The university brings in associated jobs related to academia – science parks and businesses - and so work in advancement and science is close to the population. Other characteristics of the population include relatively high wealth levels (house prices are well above national averages) and political trends, for example Cambridge voted overwhelmingly (73.8%) to remain in the EU in the referendum on the UK's membership to the European Union in 2016[24].

General themes of interview and survey population sample

Additionally, there were several main general themes which came out of analysis of the interview transcripts which are explored below before we discuss the four main behavioural groups established from our data analysis.

Mobile community

From our survey we know that, in general, our population doesn't feel particularly rooted in a culture or community or particular traditions or ways of life. While they appreciate the value of community, they are a very mobile, international group.

Valuing fairness

[24] https://www.electoralcommission.org.uk/find-information-by-subject/elections-and-referendums/past-elections-and-referendums/eu-referendum/electorate-and-count-information

For all groups fairness scored highest value when survey participants were asked to rank values. There is potential here to find green technology solutions which also address issues of social equality and opportunity.

Focus on togetherness/belonging/community

Code 9H from the coding showed a strong focus throughout the interviews on the importance of community and feeling of belonging in a neighbourhood. This was a strong theme throughout and is notable as the NWC site has a unique opportunity to help support strong community formation across the range of behavioural groups.

Practical focus

Our population sample are quite practical – not many participants focused on visuals or feelings in relation to technologies, programmes or the urban environment. This could be due to a range of reasons such as scientific links in their background or employment, which is common in the area.

Cost barrier – investment

Code 19B came out as another strong trend in the responses. It highlights that for individuals across the different behavioural groups, cost is a barrier to using green technologies – particularly in terms of initial investment in the technology. This highlights the need for green technologies to be embedded in a site from construction and makes the NWC a good test of whether having this technology in place from initial occupation means more people can interact regularly with green technologies, leading to energy and carbon savings.

Interest in being a part of programmes and invest in/use green technologies in the future

Code 19I shows that across our groups, participants showed a keenness to get involved in green technologies. Where current cost or practical barriers existed, there was still a strong intention to do more where possible in the future.

Groupings from the interviews

Transcripts from the 17 interviews were coded and through several levels of matrix matching (see methodology section for full detail on the process), groupings were found with particular answer traits.

We then used the particular matched traits to coordinate with the relevant questions in the survey and the most closely matched answer to the transcript code. This allowed us to create synthetic variables (the set of answers to particular key survey questions which would match with the behavioural grouping found through interviews). We then checked these against the survey responses to see which behavioural group each response most closely matched. Cross tabs of survey response data (see attached spreadsheet) are also available to see the relationship between the core responses used to create these groupings.

The process described in the analysis techniques section describes how the full set of survey responses were then sorted into the closest match of the four behavioural categories, based on their answers to the given sets of synthetic variables.

Synthetic variable creation

The process for creation of the synthetic variables is set out in the methodology chapter. The specific interview codes and corresponding synthetic variables are set out for each behavioural group below.

Behavioural group A – "Practicalities first"

- Emphasis on *investment* cost
- This group is in theory keen to help the environment, but for them other priorities come first e.g. costs/financial position
- Practicalities also limit what this group can do – they are renters and so do not have the opportunity to make key changes to their properties

Synthetic variable factors:

Interview code	Number	Matched Survey Question	Survey answer
Think about other things too/not always practical	11A	11B	Disagree/strongly disagree
Environmental decisions need to be easy	13C	12B	Disagree/strongly disagree
Not first priority	13F	12B	Disagree/strongly disagree
Renting	19E	18B, D	Practicalities, not a priority
Wouldn't move there just because of green tech	19H		
If it was established in community, would do	25C	24E, A?	Others participating, minimal effort

Figure 54: Group A synthetic variables

Interviews: 3, 8, 12, 15, 16

No. surveys in this grouping: 17

Demographics:

- Age: 18-25 (64.7%)
- Occupation: postgraduate student (64.7%)
- Dependents (age): no dependents (94.1%)
- From: the UK (64.7%)
- Tenure: private rental (35.3%)/university-owned rental (35.3%)
- Education: master's degree (41.1%)

Behavioural group B – "We are keen, bring it to us"

- Emphasis on a good *future* for the whole *community*.
- This group think that environmental protection is a key issue and want to do what they can to contribute towards it.
- For them it is a priority, but needs to be made easy.

- This group is also concerned with social equality and progress.

Synthetic variable factors:

Interview code	Number	Matched Survey Question	Survey answer
Advancement/education/science is the way forward	9F	10	Advancement high
Environment becoming more important/on a global level	9G	10	Environment high
Close relationships/love missing	9I		
Fairness/equality	9J	10	Fairness high
Environmental decisions need to be easy	13C	12B	Disagree/strongly disagree

Figure 55: Group B synthetic variables

Interviews: 4, 6, 9, 10, 14

No. surveys in this grouping: 8

Demographics:

- Age: 26-35 (50%)
- Occupation: postgraduate student (50%)
- Dependents (age): no dependents (75%)
- From: the UK (50%)
- Tenure: private rental (50%)
- Education: master's degree (37.5%)

Behavioural group C – "Doing what I think is right"

- This group independently strives for a good *future* for their local and global *community*.
- This group either work alone or independently within groups. They are principled and want change that they believe in.
- They do not feel swayed by others and are happy to speak up for what they believe in.

- In the same way, while they think that environmental issues are important, they will engage on their own terms.

Synthetic variable factors:

Interview code	Number	Matched Survey Question	Survey answer
See themselves as 'weird'/'not normal'	7A	9B	Disagree/strongly disagree
Conscious decision not to follow/rebellion	7B	9B	Disagree/strongly disagree
'Lone ranger'/chose not to	8B	9C	Disagree/strongly disagree
Do not feel the need to be part of	8C	9C	Disagree/strongly disagree
Is proactive in groups	8D	9C	Agree/strongly agree
Participates in groups	8E	9C	Agree/strongly agree
Fairness/equality	9J	10	Fairness high
Wouldn't move there just because of green technologies	19H		
Not close to family/if had own family would be different	24B	22B	Family – disagree/strongly disagree
Do not need to follow others	25E	22C/D	Disagree/strongly disagree

Figure 56: Group C synthetic variables

Interviews: 1, 2, 5, 11

No. surveys in this grouping: 13

Demographics:

- Age: 26-35 (69.2%)
- Occupation: employed by the University of Cambridge (69.2%)
- Dependents (age): no dependents (92.3%)
- From: the UK (38.5%)/other international country (38.5%)
- Tenure: private rental (76.9%)
- Education: PhD (61.5%)

Behavioural group D – "Preserve the beauty"

- This group wants a beautiful environment preserved for the *future*.
- They are very visual – they notice and appreciate their surroundings.
- While they want the best for the environment, they also carefully consider practical considerations.

Synthetic variable factors:

Interview code	Number	Matched Survey Question	Survey answer
Environment becoming more important/on a global level	9G	10	Environment high
Visual beauty important	9L	10	Aesthetics high
Cost ongoing	19C	18	A
We have a responsibility to	13B	12C	Agree/strongly agree
Aware of the kind of space I'm in	27A	25A	Agree/strongly agree
Feeling happier in beautiful spaces	27C	25B	Agree/strongly agree

Figure 57: Group D synthetic variables

Interviews: 5, 7, 13, 17

No. surveys in this grouping: 40

Demographics:

- Age: 26-35 (50%)
- Occupation: postgraduate student (40%)
- Dependents (age): no dependents (92.5%)
- From: the UK (52.5%)
- Tenure: private rental (52.5%)
- Education: master's degree (40%)

Note on group allocations

The original groups were created from the grouping of similarly coded interview transcripts. The corresponding surveys completed by the individuals interviewed have automatically been allocated to those initial groups. While they may not have a perfect correlation with the subsequently-created synthetic variables, they were part of the original basis for the groups through in-depth interview discussions and so there is confidence in their placement in those groups.

With the remaining survey responses, we have attempted a best fit approach – we are going with the group with which the response shares the most question response-synthetic variable matches. In some cases this is higher than others, but is a best estimate based on the available survey data. It is more useful for us to have all survey responses sorted into best fit groups than to have a very small number which perfectly match, as this allows us to have a bigger sample to gather from e.g. demographic data to use in the next parts of the analysis.

Barriers, motivations and potential solutions

In this section, now that we have the behavioural groups created and our responses allocated to these, we start to bridge to technologies, programmes and urban spaces. In this section we begin a general analysis of motivations, potential and barriers for each of our behavioural groups and what this means for policies, programmes and urban design features and resultant interaction with green technologies.

Initially what we are looking for in each group is:

a) Motivations
b) Areas of potential
c) Barriers to overcome

Then we are able to look to design tailored solutions in technologies and programmes which will work best with each group. This information is based on what we know from the review of green technologies in the literature review, and in particular from the external dataset (set out in chapter 3.4, 'Secondary data analysis') Carbon CAP reports (2015), in terms of the applicable instruments

and our analysis of the level of human interaction required (whether each technology is considered stand-alone, combination or behaviour-dependent).

Some key 'hooks' cross-cutting the groups (from above survey and interview analysis):

- Values
- Urban environment
- Cost (for some)
- Practicalities
- Career relevance
- Cycling & walking

Group 1 – The average respondent
a) Motivations:
- Career progression - Finances - Values – fairness & community - Hobbies and interests
b) Areas of potential:
- Surroundings affect mood - Cycling and walking - Local impact
c) Barriers to overcome:
- Living in private rental - Practicalities - Not particularly rooted in particular community/culture
d) Potential solutions:
- Scheme to encourage people to cycle locally for leisure and commuting - Infrastructure, financial assistance and benefits for local area

Figure 58: Average respondent barriers, motivations and potential solutions

Group 2 – The average postdoc
a) Motivations:
- Socially-established norms - Values – fairness, environment, community - Career progression - Leisure - Global impact > local
b) Areas of potential:
- Cost is not a barrier - Surroundings affect mood
c) Barriers to overcome:
- Not rooted in a particular community/culture - Very mobile group
d) Potential solutions:
- Cycle hire scheme – easy to join in, social norm in space, can afford, more convenient than buying - Scheme that can be part of something bigger/have a global impact e.g. practical project linked to online community

Figure 59: Average postdoctoral researcher barriers, motivations and potential solutions

Group 3 – The average postgraduate student
a) Motivations:
- Career progression - Finances - Values – fairness & advancement - Actions having a big impact
b) Areas of potential:
- Living in university rental
c) Barriers to overcome:
- Living in university rental - Financial
d) Potential solutions:
- Bike pool – low/no cost, linked to accommodation

Figure 60: Average postgraduate student barriers, motivations and potential solutions

Group 4 – "Practicalities first"
a) Motivations:
- Financial - Environment - Community
b) Areas of potential:
- Making decision-making easy - Built in – would not move somewhere just for green technologies - Establishing in community
c) Barriers to overcome:
- Investment costs - Other priorities - Practicalities - Living in private rental
d) Potential solutions:
- Bike network that fits routine – easier than car - Technologies embedded in home e.g. smart meter

Figure 61: Group 4 barriers, motivations and potential solutions

Group 5 – "We are keen, bring it to us"
a) Motivations:
- Good future for whole community - Environment key priority - Social equality & progress - Advancement - Close relationships/love
b) Areas of potential:
- Making it easy - Addressing issues of equality - Strengthen communities
c) Barriers to overcome:
- Needs to be easy
d) Potential solutions:

- Programmes that are accessible to all and bring the community together - Subsidies to reduce financial barriers - Community technology

Figure 62: Group 5 barriers, motivations and potential solutions

Group 6 – "Doing what I think is right"
a) Motivations:
- Good future for local and global communities - Principled and want change that they believe in - Not swayed by others - Fairness/equality
b) Areas of potential:
- Working individually/influence within groups - Want change - Will speak up for what they believe in
c) Barriers to overcome:
- Working individually - Engage on their own terms - Not swayed by peer influences
d) Potential solutions:
- Something with a visible impact that they can lead on - Innovative ways of engaging with issues, flexible involvement and ownership of projects

Figure 63: Group 6 barriers, motivations and potential solutions

Group 7 – "Preserve the beauty"
a) Motivations:
- Preservation of a beautiful environment for the future - Visual surroundings - Environment as a global issue - Ongoing cost - Responsibility of individuals
b) Areas of potential:
- Urban design - Individual responsibility
c) Barriers to overcome:
- Financial - Other priorities
d) Potential solutions:
- Infrastructure which enhances the beauty of the area - Initiatives which encourage enjoyment of outdoor space e.g. for leisure

Figure 64: Group 7 barriers, motivations and potential solutions

Group behaviour tendencies

While we have started to include some suggestions above for policies, programme and urban design features suited to each group, it is helpful to look at our groupings more broadly.

One way of doing so is on scales of the key differentiators we have noted in analysis of the groups:

Action: individual -> community

Within the behavioural grouping is there a tendency towards wanting action to be taken on an individual or a community level?

Impact: local -> global

Do people prefer any positive impact of their actions to be local or global?

Priority: ease of use -> environmental impact

In broad terms, does the group value ease of use or environmental impact more highly?

While not an exact science, this allows us to create visual graphs with four quadrants of the different combinations of each two differentiators. These serve as useful charts for finding programmes and urban design features which work with the characteristics of more than one behavioural grouping. These examples are drawn from the programmes, policies and actions explored in the literature review (see p82, for example), and adapted based on the understanding of the characteristics of each group from the survey and interview data.

These scores have been produced from an evaluation of the descriptive data/synthetic variables in relation to the three differentiators, in comparison to the other groups.

Chart group	Name	Action (3=individual, -3=community)	Impact (3=local, -3=global)	Priority (3=ease of use, -3=environmental impact)
A	1 Average respondent	2	3	2
B	2 Average postdoc	1	-3	-1
C	3 Average postgraduate	2	-1	1
D	4 "Practicalities first"	-2	2	3
E	5 "We are keen, bring it to us"	-3	2	-1
F	6 "Doing what I think is right"	3	1	-2
G	7 "Preserve the beauty"	3	-2	-2

Figure 65: Group behavioural tendencies

In the figures below, circles are placed in the place on the chart which corresponds to the figure in the above table for each axis. The size of the circle shows the number of responses in the group.

Action and Impact:

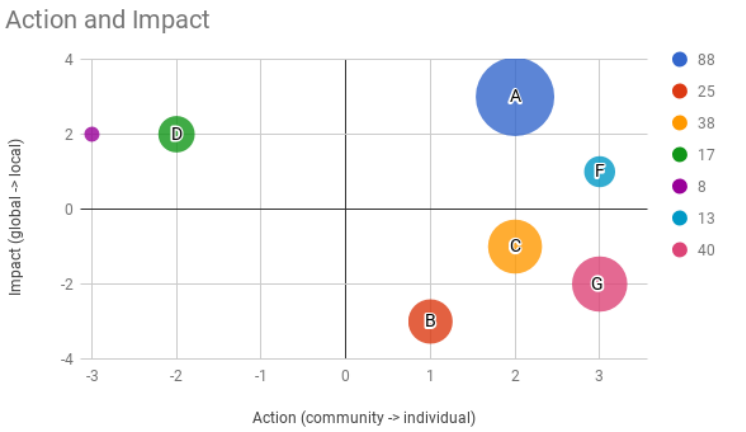


Figure 66: Action and impact chart

Individual action, local impact: groups 1 and 6 (A and F)

Suggested policies, programmes and urban design features:

- Community gardening projects
- Local cycle hire scheme
- Local car hire scheme

Individual action, global impact: groups 2, 3 and 7 (B, C and G)

Suggested policies, programmes and urban design features:

- Energy-saving incentive scheme
- Carbon footprint counting programme
- Solar panel subsidy scheme

Community action, global impact: no groups

Suggested policies, programmes and urban design features:

- Renewable energy microgeneration
- Ethical investment of community funds

Community action, local impact: groups 4 and 5 (D and E)

Suggested policies, programmes and urban design features:

- Community smart meter system

- Community gardening scheme
- Environmental energy-saving challenges
- Active travel club

Action and Priority:

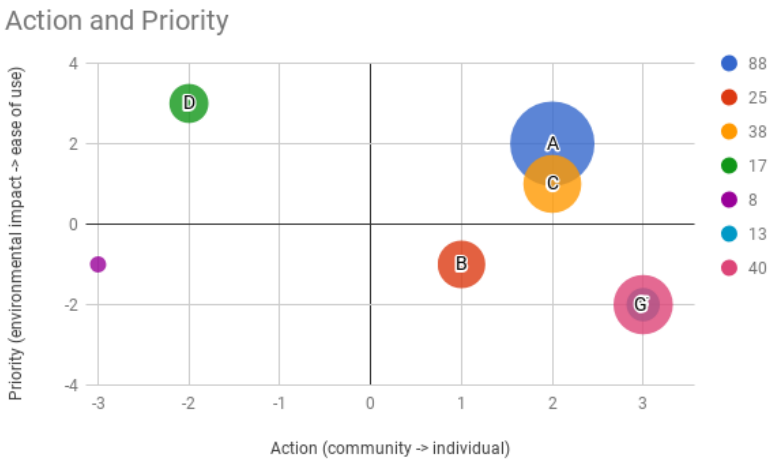


Figure 67: Action and priority chart

Individual action, ease of use priority: groups 1 and 3 (A and C)

Suggested policies, programmes and urban design features:

- Solar panel subsidy scheme
- Greywater recycling scheme

Individual action, environmental impact priority: groups 2, 6 and 7 (B, F and G)

Suggested policies, programmes and urban design features:

- Smart meters
- Electric car charging points
- Cycle hire scheme

Community action, environmental impact priority: group 5 (E)

Suggested policies, programmes and urban design features:

- Community district heating scheme
- Pedestrianisation of site

- Renewable energy microgeneration
- Sustainable drainage system
- Community smart meter system

Community action, ease of use priority: group 4 (D)

Suggested policies, programmes and urban design features:

- Active travel club
- Greywater recycling scheme

Impact and Priority:

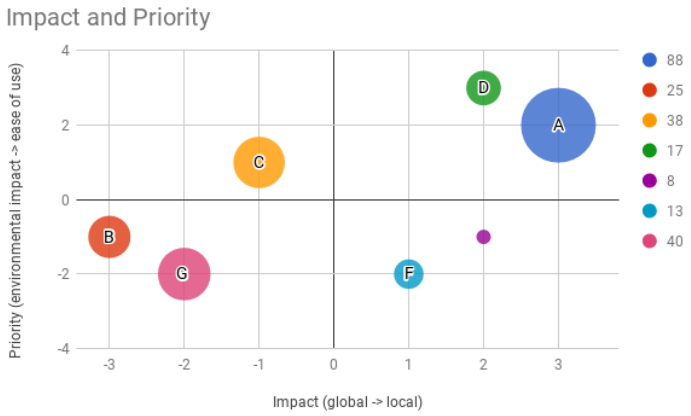


Figure 68: Impact and priority chart

Local impact, ease of use priority: groups 1 and 4 (A and D)

Suggested policies, programmes and urban design features:

- Active travel club
- Greywater recycling scheme

Local impact, environmental impact priority: groups 5 and 6 (E and F)

Suggested policies, programmes and urban design features:

- Community gardening scheme
- Renewable energy microgeneration
- Pedestrianisation of site

Global impact, environmental impact priority: groups 2 and 7 (B and G)

Suggested policies, programmes and urban design features:

- Community smart meter system
- Ethical investment of community funds
- Carbon footprint counting programme

Global impact, ease of use priority: group 3 (C)

Suggested policies, programmes and urban design features:

- Renewable energy microgeneration
- Local cycle hire scheme
- Local car hire scheme

5.3 Bespoke dataset

Looking to external data to build energy profiles to support our behavioural groups.

Introduction

The results of this behavioural narratives work will be combined with the bespoke dataset in a following section and used in scenarios to come up with a final suggested package of policies, programmes and urban design features which would have the best energy and carbon outcomes for the North West Cambridge demographic case study example.

Bespoke external dataset creation

In this section we look at matching our behavioural groups with energy profiles through creating and using a bespoke external dataset.

As seen in the previous sections, we have explored four external sources of data on behavioural patterns and energy profiles. We will now look at our findings in light of this external data and see

where similarities allow us to extend our expectations of the energy use behaviour which we might find in our behavioural groups, as we establish energy use profiles for use in scenario testing for the NWC site.

Pelenur and Cruickshank's Barriers and Motivations

We have previously seen that through their work on barriers (Pelenur & Cruickshank, 2012) and motivations (Pelenur & Cruickshank, 2014) to adopting energy efficient measures, Marcos Pelenur and Heather Cruickshank established two clear energy behaviour profiles. Now that we have demographic data on our behavioural groups, we can look to find parallels with these groups. We draw on their results to enhance the analysis of the behavioural groups formed above.

The first group (see below) corresponds well to our behavioural group 4 "Practicalities First". Their second profile does not fit so well with the general demographic profile of our sample, but would fit most closely with group 6, which shows the highest percentage living in 'privately owned' properties – although only at 25%. The suggestions in their profiles around motivations and barriers confirm what has come out of our survey and interview analysis of the two groups nicely.

1. Currently single individuals, earning <£40,000/year, living in apartments/flats
- Motivations: to save resources, be more efficient out of general principle
- Barriers: landlord-tenant/housing association
2. Married/common-law individuals, income >£40,000/year, living in semi/detached homes
- Motivations: to save money
- Barriers: physical property

Figure 69: behavioural groups from data in Pelenur & Cruickshank (2014)[3]

Passivhaus occupant behaviour

Several studies on Passivhaus occupant behaviour put forward the following key findings, which are relevant to our behavioural group work.

"It is found that in general passive houses are less sensitive to behaviour than anticipated" (Blight & Coley, 2013)

From this finding we can take that if newly constructed houses of this energy efficiency standard (which is similar to those on the NWC site) are less sensitive to behaviour than expected, that we

should also focus on other sources of occupant energy use e.g. transport to see where the best behavioural energy and carbon savings can be made.

"'Behavioural' factors, such as summer ventilation and shading practices were seen to impact negatively on summer overheating risk. Winter opening of bedrooms windows impacted on the space heating performance of Dwelling 2. Behavioural or occupant choices in terms of appliance use impacted on the electricity and primary energy consumptions of both dwellings" (Ridley et al., 2014)
From this observation we can take two key pointers for estimating where energy and carbon reductions can be made in residential settings. Firstly that behaviour can have a big impact on heating use and secondly that appliance use has a big impact on energy consumption.

"Small dwellings, with a floor area of less than 100m2, with relatively high occupancy levels, greater than 4 adults, will struggle to achieve passive house primary energy targets if electricity consumption from appliance use if not curbed" (Ridley et al., 2014)
This third finding tells us that the NWC postgraduate flats will require careful management of appliance use if they are going to save energy, something which we should consider in our scenarios.

NEED Domestic energy use

Using the NEED table creator, we were able to combine relevant variables of our groups to obtain electricity and gas consumption data which matches each of our behavioural groups.

Process

'Variable 1' was always set as tenure as this is a key factor for our behavioural groups – many of the energy barriers or use factors are based around the fact that most of our sample population rent rather than own their property and as a result are limited in some regards.

'Variable 2' was alternated between other relevant data for our groups: no. bedrooms, floor area (m2), income, no. adults, property type and region.

The year 2015 was used for all calculations as it was closest to when the survey and interviews were carried out and was the most recent data available.

The fuel types were alternated to provide a calculation for each of electricity and gas for each combination of variables.

Each calculation was calculated for the 'mean' rather than 'median' level – an average seemed the best way to calculate as it gives a fuller representation of the data.

Calculations

With each of the variables came sub-categories. We had to do some additional work to find the data for our groups to assess which categories the behavioural groups would fit into. The following data was used:

Income (calculated for our two biggest occupation groups)**:**
Average PhD researcher annual salary (Cambridge, UK): £15,490[25] - so we can assume this falls within the £15,000 - £19,999 income category.

Average postdoctoral researcher annual salary (UK): £33,538[26] or £30,839[27] - so we can assume that this falls within the £30,000 - £39,999 income category.

Tenure:
Privately rented suits the majority of our respondents

No. bedrooms:
We know from the plans for the NWC phase one development that residents will be housed in either:

- 1 or 2 bedroom apartments (key workers/postdoctoral researchers)
- Individual rooms within a shared flat of four to eight bedrooms (postgraduate students)
    - We use an average of six people sharing for the calculations

Floor area (m^2):
From the NWC plans[28] we know the average floor areas of the different types of accommodation:

[25] https://www.glassdoor.co.uk/Salaries/phd-student-salary-SRCH_KO0,11.htm
[26] https://www.glassdoor.co.uk/Salaries/cambridge-postdoctoral-researcher-salary-SRCH_IL.0,9_IM1028_KO10,33.htm
[27] https://www.payscale.com/research/UK/Job=Postdoctoral_Research_Associate/Salary
[28] https://www.accommodation.cam.ac.uk/FindAHome/UniversityAccommodation/UniversityOwnedProperties/NorthWestCambridge

- 1-bedroom apartment – 52 m^2
- 2-bedroom apartment – 65 m^2
    - For postdoctoral researchers we use an average of the two, as there is a mixture of both one and two-bedroom apartments on the site = 58.5 m^2
- 6-bedroom shared apartment - 49m^2 per person = 294 m^2

Number of adults:

From the types of property available, we know that the number of adults per property is likely to be:

- 6 for postgraduate shared apartments
- 1 or 2 for 1 or 2-bedroom key worker apartments

From the Domestic NEED Methodology Note (2017), we can establish that the average household size is two adults.
We find this by the following calculation:

Experian data on no. adults per household.
Figure 6.9 – comparison of distributions by number of adults in a household
NEED sample shows (estimated based on graph on p38):
1 adult – 35%
2 adults – 42%
3 adults – 14%
4 adults – 6%
5 or more – 3%

The largest group is two adults and the skew towards one, so we can assume that an average house size would be just under two people, rounded up to two.

For the purposes of our study, this means that we should divide all NEED data by two, as the figures are given per household and we are looking for figures per person.

There are exceptions to this for the number of adults variable when viewed against tenure, as in this case we can also use the five plus category and divide by six, to fit the postgraduate flats on NWC and for income as these income figures are already matched to our groups.

Property type:

We know that all properties in phase one of the NWC project are purpose built flats.

Region:

The NWC site is within the East of England region.

Electricity (kWh)

As a result of the information above on our site, the relevant electricity figures from the NEED spreadsheet are (in kWh):

Income:

- £15,000 - £19,999: 3,500
- £30,000 - £39,999: 3,900

No. bedrooms:

- 1 bedroom: 3,500
- 2 bedrooms: 3,700
- 5 or more bedrooms: 6,800

Floor area (m^2):

- 51 to 100: 3,600
- Over 200: 7,600

Number of adults:

- 2: 3,900
- 5 or more: 5,200

Property type:

- Purpose built flat: 3,900

Region:

- East of England: 4,100

We next can calculate the average for each behavioural group based on the above, calculating the rate per person where accommodation is shared.

1) **The average respondent (average group A) electricity kWh**

- Income:
    - £15,000 - £19,999: 3,500
- No. bedrooms:
    - 5 or more bedrooms: 6,800 /6[29] = 1,133
- Floor area (m2):
    - Over 200: 7,600 /6[11] = 1,267
- Number of adults:
    - 5 or more: 5,200 /6[11] = 867
- Property type:
    - Purpose built flat: 3,900/2 = 1,950
- Region:
    - East of England: 4,100/2 = 2,050

Total = (3,500 + 1,133 + 1,267 + 867 + 1,950 + 2,050) /6 = **1,795** kWh

For each of the variables NEED gives us a household energy output. As the average household size of the HEED data is two, for most variables we divide the result by two to get a figure for the individual. However, in certain cases where we know that dividing it by six will give us a more appropriate output for our population living in flats shared between six people (on average), we divide by six for an individual figure. As aspects of all of the variables will have an impact on individual energy use and because we have divided some by six for the reasons listed above, we find an overall average figure by adding all six output figures together and dividing by six. A similar process is adapted for each of the following groups.

2) The average Postdoc (average group B) electricity kWh

- Income:
    - £30,000 - £39,999: 3,900
- No. bedrooms:
    - 1 bedroom: 3,500
    - 2 bedrooms: 3,700

[29] postgraduate student accommodation arranged in groups of 4-8 rooms sharing a kitchen/living area – 6 taken as an average for this calculation https://www.girton.cam.ac.uk/for-graduate-students/accommodation/graduate-accommodation-overview/swirles-court

    - average of 1 and 2-bedrooms: 3,600/2 = 1,800
- Floor area (m2):
    - 51 to 100: 3,600/2 = 1,800
- Number of adults:
    - 1: 3,400
    - 2: 3,900
    - average of 1 and 2 adults sharing: 3,650/2 = 1,825
- Property type:
    - Purpose built flat: 3,900/2 = 1,950
- Region:
    - East of England: 4,100/2 = 2,050

Total = (3,900 + 1,800 + 1,800 + 1,825 + 1,950 + 2,050) /6 = **2,221** kWh

3) The average postgraduate student (average group C) electricity kWh

- Income:
    - £15,000 - £19,999: 3,500
- No. bedrooms:
    - 5 or more bedrooms: 6,800 /6[30] = 1,133
- Floor area (m2):
    - Over 200: 7,600 /6[11] = 1,267
- Number of adults:
    - 5 or more: 5,200 /6[11] = 867
- Property type:
    - Purpose built flat: 3,900/2 = 1,950
- Region:
    - East of England: 4,100/2 = 2,050

Total = (3,500 + 1,133 + 1,267 + 867 + 1,950 + 2,050) /6 = **1,795** kWh

[30] postgraduate student accommodation arranged in groups of 4-8 rooms sharing a kitchen/living area – 6 taken as an average for this calculation

4) **"Practicalities first" (behavioural group A) electricity kWh**

- Income:
  - £15,000 - £19,999: 3,500
- No. bedrooms:
  - 5 or more bedrooms: 6,800 /6 = 1,133
- Floor area (m2):
  - Over 200: 7,600 /6[11] = 1,267
- Number of adults:
  - 5 or more: 5,200 /6[11] = 867
- Property type:
  - Purpose built flat: 3,900/2 = 1,950
- Region:
  - East of England: 4,100/2 = 2,050

Total = (3,500 + 1,133 + 1,267 + 867 + 1,950 + 2,050) /6 = **1,795** kWh

5) "We are keen, bring it to us" (behavioural group B) electricity kWh

- Income:
  - £15,000 - £19,999: 3,500
- No. bedrooms:
  - 5 or more bedrooms: 6,800 /6 = 1,133
- Floor area (m2):
  - Over 200: 7,600 /6 = 1,267
- Number of adults:
  - 5 or more: 5,200 /6 = 867
- Property type:
  - Purpose built flat: 3,900/2 = 1,950
- Region:
  - East of England: 4,100/2 = 2,050

Total = (3,500 + 1,133 + 1,267 + 867 + 1,950 + 2,050) /6 = **1,795** kWh

6) "Doing what I think is right" (behavioural group C) electricity kWh

- Income:
    - £30,000 - £39,999: 3,900
- No. bedrooms:
    - 1 bedroom: 3,500
    - 2 bedrooms: 3,700
    - average of 1 and 2-bedrooms: 3,600/2 = 1,800
- Floor area (m2):
    - 51 to 100: 3,600/2 = 1,800
- Number of adults:
    - 1: 3,400
    - 2: 3,900
    - average of 1 and 2 adults sharing: 3,650/2 = 1,825
- Property type:
    - Purpose built flat: 3,900/2 = 1,950
- Region:
    - East of England: 4,100/2 = 2,050

Total = (3,900 + 1,800 + 1,800 + 1,825 + 1,950 + 2,050) /6 = **2,221** kWh

7) "Preserve the beauty" (behavioural group D) electricity kWh

- Income:
    - £15,000 - £19,999: 3,500
- No. bedrooms:
    - 5 or more bedrooms: 6,800 /6 = 1,133
- Floor area (m2):
    - Over 200: 7,600 /6 = 1,267
- Number of adults:
    - 5 or more: 5,200 /6 = 867
- Property type:

    - Purpose built flat: 3,900/2 = 1,950
- Region:
    - East of England: 4,100/2 = 2,050

Total = (3,500 + 1,133 + 1,267 + 867 + 1,950 + 2,050) /6 = **1,795** kWh

We have found that through the groups we are coming up with two distinct electricity consumption levels – **1,795 kWh (average respondent group 1/postgraduate students group 3 + groups 4, 5 & 7)** and **2,221 kWh (postdoctoral researchers group 2 + group 6)** – due to the dominance of particular demographic groups in each behavioural group.

Gas (kWh)

As we are using the same variables, for the gas calculations we need only create two profiles:

2) The average Postdoc (average group B) gas kWh

- Income:
    - £30,000 - £39,999: 11,500
- No. bedrooms:
    - 1 bedroom: 6,900
    - 2 bedrooms: 9,700
    - average of 1 and 2-bedrooms: 8,300/2 = 4,150
- Floor area (m2):
    - 51 to 100: 10,700/2 = 5,350
- Number of adults:
    - 1: 9,800
    - 2: 11,600
    - average of 1 and 2 adults sharing: 10,700/2 = 5,350
- Property type:
    - Purpose built flat: 7,800/2 = 3,900
- Region:
    - East of England: 11,600/2 = 5,800

Total = (11,500 + 4,150 + 5,350 + 5,350 + 3,900 + 5,800) /6 = **6,008** kWh

3) The average postgraduate student (average group C) gas kWh

- Income:
  - £15,000 - £19,999: 10,200
- No. bedrooms:
  - 5 or more bedrooms: 23,000 /6[11] = 3,833
- Floor area (m2):
  - Over 200: 27,100/6[11] = 4,517
- Number of adults:
  - 5 or more: 16,700 /6[11] = 2,783
- Property type:
  - Purpose built flat: 7,800/2 = 3,900
- Region:
  - East of England: 11,600/2 = 5,800

Total = (10,200 + 3,833 + 4,517 + 2,783 + 3,900 + 5,800) /6 = **5,172** kWh

The two distinct gas consumption levels are – **5,172 kWh (postgraduate students)** and **6,008 kWh (postdoctoral researchers)**.

HEED Domestic energy use

On exploration of the HEED domestic energy use data, the following points from the Cambridge data (2016 & 2017) were of relevance to our study.

The data shows no installations in Cambridge in 2016 or 2017. There are pockets of installations in previous years – but before the period of our survey and interviews.

There is no record of any community heating systems being installed in Cambridge for the available years of HEED records (1993-2017). There are some individual installations of solar PV or heating in earlier years but nothing on a large scale.

There is evidence of larger-scale installations of long lifetime RTDs (resistance temperature detectors) and visual display units in previous years.

Carbon CAP Report 5 and 6 evidence for behaviour change

Through the carbon CAP reports we earlier explored the different types of green technologies and policies and programmes to influence behaviour on a site. As a result, we decided to focus on two particular green measures on the NWC site for our scenarios:

- Community smart meter system
- Site-wide active travel plan

Department for Transport statistics – Walking and Cycling Statistics

To explore the active travel element of the scenarios, we looked at the data provided on cycling and walking uptake in the Department for Transport statistics.

Notable statistics are set out below. In the final model we only need a % decrease in high-carbon car and bus transport miles, but this is nonetheless useful for gauging how much our participants already walk and cycle and so realistic % reduction figures to input into the Cambridge Retrofit model.

Proportion of adults who do any walking or cycling, for any purpose, by frequency and local authority, England, 2015-2016 (from table CW0301):

Cambridge:

- Once per month: 91.1
- Once per week: 86.8
- Three times per week: 72.6
- Five times per week: 60.6

We also looked into the Department of Business, Energy and Industrial Strategy 2017 "Government GHG Conversion Factors For Company Reporting", but found that such data on carbon emission rates per vehicle were already embedded in the Cambridge Retrofit model.

5.4 Scenarios

In this section we present the scenarios built with the previous results.

Introduction

The scenarios set out examples of behavioural maps of the site under certain circumstances. These are built by looking at the range of possible combinations of behaviour within the different population groups and the associated potential electricity and gas savings. These are established to then be entered into the Cambridge Retrofit model to calculate resultant energy and carbon savings.

Below we set out each of the scenarios put forward for energy and carbon calculation, the inputs required and the resultant percentage of electricity and gas reductions expected from the input data.

Scenarios:

1) **Baseline** – no behavioural input, simple output based on site population and floor area
2) **Status-quo projection** – what we would expect to see with current split of demographics and behavioural groups within the population, doing as they do now, with no additional measures put in place
3) **Ideal savings projection** – the savings we could expect to see if all groups took up measures tailored to their demographic and behavioural groups

We will use the four behavioural groups established in the previous data analysis, with input from the demographic group analysis also performed on our primary data, in line with the percentage of postdoctoral researchers and postgraduate students in each group.

Additionally, we will be able to show which groups have the greatest potential percentage savings with which technologies and policies/programmes/urban design features.

This data could be used in additional scenarios with inputs somewhere between scenarios two and three.

Weighting

From the survey population sample sorted into behavioural groups we have:
49% postgraduate students
51% postdoctoral researchers

Whereas we know that the accommodation planned for phase one of NWC gives us an estimate of a population split of:
21% postgraduate students
79% postdoctoral researchers

In order to calculate predicted energy and carbon outcomes that reflect the site as closely as possible, in the scenarios weighting will be applied to address this balance between the demographic groups within our behavioural groups.

This is done by multiplying postgraduate energy figures by 0.43 (=21/49) and postgraduate energy figures by 1.55 (79/51). This only applies to the electricity and gas figures. The transport figures are whole-group projections which are not specifically demographically-linked.

Scenario analysis

Scenario one – baseline

Overview

The first scenario is a simple baseline calculation based on the population and floor area of the first phase of the NWC development. Alongside the projected electricity, gas and transport energy use

for the demographics of the site, these are the two inputs into the Cambridge Retrofit model which remain constant regardless of the scenario and so we initially run the model with just these inputs and no behavioural components.

A baseline is required so that we can have something to compare the results of the behaviour-reliant scenarios with, to establish relative energy and carbon savings.

Inputs required

There are five inputs for this baseline scenario. These are whole-site figures for phase one of the development.

Floor area

The input required by the Cambridge Retrofit model is "floor area retrofit". As this model was designed for the impact of retrofitting existing housing stock, this input points towards a retrofitted floor area. In this context the area under consideration is the NWC development, as a percentage of whole Cambridge floor area and so we can consider this input to be the relevant floor area of the NWC development in which our population will be living.

We therefore find a figure for the living accommodation which the key populations of our study (postdoctoral researchers and postgraduate students) will be accommodated in.

Population

The model asks for the population in order to calculate energy and carbon outputs for the Cambridge city at a certain population. In the case of our study, we are focused on the NWC development and so will use the population of the first phase of the site which corresponds with the floor area of the accommodation we have inputted. By doing so we are calculating energy and carbon outcomes which are purely based on our case study site.

Site electricity use

The projected energy profiles attached to our behavioural groups, from the NEED data, are used to find the total electricity use for the site. This is entered as baseline electricity consumption. In further scenarios we will look at how our behavioural groups vary from these figures (scenario two) and can then see further reductions through behaviour change (scenario three).

When it comes to behavioural group projected electricity reductions, from the HEED dataset we know that in Cambridge, only 6% of heating energy use is through electricity. This means we will see the emphasis on gas reductions in terms of space heating. We also know that appliance use is an important contributor to electricity use in low carbon homes (Ridley et al., 2014). We will consider this to be categorised under the 'computing' heading.

Site gas use

As above, for site gas use, the behavioural group projected energy profiles are used to find the total gas use for the site. 92% of heating energy is gas in the Cambridge area (HEED) and so this will be a main focus in this area. On the NWC site all accommodation will be heated by a district heating system. Initially this will be gas powered, so we can expect 100% of heating energy to be from gas on the site, with residents potentially saving if switching from electricity (but as above, very few systems are electric). There are additional behavioural aspects to consider in relation to this such as demotivation to save energy due to the use of a centralised system (e.g. easy access, potential heating cost inclusion in rent) and human behaviours such as opening of windows when not technically required (Ridley et al., 2014).

Site transport energy use

Car/van and bus energy use from the National Transport Survey for our demographic is inputted into the model to calculate baseline transport emissions for the site.

Calculations

The following sets out the calculations followed to get each of the input figures for the Cambridge Retrofit model.

Floor area

The next section sets out the data prepared to input into the Cambridge Retrofit model. All data is based on the first phase of development of the NWC site, focusing on key worker and postgraduate student accommodation.

Floor area

Key worker housing

1230 units over full site development

700 units in phase one

Full development – 645 one-bedroom units and 585 two-bedroom units

Of those two types,

= 52% one-bedroom units, 48% two-bedroom units

One-bedroom unit = 52 m^2, two-bedroom unit = 65m^2

Floor area one-bedroom units = 52*364 = 18,928 m^2

Floor area two-bedroom units = 65*336 = 21,840 m^2

Total floor area phase 1 key worker housing = 40,768 m^2

Postgraduate housing

2000 rooms in shared flats over full site development

325 rooms in shared flats of four to eight students in phase one

Total floor area = 98,000 m^2 /2000 = 49m^2 per room

Total floor area phase one postgraduate housing = 15,925 m^2

Total floor area accommodation phase one = 56,693 m^2

In the model a percentage 'retrofitted' (here we count the developed area) floor area per sector is required. Here, one hundred percent is attributed to the 'residential' category.

Population

Postdoctoral researchers

Total units key worker housing = 700 units of one and two-bedroom apartments.
Occupants could be:

- 1 adult
- 2 adults
- 2 adults and one child

Various combinations could end up in either one or two-bedroom apartments. Given the statistics from our survey that most postdoctoral researchers have no dependents, we can assume that most units will have either one or two adult occupants. We will estimate this at 30% single occupancy, 70% two adult occupancy based on the age group (likely to live with a partner or a flat mate) because of our understanding of the lifestyle patterns of this group (and the sharing norm amongst those millennial+ groups living in high rent locations such as London and Cambridge).

This would give us:
700*0.7 = 490 units with two occupants = 980 people
700*0.3 = 210 units with single occupant = 210 people
Total = 1,190 people

Postgraduate students

325 individual rooms in phase one
Total = 325 people

Total population in postdoctoral researcher/postgraduate student accommodation in phase one = 1515

79% postdoctoral researchers

21% postgraduate students

Site electricity use

Figures are rounded up to give round numbers of people in each group, which means the total population reaches 1,516.

1,795 kWh (average respondent group 1/postgraduate students group 3 + groups 4, 5 & 7)
2,221 kWh (postdoctoral researchers group 2 + group 6).

Group A (22% population) = 0.22*1515 = 333 people
No. postgraduate students = 0.65*333 = 216
No. postdoctoral researchers = 0.35*333 = 117

Postgraduate students: 216 * **1,795 * 0.43 = 166,720**
Postdoctoral researchers: 117 * **2,221 * 1.55 = 402,778**

Total = 569,498 kWh

Group B (10% population) = 0.10*1515 = 152 people
No. postgraduate students = 0.5*152 = 76
No. postdoctoral researchers = 0.5*152 = 76

Postgraduate students: 76 * **1,795 * 0.43 = 58,661**
Postdoctoral researchers: 76 * **2,221 * 1.55 = 261,634**

Total = 320,295 kWh

Group C (16.8% population) = 0.168*1515 = 255 people
No. postgraduate students = 0.31*255 = 79
No. postdoctoral researchers = 0.69*255 = 176

Postgraduate students: 79 * **1,795** * 0.43 **= 60,976**

Postdoctoral researchers: 176 * **2,221 * 1.55 = 605,889**

Total = 666,865 kWh

Group D (51.2% population) = 0.512*1515 = 776

No. postgraduate students = 0.4*776 = 310

No. postdoctoral researchers = 0.6*776 = 466

Postgraduate students: 310 * **1,795 *0.43 = 239,274**

Postdoctoral researchers: 466 * **2,221 * 1.55 = 1,604,228**

Total = 1,843,502 kWh

Electricity for the site population:

A + B + C + D

= **569,498** + **320,295** + **666,865** + **1,843,502**

= 3,400,160 kWh

Site gas use

Figures rounded up to give round numbers of people in each group, which means the total population reaches 1,516.

5,172 kWh (average respondent group 1/postgraduate students group 3 + groups 4, 5 & 7)

6,008 kWh (postdoctoral researchers group 2 + group 6).

Group A (22% population) = 0.22*1515 = 333 people

No. postgraduate students = 0.65*333 = 216

No. postdoctoral researchers = 0.35*333 = 117

Postgraduate students: 216 * **5,172 * 0.43 = 480,375**

Postdoctoral researchers: 117 * **6,008 * 1.55 = 1,089,551**

Total = 1,569,926 kWh

Group B (10% population) = 0.10*1515 = 152 people

No. postgraduate students = 0.5*152 = 76

No. postdoctoral researchers = 0.5*152 = 76

Postgraduate students: 76 * **5,172 * 0.43 = 169,021**

Postdoctoral researchers: 76 * **6,008 * 1.55 = 707,742**

Total = 876,763 kWh

Group C (16.8% population) = 0.168*1515 = 255 people

No. postgraduate students = 0.31*255 = 79

No. postdoctoral researchers = 0.69*255 = 176

Postgraduate students: 79 * **5,172 * 0.43 = 175,693**

Postdoctoral researchers: 176 * **6,008 * 1.55 = 1,638,982**

Total = 1,814,675 kWh

Group D (51.2% population) = 0.512*1515 = 776

No. postgraduate students = 0.4*776 = 310

No. postdoctoral researchers = 0.6*776 = 466

Postgraduate students: 310 * **5,172 * 0.43 = 689,428**

Postdoctoral researchers: 466 * **6,008 * 1.55 = 4,339,578**

Total = 5,029,006 kWh

Gas for the site population:

A + B + C + D

= **1,569,926** + **876,763** + **1,814,675** + **5,029,006**

= 9,290,370 kWh

Site transport energy use

Site transport energy use us calculated from the National Travel Survey data (2016)[31].

Nts9904: Average distance travelled by mode, region and rural-urban classification, England, 2015/16 – East of England

Car/van passenger: 2,043 miles per person per year

Car/van driver: 3,958

Local bus: 162

Bicycle: 45

Walk: 180

Walks of over a mile: 98

For our model:

Car/van miles per person per year = 2,043 + 3,958 = 6,001

Site total = 6,001*1,516 = **9,079,516**

Bus miles per person per year = 162

Site total = 162*1,516 = **245,592**

Reductions

As this scenario presents the baseline for our site and population, there will be no behavioural component inputted and so no reduction figures are required.

[31] Department for Transport - National Travel Survey (2016)

Scenario two – status-quo projection

Overview

The second scenario is where we input the data which we have collected on the population of the NWC site into the model to establish how this differs from the baseline outputs.

Here, we are looking to find out what the energy and carbon savings would be, compared to the baseline, if our behavioural groups do as they do now. This differs from the baseline as our data has shown a more nuanced picture of the specific demographic groups likely to live on the NWC site, with a detailed insight into the behavioural characteristics of each group.

To calculate the different energy use levels between the groups, we take the group with the highest energy figures and look at how much energy the other groups use which is less than the top group. This provides us with a mechanism for creating depth in the data. This is purely for comparison between the groups, rather than any behaviour change.

We do not include any measures to attempt to change the status-quo behaviour established from our research in this scenario. This stage shows what the energy and carbon outlook would be if we simply placed the relevant demographic groups (with their specific related behaviours) on the NWC site, without specifically attempting to alter their behaviour towards more environmentally-friendly actions.

Inputs required

For the status-quo projection, we input current % electricity and gas energy savings per group.

For this we require:

Electricity savings per group

- Catering saving %
- Computing saving %
- Cooling/ventilation saving %
- Hot water saving %

- Heating saving %
- Lighting saving %
- “Other” saving %

Gas savings per group

- Catering saving %
- Computing saving %
- Cooling/ventilation saving %
- Hot water saving %
- Heating saving %
- Lighting %
- “Other” saving %

We find these percentages for each group based on the behavioural trends we have established through the previous stages of data analysis.

We then add these together to find total % savings for each of the above categories to input into the Cambridge Retrofit model for this scenario.

Calculations

Here we use the electricity and gas totals per group as calculated above.

For these calculations we take the majority occupation/demographic group (from postgraduate student/postdoctoral researcher) and use it, with the remainder allocated to the other of the two key groups. We do not consider the other occupation groups as these are more minor and below the level of detail required for this part of the study.

Reductions

The % overall reduction for each group in the electricity and gas categories is calculated by:

a) Finding the highest (per person) figure for electricity and gas between the four groups (highlighted)
b) Finding the % variance from the highest figure, for each group, for electricity and gas
c) The highest figure group for each category is give 0% variance figure

d) These % figures are then used as the reductions for each group for each category. This will be the total % reduction, to be split amongst the model categories, according to the motivations of and barriers facing each behavioural group – see next step

Group	Electricity (kWh)	Variance from highest electricity (%)	Gas (kWh)	% variance from highest gas
A	569,498/333 = 1,710	35	1,569,926/333 = 4,714	34
B	320,295/152 = 2,107	19	876,763/152 = 5,768	19
C	666,865/255 = 2,615	0	1,814,675/255 = 7,116	0
D	1,843,502/776 = 2,376	9	5,029,006/776 = 6,481	9

Figure 70: Percentage group reductions

In this section we set out why groups A, B and D use less energy than group C which is the highest level electricity and gas consumer group. Based on previous understanding of behavioural trends in the groups and findings from the literature, we set out how this percentage variance is likely to be split amongst the common energy uses.

Group A

This group is young (64.7% aged 18-25), majority postgraduate student (64.7%) and lives in private rental (35.3%) or university-owned rental (35.3%). 41.1% have a master's degree, suggesting that the majority of this group are PhD students.

We know that the priority for this group is practicalities – if they use any green technologies, they want things which have a low financial cost and are easy to do – although they also care about the impact it will have. They will only use what is already built-in as they have little ability to purchase technologies, or to change elements of their accommodation.

We know that they pay attention to their energy and water use and use cycling as a main mode of transport.

Given this profile, we suggest that the main areas for energy-saving for this group will be in heating and lighting. Limiting heating use and turning of lights are two of the perceived obvious ways of saving money in rented accommodation. This group as less likely to save money on computing as they are students who will need this to complete their degree work. Minimal savings may be made

on cooking. We have given savings for catering and hot water for both electricity and gas as rented accommodation could have either system in place.

Electricity reduction total = 35%

- Catering saving 4%
- Computing saving 4%
- Cooling/ventilation saving 0%
- Hot water saving 7%
- Heating saving 0%
- Lighting saving 20%
- "Other" saving 0%

Gas reduction total = 34%

- Catering saving 5%
- Computing saving 0%
- Cooling/ventilation saving 0%
- Hot water saving 9%
- Heating saving 20%
- Lighting 0%
- "Other" saving 0%

Group B

Group B are a little older than group A – 50% are aged 26-35 and they are split roughly 50/50 postgraduate student and postdoctoral researcher. The majority (50%) live in private rental accommodation.

For this group, we know that environmental protection is a priority which they are happy to put energy and resources towards, but it needs to be made easy for them.

They are likely to have quite a good knowledge of what they can do to reduce their energy and carbon use and incorporate this into their routine, such as walking or cycling as a main mode of transport.

Given this profile, it is likely that main savings also lie in heating and lighting, although they may also be more conscious of hot water use. Computing will still be low as this group require this technology to complete their course or research work. They may consider how they can save energy by cooking in more energy efficient ways, but this is unlikely to be a major factor.

Electricity reduction total = 19%

- Catering saving 2%
- Computing saving 2%
- Cooling/ventilation saving 0%
- Hot water saving 5%
- Heating saving 0%
- Lighting saving 10%
- "Other" saving 0%

Gas reduction total = 19%

- Catering saving 1%
- Computing saving 0%
- Cooling/ventilation saving 0%
- Hot water saving 6%
- Heating saving 12%
- Lighting 0%
- "Other" saving 0%

Group C

Group C has the highest totals for electricity and gas consumption and so is entered at a 0% reduction rate. However, we can still explore the background to this result, as it will help with scenario three.

This group are older than the previous two groups (69.2% aged 26-35), majority postdoctoral researchers (69.2% employed by university, 61.5% have a PhD), more international (38.5% from international countries outside of EU) and largely living in private rental accommodation (76.9%).

This group is principled and strives to contribute towards a positive future locally and globally. They tend to work according to their own beliefs, either independently or within groups, on their own terms.

This means that if these individuals are convinced of the impact that a green technology can have, they are likely to use it to the best of their ability. But if they are not, they are unlikely to engage – regardless of what those around them too. This means that they could either have very high savings or very low savings, depending on the circumstances and their control over the situation. We will explore this further in the next section where behavioural components are influenced by various measures.

Electricity reduction total = 0%

- Catering saving 0%
- Computing saving 0%
- Cooling/ventilation saving 0%
- Hot water saving 0%
- Heating saving 0%
- Lighting saving 0%
- "Other" saving 0%

Gas reduction total = 0%

- Catering saving 0%
- Computing saving 0%
- Cooling/ventilation saving 0%
- Hot water saving 0%
- Heating saving 0%
- Lighting 0%
- "Other" saving 0%

Group D

Group D are a similar age profile to group B – 50/50 postgraduate students and postdoctoral researchers, although slightly more have a master's degree (40%) so they may be more in the PhD and postdoctoral researcher groups than the master's student stage. They live in private rental (50%).

This group's motivation, though, is different. They are more concerned by the beauty and inherent value in the natural environment and wish to contribute to preserving it for future generations to enjoy as they do.

This means that their interaction with energy-saving measures is more likely to be in the realm of those changes that they can see making a direct impact on natural resource use e.g. water use. They are also less likely to be attached to computers and that kind of technology, as they value being present in nature where possible, so we may see small savings there.

Electricity reduction total = 9%

- Catering saving 0%
- Computing saving 2%
- Cooling/ventilation saving 0%
- Hot water saving 5%
- Heating saving 0%
- Lighting saving 2%
- "Other" saving 0%

Gas reduction total = 9%

- Catering saving 0%
- Computing saving 0%
- Cooling/ventilation saving 0%
- Hot water saving 5%
- Heating saving 4%
- Lighting 0%
- "Other" saving 0%

Totals

To find the true total predicted % reduction for the site population, we must weigh the data according to the % population sample in each behavioural group. This is calculated in the tables below for electricity and gas. For each group we multiply the % reduction for each category by the % population (e.g. group A electricity by catering = 1*0.22) and add up these weighted totals (marked by group/W).

Group	No. surveys	% population
A	17	22
B	8	10
C	13	16.8
D	40	51.2

Figure 71: Groups percentage of population

Electricity percentage reductions, per category, per group and total (%)

Electricity	A	A/W	B	B/W	C	C/W	D	D/W	Total
Catering	4	0.88	2	0.2	0	0	0	0	**1.08**
Computing	4	0.88	2	0.2	0	0	2	1.024	**2.104**
Cooling/ventilation	0	0	0	0	0	0	0	0	**0**
Hot water	7	1.54	5	0.5	0	0	5	2.56	**4.6**
Heating	0	0	0	0	0	0	0	0	**0**
Lighting	20	4.4	10	1	0	0	2	1.024	**6.424**
"Other"	0	0	0	0	0	0	0	0	**0**
Total	**35**	**7.7**	**19**	**1.9**	**0**	**0**	**9**	**4.608**	**14.208**

Figure 72: Electricity reductions scenario two

Gas percentage reductions, per category, per group and total (%)

Gas	A	A/W	B	B/W	C	C/W	D	D/W	Total
Catering	5	1.1	1	0.1	0	0	0	0	**1.2**
Computing	0	0	0	0	0	0	0	0	**0**
Cooling/ventilation	0	0	0	0	0	0	0	0	**0**
Hot water	9	1.98	6	0.6	0	0	5	2.56	**5.14**
Heating	20	4.4	12	1.2	0	0	4	2.048	**7.648**
Lighting	0	0	0	0	0	0	0	0	**0**
"Other"	0	0	0	0	0	0	0	0	**0**
Total	**34**	**7.48**	**19**	**1.9**	**0**	**0**	**9**	**4.608**	**13.988**

Figure 73: Gas reductions scenario two

Scenario three – ideal savings projection

Overview

Scenario three is where we build on the status-quo (scenario two) to put forward our suggested package of interventions to encourage behaviours within the NWC population which will provide larger energy and carbon savings than that of the status quo.

This scenario is the sum total of the energy and carbon we would expect to see saved if each of the behavioural groups were to take up and use green technologies to the extent that we predict, given measures tailored to their behavioural profiles. This is in addition to the percentage variances in behaviour between groups from the predicted averages in the previous scenario.

For each group we have analysed the data and trends observed in the survey, interview and fieldwork research and the recommendations put forward as a result in terms of which policies, programmes and urban design features would encourage the greatest take up and use of green technologies on the NWC site.

We find each behavioural group's electricity and gas % savings based on the take up and use of the two selected example technologies:

- community smart meter system
- site-wide active travel plan

We put this in the context of best-fit policies, programmes and urban design features being implemented on the site. These are underpinned by the group differentiators – action (community -> individual), impact (global -> local) and priority (environmental impact -> ease of use).

In this third scenario, we bring in energy savings associated with the second green feature – site-wide active travel plan – which will be calculated in a separate category, as this is based on a switch from higher-carbon transport forms (such as personal petrol/diesel car or bus) to low carbon transport (cycling and walking). For this element we will estimate a % reduction in high-carbon transport use and calculate the energy and carbon within the transport category of the Cambridge Retrofit model in the next stage.

Inputs required

As with the previous scenario, we require the following inputs:

Electricity savings per group:

- Catering saving %
- Computing saving %
- Cooling/ventilation saving %
- Hot water saving %
- Heating saving %
- Lighting saving %
- “Other” saving %

Gas savings per group:

- Catering saving %
- Computing saving %
- Cooling/ventilation saving %
- Hot water saving %
- Heating saving %
- Lighting %
- “Other” saving %

These % reductions are then totalled up for the site population at large, ready to be inputted into the Cambridge Retrofit model.

% reduction in high-carbon transport forms will also be estimated, to be calculated separately in the next stage.

Calculations

Group A:

We find each behavioural group’s electricity and gas % savings based on the take up and use of the two selected example technologies:

- community smart meter system
- site-wide active travel plan

We put this in the context of best-fit policies, programmes and urban design features being implemented on the site. These are underpinned by the group differentiators – action (community -> individual), impact (global -> local) and priority (environmental impact -> ease of use).

In scenario two we saw group A have expected overall reductions of 15% electricity and 14% gas.

In this scenario we are looking to what we know about this behavioural group to find the best-fit policies, programmes and urban design features which would encourage take up and use of community smart meters and active travel (cycling and walking).

Community smart meter system:

The community smart meter system is likely to suit group A very well. It ties in with their key motivators – community (it brings them together virtually and increases in-person conversation), environment (they can see a direct impact on the environment through visible, easy to access data on energy savings) and finances (they can see money savings linked to energy savings). It also will have a local impact as it is a scheme which will be a team effort from those living in the immediate area, which this group is likely to buy into.

This group require participation to be easy – so if this technology is built in when they move in this will increase likely take up, although regular use may be lower than in other groups as it may not be a priority unless embedded easily into their daily lifestyle. However, there is a chance that this may seem like one of the lower effort options for energy-saving on heating, lighting and cooking for this group and so may have a higher take up than other more user-dependent technologies.

Overall, we expect that Group A could see the following additional savings through take up and use of a community smart meter system:

Additional electricity savings group A (total 18%):

- Catering saving 1%
- Computing saving 1%
- Cooling/ventilation saving 0%
- Hot water saving 3%

- Heating saving 8%
- Lighting saving 5%
- "Other" saving 0%

Additional gas savings group A (total 12%):

- Catering saving 1%
- Computing saving 0%
- Cooling/ventilation saving 0%
- Hot water saving 3%
- Heating saving 8%
- Lighting 0%
- "Other" saving 0%

Site-wide active travel plan:

As previously discussed, group A have practical concerns and ease of use as primary decision-making factors on whether they will use a green technology. This presents a challenge for the site-wide travel plan – these residents are unlikely to switch to using low carbon transport means unless there is a strong push factor. Such factors in this situation are that the 'Ridgeway' cycle and footpath has been routed right through the centre of the development, surrounded by pedestrianized zones and covered bike racks – so it couldn't be much easier to participate in active travel. However, there will still be car parking available on the site, albeit more difficult to reach than bike racks and with restrictions on where you can drive through the site. **Overall it is likely that we will see a 10% increase in active travel from group A.**

Group B:

In scenario two group B had expected overall reductions of 8% electricity and 8% gas. Below are the projections for the reductions as a result of this group's interactions with the two selected technologies.

Community smart meter system:

Group B are concerned with contributing towards a positive future for the community and environment. Combined with a core value of advancement, they are likely to be interested in the community smart meter system and willing to give it a try. The community nature of the technology also ties in with their passion for social equity and progress as they will likely see this as a way of

bringing a diverse community together in a shared project. As a result, it is likely that this group will engage well with this technology and play a key role in empowering other groups to get and stay, involved.

Overall, we expect that Group B could see the following additional savings through take up and use of a community smart meter system:

Additional electricity savings group B (total 23%):

- Catering saving 1%
- Computing saving 2%
- Cooling/ventilation saving 0%
- Hot water saving 5%
- Heating saving 10%
- Lighting saving 5%
- "Other" saving 0%

Additional gas savings group B (total 16%):

- Catering saving 1%
- Computing saving 0%
- Cooling/ventilation saving 0%
- Hot water saving 5%
- Heating saving 10%
- Lighting 0%
- "Other" saving 0%

Site-wide active travel plan:

Their passion for community, equality and the environment means that group B are likely to buy into the many benefits of active travel and to see their individual participation as part of a wider community movement to try to do more journeys without using carbon-heavy vehicles. Many of them are likely to already use active travel where possible and so it will not take much for them to increase the regularity of this with dedicated high-quality infrastructure on their doorstep. **We are likely to see a 20% increase in active travel from group B.**

Group C:

In scenario two group C had the highest expected electricity and gas use and as such had reduction levels of 0% for both electricity and gas. In this scenario we can look at what reductions may be achieved by putting various measures in place.

Community smart meter system:

Group C members can go either way with a community scheme. While they are very passionate about environmental protection and strong in their individual beliefs, they will only follow others and take part in shared projects if it is in line with these beliefs. If an activity doesn't line up with their personal opinions, they will not be afraid to not participate out of principle. This makes it important to provide a community smart meter system which is robust enough in showing its impact that they will want to be involved and see it as a true community-led initiative in order that they can use their passionate streak to engage and enthuse others in the process. If it's made appealing in this way, we could see high take up rates from this group and long-term engagement as they get stuck into the project. In this vein, we could see the following energy savings as a result:

<u>Additional electricity savings group C (total 23%):</u>

- Catering saving 2%
- Computing saving 1%
- Cooling/ventilation saving 0%
- Hot water saving 5%
- Heating saving 10%
- Lighting saving 5%
- "Other" saving 0%

<u>Additional gas savings group C (total 17%):</u>

- Catering saving 2%
- Computing saving 0%
- Cooling/ventilation saving 0%
- Hot water saving 5%
- Heating saving 10%
- Lighting 0%
- "Other" saving 0%

Site-wide active travel plan:

This group already partake in cycling and walking as day-to-day transport options. However, given good quality infrastructure and their passion for environmental causes, we could see an additional increase in use here, instead of the higher-carbon transport they occasionally use. **We could expect a 20% increase in active travel from group C.**

Group D:

In scenario two group D had expected overall reductions of 4% electricity and 4% gas.

Community smart meter system:

Group D have a defining characteristic of a strong desire to share and protect beautiful spaces. They are sensitive to the aesthetics of urban realm streetscapes and very much value the presence of nature. Their desire to contribute to looking after these spaces and protect the environment may engage them in the smart meter system through concern for the wider environmental aims. However, there is a risk that they are slightly averse to using technology as a solution to environmental problems and if the unit itself is not aesthetically pleasant, (despite their belief in individual responsibility) they will likely find it a negative presence in their home rather than a source of interest and something they want to engage with. Balancing these factors, assuming a moderate level of engagement, we could see the following savings from this group:

<u>Additional electricity savings group D (total 11%):</u>

- Catering saving 0%
- Computing saving 1%
- Cooling/ventilation saving 0%
- Hot water saving 2%
- Heating saving 6%
- Lighting saving 2%
- “Other” saving 0%

<u>Additional gas savings group D (total 8%):</u>

- Catering saving 0%
- Computing saving 0%
- Cooling/ventilation saving 0%
- Hot water saving 2%

- Heating saving 6%
- Lighting 0%
- "Other" saving 0%

Site-wide active travel plan:

Urban design factors come into the spotlight with group D. They are far more likely to take part in active travel if they know that they will be doing so in a streetscape which they find aesthetically pleasant and with natural elements. Given that the site-wide active travel routes on NWC have been carefully planned to include elements such as curved routes, a variety of man-made and natural materials and natural areas along the route, it is highly likely that we would see an increase in active travel use by this group. If done so well that the group looks forward to this travel as a way of enjoying the outdoor space, **we could see an increase of up to 25% active travel use from group D.**

Reductions

We now add the predicted reductions for all groups under scenario three to find the following total reduction rates:

Total electricity and gas reductions:

To find the true total predicted % reduction for the site population, we again must weigh the data according to the % population sample in each behavioural group. This is calculated in the tables below for electricity and gas.

Group	No. surveys	% population
A	17	22
B	8	10
C	13	16.8
D	40	51.2

We have also added the total category percentages from the previous scenario (2). For the model it has to be cumulative as, for our study, those status quo figures are required to be entered as percentage reductions from baseline in model, so to build on these we need to add scenario three reductions to scenario two 'reductions'.

Electricity percentage reductions, per category, per group and total (%)

Electricity	A	A/W	B	B/W	C	C/W	D	D/W	Total	Total + scenario 2
Catering	1	0.22	1	0.1	2	0.336	0	0	0.656	1.736
Computing	1	0.22	2	0.2	1	0.168	1	0.512	1.1	3.204
Cooling/ventilation	0	0	0	0	0	0	0	0	0	0
Hot water	3	0.66	5	0.5	5	0.84	2	1.024	3.024	7.624
Heating	8	1.76	10	1	10	1.68	6	3.072	7.512	7.512
Lighting	5	1.1	5	0.5	5	0.84	2	1.024	3.464	9.888
"Other"	0	0	0	0	0	0	0	0	0	0
Total	**18**	**3.96**	**23**	**2.3**	**23**	**3.864**	**11**	**5.632**	**15.756**	**N/A**

Figure 74: Electricity reductions scenario three

Gas percentage reductions, per category, per group and total (%)

Gas	A	A/W	B	B/W	C	C/W	D	D/W	Total	Total + scenario 2
Catering	1	0.22	1	0.1	2	0.336	0	0	0.656	1.856
Computing	0	0	0	0	0	0	0	0	0	0
Cooling/ventilation	0	0	0	0	0	0	0	0	0	0
Hot water	3	0.66	5	0.5	5	0.84	2	1.024	3.024	8.024
Heating	8	1.76	10	1	10	1.68	6	3.072	7.512	15.16
Lighting	0	0	0	0	0	0	0	0	0	0
"Other"	0	0	0	0	0	0	0	0	0	0
Total	**12**	**2.64**	**16**	**1.6**	**17**	**2.856**	**8**	**4.096**	**11.192**	**N/A**

Figure 75: Gas reductions scenario three

High-carbon transport use reductions:

Combining the results from each group we can find overall high-carbon transport use reduction figures. Here we are assuming an increase in active travel will be in place of bus or car journeys as residents engage in modal shift. A limitation of this approach is that we assume this direct modal shift. Generally, modal shift could vary according to length of journey (e.g. medium length journeys by car now taken by train) but here we focus on journeys at short distances within the site and Cambridge and so the likely shift is to active travel as public transport is less applicable to the length of journey.

Group A = 10% increase in active travel = **10%** decrease in distance by high-carbon transport

Group B = 20% increase in active travel = **20%** decrease in distance by high-carbon transport

Group C = 20% increase in active travel = **20%** decrease in distance by high-carbon transport

Group D = 25% increase in active travel = **25%** decrease in distance by high-carbon transport

= (10/4) + (20/4) + (20/4) + (25/4) = 2.5 + 5 + 5 + 6.25

= **18.75% overall site reduction in high-carbon transport**

Car/van miles scenario three = 0.8125***9,079,516 = 7,377,107**

Bus miles scenario three = 0.8125***245,592 = 199,544**

This is input into the Cambridge Retrofit model as a percentage saving on VMT (vehicular miles travelled) for bus and private car.

We split this total reduction by car & bus equally as we do not have specific car ownership or bus use data for the Cambridge area.

5.5 Energy and carbon outcomes

Having run the scenarios under the Cambridge Retrofit model, we now explore the energy and carbon results.

Introduction

Having built up the behavioural groups, energy profiles, external dataset and scenario inputs in the previous sections, we are now able to see the energy and carbon outputs from each of the scenarios run through the Cambridge Retrofit model.

We used the model to give projections for 2020 as this is a reasonable timeframe to start seeing results from phase one of the NWC development green technology initiatives ahead of the next stages being completed.

As previously explored, our results are based on our analysis of how each behavioural group is likely to interact with each of two example technologies, due to the relevant policy and urban environment factors being implemented around them. Therefore, the reductions are what we could expect for these two technologies as opposed to all low carbon features of the NWC site.

Scenario one – baseline

This was run based on 100% "retrofit floor area" being in the residential sector. Calculations use 2009 DECC subnational electricity and gas figures. The model calculates a total for the whole of the Cambridge area, considering all sectors and so when we enter our population of 1515, we get a much higher CO2/person total than is true of the site. We instead look at the resultant % reductions in our totals to see the impact of these initiatives on the overall energy and carbon outcomes.

Scenario one result:

By 2020: Per capita CO2: **5.6 tons CO2/person-year**

Scenario two – status quo projection

Scenario two result:

By 2020: Per capita CO2: **5.5 tons CO2/person-year**

= 2% saving on baseline

This outcome shows us that already the make-up of our site population is likely to have a lower energy and carbon use than the Cambridge population as a whole, simply due to the fact that the site is being developed with this higher environmental specification. However, as we see in the next scenario, there is great potential for savings beyond this status quo outcome.

Scenario three – ideal savings projection

Scenario three result:

By 2020: Per capita CO2: **5.0 tons CO2/person-year**

= 11% saving on baseline

These results are the overall reduction in CO2 per person, per year. Calculation in the Retrofit model includes the other sectors (industry/business, university, other fuel and solid waste), remaining constant. We are therefore looking at the impact that energy reductions in the residential setting and transport use can have on the carbon footprint for those sectors specifically.

We can look at the sector CO2 actuals break down and see that this is a predicted saving of**:**

Electricity:

Baseline: 3,400,160 kWh/year

With reduction: 3,342,357 kWh/year

= 57,803 kWh/year electricity saving

Gas:

Baseline: 9,290,370 kWh/year

With reduction: 8,045,460 kWh/year

= **1,244,910 kWh/year gas** saving

Residential total carbon:

Baseline: 3,477.5 tons CO2/yr

With reduction: 3,218.4 tons CO2/yr

= 259.1 CO2/yr residential carbon saving

Reducing sector contribution by 7.5%

Transport:

Car/van:

Baseline: 9079516

With reduction: 7377106.75

1,702,409 VMT car saving

Bus:

Baseline: 245592

With reduction: 199543.5

46,049 VMT bus saving

Transport total carbon:

Baseline: 4943.3

With reduction: 4306.3

= 637 tons CO2/yr transportation carbon saving

Reducing sector contribution by 13%

This result shows that impactful energy and carbon savings of 11 percent can be made on the site through engaging in careful planning of implementation measures which address the needs and behaviour patterns of the range of behavioural groups found within the NWC population. This figure reflects the impact of implementing these measures for the behavioural groups in relation to the two chosen green technology examples, as opposed to the whole range of green features and associated policies planned for the North West Cambridge site.

This final scenario focused on two specific technologies and still shows significant energy and carbon impacts of a 7.5% reduction to the residential sector carbon emissions and a 13% transport sector carbon reduction. If we were to expand the range of technologies considered, we would likely see even larger impacts. This scenario achieves an average of 5.6% reduction in carbon emissions per technology (although we can see a larger actual carbon reduction through the implementation of the site wide travel plan in this case). Of course some features and policies will overlap and so we might see diminishing reduction levels per technology as more are added to the scenarios, and there will naturally be variations person to person. However, our results show that even careful thought in the way we market an individual technology to an individual moving onto a new development can have a direct impact on how their community engage in the technology and therefore the size of the overall impact.

Equally, if this sort of consideration is not put in place, the level of energy-saving is vulnerable to reduce potentially right down to the baseline level. This is particularly important for groups such as behavioural group C, where the individual motivation and belief in the impact of the technology has to be there or they will be happy to disengage completely. However, if you capture their interest from the start, this group has very high potential to in fact lead others within the community to enthusiastic engagement in the project. Far from just putting the technologies in place and waiting for energy savings, planning for increase carbon savings is as much a strategic community

engagement exercise as it is a practical task. The impact of this work has the potential to make or break a site's energy and carbon targets.

5.6 Chapter conclusions

The results of our study are notable at various levels, explored below.

At the very top level, we see that significant energy and carbon savings in the residential and transport sectors are possible for each technology put in place with the population of the NWC site. This is possible through implementing green technologies in line with the recommendations of take up and use measures to engage each of the behavioural groups in ways that work best with their motivations, barriers and potentials. These reductions have the potential to be even greater when additional technologies are included in the scenarios.

Aside from the energy and carbon figures, we have notable results in terms of detailed exploration of the tendencies of each of our behavioural groups. Combining what we know about the demographics of each group, their passions and the ways in which they like interacting with people and places around them, we are able to think about which types of technologies each group would likely have the highest energy savings with and ways of encouraging interaction with less likely technologies too.

On a site level, in-depth analysis of the two key groups of residents on the NWC site builds us a picture of what the first community living on the site may look like – how they are likely to interact with each other and which measures will be particularly successful in such a group.

Further implications of this research are discussed in the following chapter.

6 Implications

6.1 Introduction

In this chapter, following the results from our study, we now look at how these results fit into the wider context into which this study places itself. We start by evaluating the method and its advancement, followed by contributions beyond the main case study site. Finally, we look at issues raised and remaining concerns.

The study provides insight into policies and programmes that can influence behaviours in ways that in turn affect the energy and carbon impacts of new build developments. In terms of the North West Cambridge Development itself, this research provides data on the extent to which two of the green technologies being put in place on site in the first phase reduce energy and carbon emissions. Recommendations could be implemented to help ensure that the development meets its desired sustainability standards and reputation.

These results are applicable more widely to the sustainable urban development field. Through use of our set of urban design and behavioural grouping methodologies and recommendations, energy and carbon reduction programmes could be implemented on existing sites or embedded into plans for future developments.

From a wider perspective, this study provides an insight into what is a new way of universities using their influence to ensure environmentally sustainable development. If comparison with non-university-led developments shows better sustainability outcomes through greater take up and use on a site where the university community is prevalent, then that would be of substantial interest to the building and education sectors.

6.2 Evaluation of the methods

In this section we evaluate how well each of the chosen methods enabled us to achieve the thesis aims and answer the research questions.

Background theory

The study started with a basis of literature from a number of different fields which had relevance to the research questions. While this presented a challenge in terms of narrowing down the theoretical

scope, it paved the way for the mixed methods methodology which provided a more holistic understanding of the issues and potential solutions, which can be considered one of the strengths of the study.

Behavioural influences

The study of literature of a wide range of behavioural influences provided a cross-cutting view of the types of influences on the ways in which individuals and communities act. However, it was difficult to know exactly where to place the limits, and so while this study focused on a range of influences crosscutting psychology, demographics and urban design amongst others, it is possible that additional factors from other fields could also be brought into this context.

Social practice theory

The social practice theory lens provided the link between the individual and site-wide impact, through exploring the role of communities of people in sharing and developing behaviours, to the extent that the overall energy and carbon impact of the site could be influenced. Further study could delve further into the interaction between social practice theory and behavioural groupings.

Nudge theory

Nudge theory provided a useful framework in which to bring in the range of different aspects of the environment around an individual which affect decision-making, including the role of the urban environment in influencing behaviour, through the consideration of visual signals in decision-making.

Methods used

The mixed methods approach designed specifically for this study enabled a more holistic view of the context, using the most relevant methods from a range of types. However, the innovative nature of this, combined with the predictive nature of the study, meant that part of the study was by its nature testing the combination of methods.

Data collection

The combination of more traditional quantitative data from the survey and external datasets provided a strong basis upon which to use slightly more experimental techniques of data collection in the fieldwork and interview photo rounds.

Data processing

The use of a platform for the survey data made the processing simple and effective.

Data analysis

By using standard descriptive analysis of the survey data, we had a useful base of analysis upon which to develop the more innovative method for analysis of the interview data, through the coding matrix, behavioural grouping and synthetic variables. Doing this by hand enabled a closer relationship with the raw data, a proximity which helped with the development of narratives.

Scenario analysis

There were many benefits to using scenarios, such as providing a range within which the outcomes could be expected, based on different levels of policy and programme intervention. However, there were limitations to this method. The predictive nature of the scenarios meant that it was difficult to say with which degree of certainty we can take these results.

Energy and carbon modelling

The Cambridge Retrofit model provided a suitable tool for calculating the outputs we needed, without necessitating the creation of a new model. If real life energy data was available for the main case study, the predictive risk of this could be mitigated, however this was not possible in this case.

6.3 Advancement of the method

In this section we look at where the research and results of this study have advanced the methods and theories used, and in which ways.

Background theory

By establishing gaps in the intersections of different fields of literature, this study has been able to build upon and bridge gaps between different bodies of study, towards furthering research on the topics raised in the research questions.

Behavioural influences

The behavioural influences literature was in this study applied to a new context, of this particular population sample, with this type of low carbon urban development site. This provides further insight on the applications of such knowledge to current contexts.

Social practice theory

In this study social practice theory was applied to the new context of visual signals in the urban environment, and their effect on community practices, with the effect measured, combined with policies and programmes.

Nudge theory

Nudge theory was also applied to this unique context of visual signals on low carbon sites, in the frame of behaviour change combining visual signals, green technologies and policies and programmes. This shows that the scope of nudge theory and behavioural influences can be usefully expanded to the physical construction of sites at a larger scale than the immediate environs of a decision-maker.

Methods used

Data collection

While mixed data collection methods are not unusual, this study had its own application of a variety of collection techniques, by different forms and a range of means. This enabled a more holistic view of the topic area as in person, interactive and desk-based methods were combined.

Data processing

For this study, a unique and innovative coding method was created. This shows how the principles of standard coding methods can be applied to a specific dataset, to get the most from the data. Additionally, in order to strengthen the areas of potential weakness in the study (e.g. the lack of current energy data), the process of bespoke external dataset matching and use was a key part of the methodology in terms of building the robustness of the results. In bringing the different external data together, this study has supplemented them with a unique perspective on how each of them could be built upon, in combination with the others. The inclusion of that data has enabled this study to build on the existing research, providing further insight into the different topics they tackle – from behavioural groupings to active travel potential.

Data analysis

The behavioural grouping system built upon existing methods to enable the creation of groups which fit the context of the study, incorporating different types of data, and within the limitations of

the available data. This process of adaptation of process to fit the data shows the applicability of methods to mixed data sets.

Scenario analysis

While the need to use predictive methods of analysis was a challenge for this study, in terms of the robustness of results that could be produced, this limitation did encourage a more creative approach. This mean that the scenario method was additionally boosted by the data inputs being created from a bespoke dataset gathered to match with the findings of the primary data that the study was able to gather. This type of approach could be applied to a range of situations where a full dataset is not available, needs to be strengthened, or is predictive by nature.

Energy and carbon modelling

In terms of the energy and carbon modelling stage of the study, the use of the Cambridge Retrofit model not only gave the opportunity for it to be applied to a different context (testing its adaptability – which in this case worked well). It additionally meant there was no need to develop a full new model as part of the study, enabling energy to be spent on developing and finessing other parts of the methodology. It also shows an example of how to adapt a model to fit different types of study on a smaller scale than that for which it was originally designed.

6.4 Additional contributions to the field

Beyond North West Cambridge

While our main case study was the North West Cambridge development, the general context in which the study was undertaken is applicable to a range of other situations. Additionally, the methodology which we have followed shows how understanding the behavioural patterns of residents of a site can influence the way you design their potential interaction with the built-in technologies and green features.

Sustainable urban development projects are likely to share at least one physical aspect with NWC – whether it be the scale of the development, the style of streetscape design or the urban extension location. Comparisons can be made with implementation of the same types of green technologies in different contexts. The analysis and creation of behavioural groupings within the population sample could be applied to postgraduate students and postdoctoral researchers elsewhere and in slightly different behavioural contexts. Many of the core aspects of the groupings reflect their general view of and interaction with the world around them and so could be applied in different ways to which

we have matched these with green technologies specifically. These findings have supplemented the combination of external datasets to further the research in each of those contexts, and the way in which they can be combined to provide a more holistic picture of a site.

The results of our study model the ways in which significant energy and carbon emission reductions of 11% can be achieved through careful implementation of policies and urban design features alongside two green technologies. The results for these technologies can apply to other sites implementing them and for different technologies, a similar process can be applied to a range of green features to increase the reductions seen across a site.

The methodology used was intentionally made up of parts which could be adapted and used in the context of other sites. For example, the method behind the behavioural groupings could be used with a different population, the outcomes of which would then provide the behavioural context within which to consider the influence of various factors on resident behaviour on a new low carbon site (which could be in another country, of a different scale, with a different urban structure etc.). This process could be used in the design stages to consider which technologies will have the biggest impact and post construction to consider which technologies could still have a reduction factor when added at a later stage.

Designing for sustainable behaviour

The visual signals work can be taken out as a distinct piece of work within this wider piece of work and applied to urban developments as it focuses on particular design elements and presents a set of recommendations which can be applied on different scales on different types of urban developments, according to the particular environmental constraints of each site and the behavioural traits of the projected future residents.

These recommendations are aimed at encouraging environmentally sustainable behaviours, but could equally be applied to address different urban goals. For example, many factors highlighted as beneficial for creating spaces in which people will gather could be applied to a general community-building context; incorporation of nature could be applied to projects to improve mental health within an urban population and features which create a sense of purpose used to encourage active travel could be applied to promotion of physical health and wellbeing.

Bridging the qualitative and quantitative

This study uses a combination of methods from different contexts. It bridges the qualitative and quantitative divide. There is a movement towards more interdisciplinary work in the field of sustainable development and this thesis is one example of how to approach this. While there are some limitations to this approach (see later sections), by finding ways of bringing methods from different fields together in the same study we are able to strive for a more holistic approach to the issues and gain results which apply to a range of contexts.

6.5 Issues raised

Quantifying projected behavioural impacts

In this piece of research, we used a combination of qualitative and quantities methods to establish a set of predicted behaviours and resultant energy reductions. Further exploration of such interdisciplinary methods could lead to more robust projections of human behaviour in a variety of contexts, as our ability to measure the exact impact of a specific action on a technology is advanced further.

Exploring the interaction between people and technologies

There is still work to be done in understanding the relationship between human behaviour and technology use, particularly in terms of understanding the relationship between the role of occupant behaviour and its direct impact on energy outcomes. While we have evidence that various factors influence behaviour and can see the end outcomes in terms of energy and carbon reductions, there is further work to be done in finding the direct links between a specific behaviour and a quantifiable energy reduction (as opposed to working with translated percentage reductions).

Movement between behavioural groups

A natural extension to this study is to look at movement *between* behavioural groups. In this study we establish a set of groupings in a population and find projected energy and carbon emission levels based on those individuals staying in those groups. However, there is scope to look at the characteristics and energy-saving potentials of each group in relation to the context (e.g. the technologies, policies and urban design features available) and make an assessment of which groups are able to achieve the highest carbon savings. From there work could be undertaken to find which policies, programmes and urban design features have the ability to encourage people to move from

a higher energy group to a lower energy behavioural group. This sort of movement could have significant impacts in terms of energy-saving potential of urban developments.

6.6 Remaining concerns

Importance of follow-up and evaluation

While this study presents a positive outcome in terms of our ability to reduce energy and carbon footprints of developments, this type of analysis can only develop when there is sufficient follow-up and evaluation of the actual energy and carbon use on site, to measure against projections.

With on-site data to compare to the pre-occupation projections, we can fully evaluate the level of success of the projections and adapt the methodology as necessary for future research. Repeating the behavioural group analysis (preferably with the same group for both, in future studies) would allow further detail to be added to the behavioural group characteristic maps and additionally provide data on behavioural movement of individuals. This could form the basis of an additional study on movement between behavioural groups on such sites and the factors influencing this. Additionally, a comparison could be made between the predictions of this survey, and the actual data from the site, when possible in the future.

Evolution of behavioural groups due to site

A question remains around whether the behavioural group traits themselves will be altered by the individuals living on the site. Further research could focus on the comparison between pre-site and on-site behaviour and therefore what sort of trends we can predict when using a population sample to project behavioural outcomes of a future development.

6.7 Chapter conclusions

This chapter has provided discussion of the place of the findings of this thesis in the wider field, addressed some issues arising from the work and set out the remaining concerns which could be addressed in further research.

7 Recommendations and conclusions

7.1 Introduction

In this final chapter, we set out the overarching conclusions of the thesis. We discuss the contributions to the fields of study as well as the limitations faced in this piece of research. Finally, we provide a brief of the main policy recommendations from the results for stakeholders in the creation and development of low carbon urban communities and suggest a number of follow-on study topics.

7.2 Limitations of the study

There are some key limitations to this study. The fact that the North West Cambridge site is still under construction is a known challenge that the thesis has to work around with robust modelling and predictive analysis. The combined use of scenarios with survey data of a current similar population has minimised the impact of small changes throughout the timeline in reaching the end point, as different trajectories can take place within the overall range, which provides a certain element of certainty rather than a single outcome which could quickly become unrealistic should one variable change significantly. Additionally, policy, programme and urban environment feature instruments have been selected as *possible* for use on this kind of site, or other similar sites.

In terms of data collection there is always a risk of self-selection bias. While being transparent about the purpose of the survey, it has been framed in such a way as to avoid marketing it as something that only environmentally-conscious people should participate in.

The communication and distribution plan also looked to address this issue by encouraging responses from a diverse range of groups. When individuals respond to a survey or interview, the data collected may represent their personal impressions of activities, issues or situations, rather than the reality of the behaviour happening. This contributes to the performance gap seen in sustainable building. The surveys and interviews were designed to get to the reality of the issue, whilst separately testing the perception of reality, providing robust data.

Measuring impact of individual factors on behaviour is always a difficult task. Each of the areas is addressed in separate questions in the survey to attempt to isolate different factors, but the behavioural grouping process was designed ensure that these were as accurate as possible in terms of clustering groups or types of responses, regardless of the specific measurable influence of

individual factors. Additionally, it is difficult to conclude on the extent to which take up of specific green technologies is 'imposed' or by individual choice.

The methodology moves from qualitative to quantitative data – a bridging that is often complex. The methodology has been structured carefully to make this process as robust and meaningful as possible, carefully matching behavioural elements to behavioural profiles created with external data and therefore providing specific energy outputs.

Due to its uniqueness in terms of land ownership and management by a university, it can be difficult to make generalised comparisons with the wider population or residents on other, similar sites to North West Cambridge. Nonetheless, it is hoped that by using some data from comparison case study sites and being able to isolate site-specific factors (e.g. survey respondents' links to the University of Cambridge) comparison may be possible, and useful. General policy and programme recommendations are transferable to other sites and populations.

7.3 Recommendations: a brief for low carbon urban development to enhance community sustainability

By its nature, this study has a very practical application to the design of new low carbon developments seeking to encourage low energy and carbon behaviours and communities. Therefore, the results are set out below in the form of a brief or recommendations for those looking for practical steps to enhance community sustainability.

Target audiences

The target audiences for this brief include, but are not limited to:

- Masterplanners
- Those involved in strategic oversight of new low carbon developments
- Universities looking to develop land/campuses
- Placemakers
- Urban design practitioners, planners and architects
- Sustainability practitioners
- Policy makers

Site applicability

While the main case study of this study (North West Cambridge) has certain geographical, demographic, institutional and social attributes, the method has intentionally included insights from a range of urban developments. These each have some factor in common with North West Cambridge, but between them cover a range of site locations, national contexts, scales, levels of policy and programme influence and ages of development.

This means that those looking to develop new sites should be able to find some commonality either with North West Cambridge or from the range of other sites explored throughout this work. Adaptation is key – flexibility to apply recommendations to a range of contexts will have the biggest impact.

To create this brief, we have combined policy recommendations for each of our established demographic and behavioural groupings with the urban design recommendations established in the visual signals chapter. These sit under the framework of the three themes of nature, people and purpose.

These are examples of specific policies targeted as a best fit for each of these groups – a range of other policies and features may influence several groups, to a lesser extent. These can be incorporated into new developments to encourage low carbon behaviours. For full analysis see the Visual signals chapter and the Results chapters.

Intervention refers to the action – whether a policy, programme or creation of physical urban feature. Type refers to whether the action is a physical aspect of the urban design of the development (referred to here as hardware) or social/policy interventions designed to encourage certain behaviours (software). Scale sets out whether this action would take place on a home, street or site-wide level. Target behavioural groups sets out which of the groups identified in this study could be expected to provide most energy and carbon saving when experiencing this intervention.

Nature

Creating spaces which give us the opportunity to experience being in or seeing nature

Throughout this study we have seen the importance of the relationship between people and nature in the context of low carbon behaviours, from the literature showing the benefits to health and

wellbeing of being in or near nature, to the interviewees preference for urban scenes showing plants and trees.

The interventions set out below go beyond the baseline of incorporating natural features into a site, instead focusing on how this relationship can be enhanced by policy and physical features beyond nature itself. Through these actions, site planners can tap into the motivations to be part of something bigger, and the protection of beauty and nature, which formed a part of our behavioural group characteristics.

What are we aiming for?

- Enabling experiences of nature – on site and views to beyond
- Mixed uses and types of space (natural and human-made)
- Spaces that allow people to consider their connection to the wider world, and interventions that enable actions which contribute to wider environmental goals

What should we avoid?

- Badly maintained spaces and gardens
- Main material concrete, lack of variety and nature
- Design that looks wasteful in terms of resources e.g. water use
- Design that has too many sharp edges
- Technology which does not have a clear role in contributing to wider environmental causes

Intervention	Type (hardware/software)	Scale	Target behavioural groups
Scheme that can be part of something bigger/have a global impact e.g. practical project linked to online community	Software	Site-wide	The average postdoctoral researcher
Something with a visible impact that interested individuals can lead on	Software (although could include an adaptable hardware	Street to site-wide	Group six – "Doing what I think is right"

	element e.g. community garden)		
Infrastructure which enhances the beauty of the area	Hardware	Street and site-wide	Group seven – "Preserve the beauty"
Initiatives which encourage enjoyment of outdoor space e.g. for leisure	Software linked to hardware (e.g. events planned in local parks to bring the community together in a natural space)	Site-wide	Group seven – "Preserve the beauty"

People

Developing spaces which enable us to see, be with and form relationships with other people

At the core of this study has been social practice theory, bridging the gap between the factors influencing individual behaviours and the energy and carbon outcomes of a site at large.

The recommendations below are based around the idea of creating spaces and initiatives or incentives for people to come together, build communities, and work together on reducing their energy and carbon use – both through the actions themselves, and additionally through the resultant development of low-carbon norms and practices.

What are we aiming for?

- Spaces for people to gather/communities to come together and for those relationships to strengthen
- Aesthetically pleasing design
- Bright, colourful materials; range of materials and textures
- Public art – points of interest
- Space for different users – accessibility
- People and evidence of human activities, development of shared practices
- Good lighting

What should we avoid?

- Green technologies that are not aesthetically pleasant
- Closed, dark spaces, unused spaces
- Visible cars
- Buildings at too large a scale
- Noise
- Materials that do not age well
- Heavily regulated use of space

Intervention	Type (hardware/software)	Scale	Target behavioural groups
Bike network that fits routines – making it easier than using a car	Hardware (cycle routes linking houses, amenities and neighbouring areas)	Site-wide	Group four – "practicalities first"
Programmes that are accessible to all and bring the community together around environmental issues	Software e.g. community recycling challenge linked to how many people you can involve in your neighbourhood	Street, site-wide	Group five – "We are keen, bring it to us"
Subsidies to reduce any financial barriers	Software (e.g. subsidised bike hire scheme)	Site-wide	Group five – "We are keen, bring it to us"
Community technology	Software/hardware (e.g. community energy-saving competition linked to in-home smart meters)	Home, street, site-wide	Group five – "We are keen, bring it to us"
Innovative ways of engaging with issues, flexible involvement	Software (e.g. community sustainable development group	Street, site-wide	Group six – "Doing what I think is right"

and ownership of projects	develops a range of opportunities for people to get involved in energy saving)		

Purpose

Places with purpose – building spaces which guide and encourage their users

Underpinning this study is the aim of encouraging and influencing lower energy and carbon behaviours on new urban developments. However, our research shows that more broadly, people like to feel purpose in spaces that they find themselves in. This can be used purposefully by those shaping spaces, to enable spaces to guide users, and encourage (but not limit users to) environmentally-conscious choices.

Several of the recommendations below centre on mechanisms for enabling active travel. This is one of the key focus points of this study, and furthermore, can be applied in different ways, to appeal to different behavioural groups, illustrated below.

What are we aiming for?

- Separation from cars
- Easy access to active travel and public transport
- Sense of purpose of space
- Invitation to explore and be active
- Human-scale

What should we avoid?

- Brutal transition between 'zones' e.g. personal to public and beyond development
- Confusing design
- Elements which do not blend in well

Intervention	Type (hardware/software)	Scale	Target behavioural groups
Scheme to encourage people to cycle locally for leisure and commuting	Software (promotion of active travel)	Site-wide	Average respondent
Cycle hire scheme – easy to join in, social norm in space, affordable, more convenient than buying	Hardware and software (bikes for hire, hire infrastructure e.g. payment system, promotion of scheme)	Site-wide	The average postdoctoral researcher
Bike pool – low/no cost, linked to accommodation	Hardware and software (set of bikes, maintenance, promotion, membership)	Street	The average postgraduate student
Technologies embedded in home e.g. smart meter	Hardware (and software e.g. instructions)	Home	Group four – "practicalities first"

7.4 Follow-on topics

Expansion to more technologies

These scenarios were based on two specific green features/technologies. A natural progression from this study would be to expand the range of technologies included in scenario calculations and simultaneously expand the range of influencing policies, programmes and urban design features to encourage energy-efficient behaviours.

Energy monitoring

This study could be followed up with actual energy monitoring (on completion of phase one of NWC) with a sample reflecting the behavioural profiles established in this work, to establish what actual energy and carbon figures look like compared to the projections laid out here.

Behavioural movement

Further work could be done in the field of behavioural movement. Research into what it is that causes individuals to move from one behavioural group to another, in relation to use of green technologies would be of great interest to site developers and policy makers, who could use such recommendations to encourage further reduction of emissions across sites. The study of whether sites such as NWC produce positive 'grade inflation' of green behaviours in the area, or in fact the opposite, would also be of key interest in designing green technology strategies for future developments and the building and master planning industry in general.

7.5 Chapter conclusions

This chapter has rounded up the conclusions of the thesis. We have discussed the overall conclusions, contributions to the field and limitations of the study. A summary of the policy recommendations has been set out as well as suggestions for follow on study topics.

Climate change is rapidly impacting life on this planet. The time which we have to mitigate the most damaging impacts and adapt our cities is limited. A range of societal issues in addition compete for our attention – from inequality to poverty. This means that more than ever, we need to reject siloed approaches to research and instead focus on furthering interdisciplinary methodologies, to find the best techniques from a range of fields and experiment in their collaboration to find the most effective outcomes to solve issues.

Through a fundamentally mixed method approach, this thesis set out to establish how occupant behaviour can be influenced by design and programmatic features of the community and the resultant effect on the energy and carbon outcomes of a site. Through a review of literature from a range of relevant fields, exploring the crossover areas and the gaps yet to be addressed, and ultimately expansion of nudge and social practice theories to this context, we have gathered primary and secondary data to establish behavioural groups, profiles and scenarios to calculate the energy and carbon emissions of a sustainable urban development. This innovative adaption of a range of

methods to a unique context shows both the challenges and opportunities to be had from undertaking such a bespoke approach.

The final results show that through our ideal savings projection scenario carbon savings of up to 11 percent could be made by putting in place the policies, programmes and urban design features which best fit the behavioural groups and encourage use of the two sample green technologies.

Additionally, our fieldwork, survey and interview research has enabled us to come up with a series of recommendations of features to put in place on new developments, to encourage carbon reduction behaviours from the site users. By thematic categorization we have established a three-part strategy of spaces with nature, spaces for people and spaces with purpose as the key priorities for creating policy and other interventions in urban developments which will encourage strong communities with high levels of environmentally-friendly behaviour. This brief can be used by a variety of stakeholders in the creation of low carbon urban developments on a range of scales, beyond our main case study.

We have the tools to shape sustainable development of the urban environment in a way which influences the creation of strong, resilient communities, which in turn promote and foster low energy behaviours, leading to lower carbon footprints of new developments. The next step is to apply it to our cities – a challenge, but one worth tackling for our communities now, and for the benefit of future generations to come.

8 Appendix 1 – Survey

Default Question Block

This survey is being used to collect data for my PhD in Land Economy - looking at the take-up and use of green technologies on new build sites.

There are 10 sections to the survey and it should take no longer than 15 minutes maximum. All information gathered will be kept anonymous, unless you are willing to be contacted for a follow-up interview.

Thank you for your participation!

Section 1: About you - demographic information

Please select your age group:

- ○ 18-25
- ○ 26-35
- ○ 36-45
- ○ 46-55
- ○ 56-65
- ○ 66-75
- ○ 75+

What is your current occupation?

- ○ Employed by the University of Cambridge
- ○ Public sector employment
- ○ Private sector employment
- ○ Self-employed
- ○ Postgraduate student
- ○ Unemployed
- ○ Retired

Please tick boxes for the ages of any dependents:

- ☐ Under 5
- ☐ 5-10
- ☐ 11-15
- ☐ 15-18
- ☐ Elderly
- ☐ Other age
- ☐ No dependents

Are you from:

- ○ The UK
- ○ The EU
- ○ Other international country

Section 2: About you - background & lifestyle

What is the level of your highest qualification?

- No qualifications
- Entry level (e.g. functional skills, essential skills)
- GCSE or equivalent (e.g. NVQ level 1-2)
- A-level or equivalent (e.g. NVQ level 3, Advanced apprenticeship, IB)
- HNC or equivalent (e.g. Higher apprenticeship)
- HND or equivalent (e.g. Diploma of Higher Education, Foundation Degree)
- Degree with Honours
- Master's degree
- PhD
- Other Professional Qualification

Do you agree/disagree?

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
Taking part in hobbies and interests is an important part of my life					
I have a good relationship with my colleagues					
I identify strongly with a particular culture					
Money is often the most important factor in my decision-making					

Have you been abroad on a non-work trip more than once in the past year?

- Yes
- No

Section 3: Norms, values & attitudes

Do you agree/disagree?

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
Fitting in and having a similar lifestyle to those around me is important to me					
I like to follow socially-established norms					
I feel an active part of one or more social/community groups					

Thinking of your personal values, please rank the following (top = most important, bottom = least important):

- Fairness
- Community

- Environment
- Tradition
- Spiritual growth
- Advancement
- Aesthetics

Do you agree/disagree?

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
It is important to stay true to your values	○	○	○	○	○
My personal values guide me in my decision making	○	○	○	○	○

Do you agree/disagree?

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
Religious beliefs form an important part of my life	○	○	○	○	○
I believe that I make decisions that are environmentally-friendly	○	○	○	○	○
I think it is important for individuals to make environmentally-friendly decisions	○	○	○	○	○

Section 4: Information sources

Please answer the following:

	How often?		
	Never	Sometimes	Regularly
Tabloid newspapers	○	○	○
Broadsheet newspapers	○	○	○
News websites	○	○	○
TV news channels	○	○	○
TV documentaries	○	○	○
Books	○	○	○
Academic journals	○	○	○
Social media & blogs	○	○	○
Letters	○	○	○
Email newsletters	○	○	○
Talking to others	○	○	○

What is important in an information source?

	Importance:	
	Less important	More important
Type of content	○	○
Quality of content	○	○
Ease of access	○	○

Cost	○	○
Local focus	○	○
National focus	○	○
Global focus	○	○
Ability to interact	○	○
Practical information	○	○

Section 5: Community & peers

Do you agree/disagree?

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
I know my neighbours well	○	○	○	○	○
I have local social groups	○	○	○	○	○
I like to take part in activities that make me feel part of the community	○	○	○	○	○
I am strongly influenced in my decision-making by my peers	○	○	○	○	○

Section 6: Routine & lifestyle - green technologies

Do you actively (please tick all that apply):

- ☐ Pay attention to your energy use?
- ☐ Try to lower your personal energy (e.g. electricity) use?
- ☐ Try to lower the amount of money you spend on energy?
- ☐ None of the above

I have used/currently use (please tick all that apply):

- ☐ Solar panels (heat or PV)
- ☐ Smart meter
- ☐ Electric car
- ☐ Home heated from a district heating system
- ☐ Natural ventilation/cooling system
- ☐ Greywater recycling system
- ☐ Walking as a main mode of transport
- ☐ Cycling as a main mode of transport
- ☐ None of the above

What are the barriers to you using more green technologies? (Tick all that apply)

- ☐ Financial costs
- ☐ Practicalities
- ☐ Prefer alternatives
- ☐ Not a priority
- ☐ None of the above

Section 7: Routine & Lifestyle - lifestyle choices

Thinking of the next five years, please rank these life priorities (top = most important, bottom = least important):

- Family
- Career
- Leisure

Do you agree/disagree?

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
I regularly participate in a variety of leisure activities	○	○	○	○	○
I spend my average day between three or more geographically diverse locations (e.g. home, office, shops)	○	○	○	○	○

The transport options that I use every day are (please tick all that apply):

- ☐ Personal car
- ☐ Shared car
- ☐ Bus
- ☐ Train
- ☐ Bicycle
- ☐ Walking
- ☐ None of the above

My main motivators in decision-making are:

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
Personal benefit	○	○	○	○	○
Benefit for my family	○	○	○	○	○
Benefit for others (locally)	○	○	○	○	○
Benefit for others (globally)	○	○	○	○	○
Benefit for the planet	○	○	○	○	○

Section 8: Participation in policies & programmes

I have previously been a participant in the following programmes (tick all that apply):

- ☐ Community energy use monitoring
- ☐ Car-share scheme
- ☐ Cycling scheme
- ☐ Green technology installation scheme
- ☐ Home insulation installation scheme
- ☐ Energy-saving initiative

- [ ] None of the above

I am likely to participate in a programme if:

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
It requires minimal effort	○	○	○	○	○
It is low/no cost	○	○	○	○	○
It fits into my existing lifestyle	○	○	○	○	○
It will have a big impact	○	○	○	○	○
Other people I know are participating	○	○	○	○	○

Section 9: Your surroundings

Please rate the following:

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
I often notice my surroundings	○	○	○	○	○
My surroundings have an impact on how I feel	○	○	○	○	○
My surroundings noticeably affect my decision-making	○	○	○	○	○

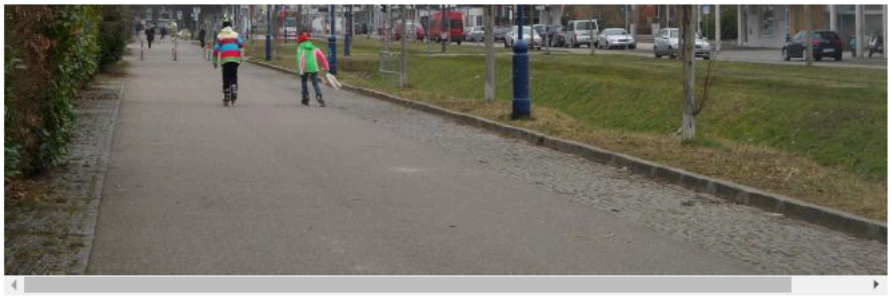
Section 10: Picture round

For the first 3 questions you will be looking at pairs of photographs of urban areas and answering questions based on your impressions. Let your immediate reactions to the scenes guide your answers.

For the final 2 questions you are asked to click on the parts of the picture that stand out to you.

Picture Round - Question 1:

Scene 1



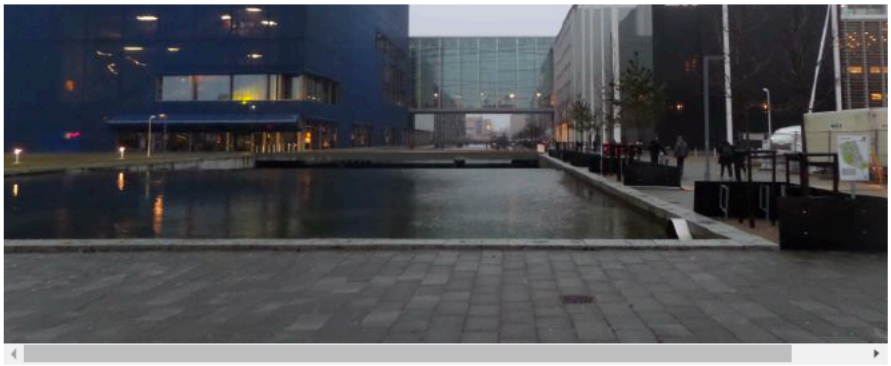
Scene 2

Look at the above photographs and answer the questions below for each:

	Scene 1		Scene 2	
	No	Yes	No	Yes
I would be likely to walk or cycle there	○	○	○	○
This environment makes me feel happy	○	○	○	○
I think I would live a 'green' lifestyle there	○	○	○	○

Picture Round - Question 2:

Scene 3



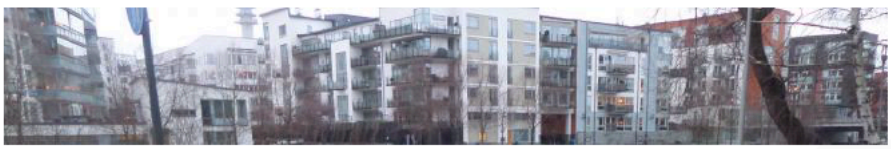
Scene 4

Look at the above photographs and answer the questions below for each:

	Scene 3		Scene 4	
	No	Yes	No	Yes
I can imagine being part of an active community there	○	○	○	○
I think I would live a 'green' lifestyle there	○	○	○	○
I would like to spend time in this space	○	○	○	○

Picture Round - Question 3:

Scene 5



Scene 6

Look at the above photographs and answer the questions below for each:

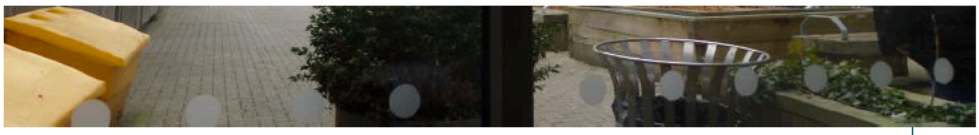
	Scene 5		Scene 6	
	No	Yes	No	Yes
I would feel comfortable in this space	○	○	○	○
I can see myself taking part in leisure activities there	○	○	○	○
This space would encourage me to look after my local area	○	○	○	○

Picture Round - Question 4:

In the image below, click on the parts of the scene which stand out to you. Click once on an area if you like it. Click twice if you dislike it.

Picture Round - Question 5:

In the image below, click on the parts of the scene which stand out to you. Click once on an area if you like it. Click twice if you dislike it.



This is the end of the survey. Would you be willing to be contacted for a follow-up interview? If yes please provide your name and an email address and/or contact telephone number in the box below. Many thanks.

9 Appendix 2 – Coding matrix

Topic		Category	Code	Description	Interview transcript															
					1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Background	1	Hobbies and interests	1A																		
			1B																		
			1C																		
	2	Colleagues	2A	Nice people/easy to work with		X							X								
			2B	Similar type of person employed there		X															X
			2C	Lifestyle differences										X							
			2D	No socialising out of work										X							
			2E	Socialising beyond work														X			
			2F	Support network									X								X
	3	Culture	3A	Nationality/national identity			X														
			3B	Multiculturalism							X										
			3C	Culture of academia							X										
			3D	Language and identities																	X
			3E	Ethnic minorities																	X
	4	Money	4A	Prioritising										X							X
			4B	More expensive than used to										X							
	5	Travel	5A																		
			5B																		
			5C																		
Norms	6	Fitting in	6A	Not bothered about fitting in		X															
			6B	Friends all have different lifestyles														X			
			6C	Socialise with different groups														X			
			6D	Nice to be around people with similar social norms																	X
			6E	Diverse group but shared living norms																	X
	7	Following norms	7A	See themselves as 'weird'/'not normal'	X										X						
			7B	Conscious decision to not follow/rebellion	X										X		X				
			7C	Things they do/like are niche/popular elsewhere											X						
	8	Groups	8A	Don't know about any															X		
			8B	Lone ranger'/chose not to		X											X				
			8C	Don't feel the need to be part of		X															
			8D	Is proactive in groups					X						X						
			8E	Participates in groups					X						X						
			8F	Similar type of people											X						
			8G	Developing communitites					X												
Values	9	Personal values	9A	Not a spiritual/religious person	X	X		X		X	X	X		X		X		X	X		
			9B	Spirituality relevant in some form in current life			X			X										X	X
			9C	Difficult to choose/rank values	X				X			X	X								
			9D	Ranked bottom up	X																
			9E	Ranked top down			X					X									
			9F	Advancement/education/science is the way forward		X		X			X		X			X		X			
			9G	Environment becoming more important/on a global level		X				X	X		X		X		X				
			9H	Focus of togetherness/belonging/community		X	X			X	X		X			X				X	X
			9I	Close relationships/love missing	X	X	X				X		X								
			9J	Fairness/equality		X	X		X		X	X	X		X			X			
			9K	Career/personal impact/actions								X		X				X	X		
			9L	Visual beauty important					X	X	X			X	X		X				
			9M	Some tradition important	X		X		X								X				
			9N	No point in tradition for sake of it		X	X				X				X			X	X	X	
			9O	Shaped by personal upbringing/places have lived					X					X							
	10	Staying true to values	10A	Important to stay true to values			X														
			10B	Live your life in line			X														
			10C	There's no right or wrong				X													
			10D	Life is better									X								
			10E	Sometimes it's difficult												X					
			10F	Don't think about it															X		
	11	Values guide in decision-making	11A	Think about other things too/not always practical		X	X									X					
			11B	To be courageous, not scared of change										X			X				X
			11C	Don't think about it															X		
	12	Religion	12A	Space for self-discovery																	X
			12B	Shapes entire outlook																X	
			12C	Want to be in spaces that reflect beliefs																X	X
			12D	Affects decision-making																X	
			12E	Beliefs have changed but formed core values													X				
			13A	In theory want to, in		X	X														
			13B	We have a responsibility to							X						X				X

Attitudes	13	Environmentally-friendly decisions	13C	Enviro decisions need to be easy		X					X					X					
			13D	My contribution is small							X										
			13E	Some things are, some aren't								X				X	X				
			13F	Not first priority							X		X			X					
			13G	Seems distant									X								
			13H	Ties in with beliefs/values																	X
	14	Environmental conscience	14A																		
			14B																		
			14C																		
Community	15	Neighbours	15A	Know because of building design					X											X	X
			15B	Sense of belonging/community					X	X											X
			15C	Safety/trust					X												X
			15D	Shaping the space together					X												
			15E	Social						X										X	
	16	Community activities	16A	Makes you feel good				X													X
			16B	Raising children				X													
			16C	Integrating people																X	X
			16D	Giving back																X	
			16E	Meet people																X	
Peers	17	Peer influence	17A	Value their opinions			X														
			17B	Influenced but not entirely			X			X			X								
			17C	Personal values more important									X								
			17D	Pushing back against norms											X						
			17E	Try to be the one influencing						X					X						
			17F	Part of an inclusive community																	X
	18	Key members	18A	If enough doing it, will do too		X															
			18B	Don't follow others													X				
			18C	Will do regardless/independent														X			
			18D	Like to be part of something																	X
Green technologies	19	Green technology use	19A	Previous experience shaping ideas	X	X				X				X							
			19B	Cost - investment	X		X		X	X	X	X	X	X	X	X	X		X	X	
			19C	Cost - ongoing	X						X			X			X		X		
			19D	Practicalities	X			X		X			X			X			X		
			19E	Renting	X	X	X		X				X			X					
			19F	Happening anyway	X					X		X									X
			19G	Don't know much about them	X																
			19H	Wouldn't move there just because of green tech	X	X						X	X		X	X		X	X	X	
			19I	Keen to do in future		X	X		X		X	X		X	X	X	X	X			X
	20	Barriers	20A																		
			20B																		
			20C																		
Lifestyle choices	21	Priorities	21A																		
			21B																		
			21C																		
	22	Leisure	22A	Time-dependent										X							
			22B	Work-life balance														X			
			22C	Social aspect														X	X		
	23	Movement/locations	23A	Mainly 2 - home and work								X	X								
			23B	Lifestyle - retired/not working			X			X											
			23C	Not a regular pattern			X			X											
	24	Motivators	24A	Priority is self		X						X									
			24B	Not close to family/if had own family would be different	X		X								X	X					
			24C	Unsure about impact actions have		X	X							X							
			24D	Willingness to be part of bigger picture/make sacrifices				X									X				
			24E	Local is closer to life								X									
			24F	Would like to but don't		X										X					
			24G	Wouldn't do something is had negative impact on group care about			X														
Participation in policies and programmes	25	Programmes (previous experience)	25A	Had a new idea		X															
			25B	Previous experience in different country		X							X	X							
			25C	If it was established in community, would do			X				X		X	X		X					
			25D	Need for routine/practicalities			X	X				X			X	X		X	X		
			25E	Don't need to follow others					X								X				
			25F	Won't actively seek out							X									X	
			25G	Like having impact, not just low effort											X						
	26	Likelihood of participation	26A	Just because someone says, doesn't mean I'll do it								X									
			26B	Depends who is influencing me									X								
			26C	Influence of those around you is important												X					
			26D	I can give more than minimal effort													X	X			

Physical surroundings	27	Surroundings	27A	Aware of the kind of space I'm in			X				X						X				
			27B	Not pinning decision-making on surroundings			X												X		
			27C	Feeling happier in beautiful spaces							X						X				
			27D	Can't pin mood on environment										X							
			28E	Might notice, then get used to														X			
			28F	Sometimes aware, sometimes not, depends on mood															X		
			28G	Subconsciuous reaction to spaces																	X
	28	Images	28A																		
			28B																		
			28C																		

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Maria Håkansson, KTH

Sofie Iverooth, KTH

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Site visits

North West Cambridge

BedZED site office

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GlasshusEtt Community Centre

Stockholm Planning Office

Ecobuild conference x2

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