Solutions to Climate Change in UK Housing Developments:

A Lifestyle Approach

Doctoral Thesis

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Degree: Engineering Doctorate

Declaration:

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

Abstract

This thesis is concerned with how sustainable and low carbon living can be enabled in new housing developments in the UK. The consumption of energy and resources is not just related to the insulating qualities of the fabric of the building and the heating, lighting, appliances and ventilation systems that go into the building, but also to the occupancy patterns and activities of future residents over the long-term. Conventional business models for new housing development, operating under current government regulations, policies and targets have failed to develop housing which encourages the adoption of sustainable lifestyles taking whole life consumption into account. This thesis aims to identify alternative ways in which UK housing development can contribute to achieving 80% carbon savings in the UK by 2050.

A tool (the Climate Challenge Tool) has been developed allowing whole-life carbon equivalent emissions and costs of various options for new developments to be calculated. These cover technical and soft measures; energy used within the home, energy embodied in the building materials and emissions from transport, food and waste treatment. Applying the tool to a case study development, it was found that carbon reductions can be achieved at much lower costs through an approach, which enables sustainable lifestyles, rather than one that purely focuses on technical measures such as those covered in the building regulations. Furthermore a wider sustainability analysis showed additional social and economic benefits from many of the lifestyles measures.

A specific opportunity to incorporate lifestyles measures into new developments was identified: Eco-self-build housing communities. The feasibility of this opportunity was assessed through a stakeholder survey and was judged to be viable. It is concluded that with additional government support or removal of regulatory barriers, eco-self-build communities has the potential to contribute considerably to an 80% emission reduction target.

Gratitude

I would like to thank my supervisor Dr Helena Titheridge for her thorough support and guidance throughout this research. I'd also like to thank my sponsor CAMCO for financially supporting this research and their shared interest and work towards a more sustainable future. At Camco I am particularly grateful to Paul Ruyssevelt for his open-minded outlook and enthusiasm. I am infinitely grateful to numerous friends, colleagues, academics, family members, experts and acquaintances for encouraging me to follow my heart and take an unconventional research route and for their specific support, ideas and encouragement on the way.

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Glossary

BERR	Department for Business, Enterprise and Regulatory Reform
BRE	Building Research Establishment
CCT	Climate Challenge Tool
CDIAC	Carbon Dioxide Information Analysis Centre of the US Department of Energy
CfT	Commission for Integrated Transport
CHP	Combined heat and power
CLG	Communities and Local Government
CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalent
CSE	Centre for Sustainable Energy
CSH	Code for Sustainable Homes
DCLG	Department of Communities and Local Government
DECC	Department of Energy and Climate Change
DEFRA	Department for Environment, Food and Rural Affairs
DETR	Department of the Environment, Transport and the Regions
DfT	Department for Transport
DIF	Digital Interoperability Forum
DTI	Department for Transport and Industry
EngD	Engineering Doctorate
EST	Energy Savings Trust
EU	European Union
FAO	Food and Agriculture Organisation of the United Nations
FES	Future Energy Solutions
IPCC	International Panel for Climate Change
Mt	Mega tonne
NAO	National Audit Office
ODPM	Office of the Deputy Prime Minister

ONS	Office of National Statistics
OPSI	Office of Public Sector Information
NaSBA	National Self-Build Association
RFA	Renewable Fuel Agency
RO	Renewable Obligation
ROCs	Renewable Obligation Certificates
SDC	Sustainable Development Commission
SEI	Stockholm Environment Institute
UNFCCC	United Nations Framework Convention on Climate Change
WBGU	German Advisory Council on Global Change
WEF	World Economic Forum
WRAP	Waste Recovery Action Programme

1 Introduction

1.1 Chapter overview

A brief summary of the core of the research towards an Engineering Doctorate (EngD) is outlined in this section. The background, aims and objectives of the thesis are described and the scope is established. A chapter-by-chapter summary and thesis overview diagram clarifies the overall structure and direction of the work.

1.2 Context

Leading UK and international organisations such as Department for Environment, Food and Rural Affairs, (DEFRA, 2006a), the Sustainable Development Commission (SDC, 2006) and the World Economic Forum (WEF, 2006) have said that they see climate change as the most pressing global problem. In response, many UK professionals working in the field of sustainable construction have warned that 2006 represented a tipping point, the time when a wide range of stakeholders began to sit up and take notice that this "Sustainable Construction" notion was not some fringe fad, that climate change is actually happening, and this does not necessarily mean living a warmer, more Mediterranean lifestyle (Masero, 2006). The Stern Review on "The Economics of Climate Change" sent a simple message: if we do not act now it will be very expensive to put right:

> *"The overall costs and risk of climate change will be equivalent to losing at least 5% of global GDP each year…the estimates of damage could rise to 20%". The cost of action can be limited to 1% of global GDP." (Stern, 2007).*

Residential buildings discharge approximately 26% of UK carbon emissions (Boardman, 2007). An even larger share of emissions, in the order of 30% is indirectly linked to homes, that is, to the way the development is designed and the lifestyles it thereby enables (Desai, 2005). The sources of the emissions include:

A. <u>Personal travel due to commuting and other purposes:</u>
Emissions from commuting are influenced by the provision of jobs near homes (mixed-use developments, access to local amenities, provision of home office space), access to low carbon transport (public transport, cycle parking, walking paths) and personal lifestyle choices (Larus, 2003b; Aplin, 2007; Desai, 2005).

B. <u>Consumables:</u>

There are many ways to reduce the embodied carbon in consumables. An example is to produce food with more energy efficient agricultural machinery and/or less fertiliser and/or without deforestation, reduced packaging, lower retail outlet energy consumption, and reduced transport miles or more carbon efficient modes of transport of the consumable (Gill, 2005).

C. Waste:

One example for reducing emissions from waste is the provision of recycling facilities to increase recycling rates. This reduces carbon emissions, as it typically takes less energy to produce a product using recycled material than producing it from virgin materials (DEFRA, 2007b).

This thesis evaluates the extent to which the design, development, post construction management and location choice for new housing developments opens opportunities to influence travel, consumption and waste patterns. In addition to enabling more sustainable lifestyle choices a sustainability framework would facilitate possibilities for designing homes with low embodied emissions, energy efficiency and renewable energy solutions that can reduce the emissions from the homes themselves.

The sponsoring company Camco provides advice to the construction industry and policy makers on how to reduce climate change impact and on energy policy solutions. This research supports Camco in this role and helps the company in its ambition to be a world leader in sustainable energy solutions.

1.3 Scope and aims

The thesis concerns the reduction of carbon dioxide emissions through the design and implementation of housing development in the UK. The thesis' main claim is that a technological approach based largely on energy efficiency and renewable energy does not sufficiently contribute to the necessary carbon emission reductions required to avoid dangerous climate change, and that a wider "lifestyle" approach which incorporates both technology and behavioural solutions could be more effective. The thesis studies the carbon emission reduction potential of new housing developments from a more holistic view through a lifestyle approach (as defined in section 1.6 and discussed in section 4.3) in order to assess the potential of this approach to deliver significant reduction in carbon emissions, and whether this approach is more sensible in terms of its overall economic and societal impact than a technology focussed approach. A specific opportunity: eco self-build communities is investigated in detail.

The area of investigation is part of a global debate about how to deal with climate change. No single solution on its own will deliver (see Chapter 4) and this thesis focuses on what can be achieved through new housing in the UK. Not only can solutions for new housing contribute towards solving the global problem of climate changes, many of the opportunities that can be applied to new housing also have implications worldwide (Chapter 4 and 5). Therefore before we focus on UK households (Chapter 4 onwards) the international context to the debate is reviewed (Chapter 2 and 3).

The key research questions are the following:

1. Is a sector-specific strategy of relying largely on technical solutions likely to achieve the required savings? And if not, could a lifestyle approach offer an alternative route to savings?
2. If so, how can this approach be applied to the design and set-up of new property developments in the UK?
3. Is there a case for enabling communities to build their own sustainable homes (eco-self-build communities)? If yes, how could it be set-up, what are the possible implications for climate change and sustainability, and is there customer demand for such an offer?

In order to answer these questions, this thesis will:

A. Provide the global context to climate change and review the role of the UK and its contribution to the problem by presenting data on UK energy use and carbon emissions, and how including international aircraft emissions and import and export data changes the picture.
B. Review whether or not current UK climate change policies affecting households are likely to sufficiently address the problem.
C. In order to identify additional opportunities, develop a calculation tool called the Climate Challenge Tool (CCT), which allows us to calculate the life-cycle emission and cost implications of various options available to property developers and community groups building their own homes.
D. Analyse alternative options for creating low carbon communities through housing development and investigate "eco-self-build communities" as a potential opportunity.
E. Through a stakeholder survey assess the perceived feasibility of a business opportunity that could enable eco self-build communities.
F. Discuss the potential for eco self-build communities to enable low carbon and sustainable lifestyles.

This EngD thesis aims to identify solutions for new housing in order to reduce carbon emissions. This is a multi-disciplinary area of enquiry, which includes elements of engineering, climate science, geography, social science, policy analysis, and business studies.

Research and policy in this area is undergoing rapid change. Major policy changes and new research up to the end of 2009 is included wherever possible. Changes after this date are incorporated where practical.

1.4 Thesis structure

The structure of the thesis is shown in an overview in Table 1.1 where each chapter is briefly summarised.

Table 1.1 Thesis Structure

Context: Identify the importance and the true challenge of achieving 80%+ CO_2e savings by 2050.	**Chapter 1:**	Introduction
	Chapter 2:	Climate change and the global context
	Chapter 3:	Discuss the UK contribution to climate change and the role of households. Identify emissions currently not counted.
Question 1: Is a strategy relying largely on technological solutions likely to achieve the required savings? Can lifestyle and behavioural change play a role?	**Chapter 4:**	Will the current policy framework deliver? Savings achieved from current policy in housing developments. Identify the role social change can play in delivering carbon savings.
	Chapter 5:	Methodology
Question 2: What can be achieved through creating low carbon and sustainable communities in new housing developments in the UK?	**Chapter 6:**	Assess the carbon that can be saved in new housing communities – create the Climate Challenge Tool and provide tool application results.
	Chapter 7:	Discuss how lifestyle changes can be enabled in new housing through fostering sustainable community formation.
Question 3: Is there a specific opportunity for eco-self-build communities in the UK? How would they need to be set-up to lead to sustainable low carbon lifestyles?	**Chapter 8:**	Feasibility study of Eco-self-build communities as a solution to climate change: Business case and environmental justification.
Conclusion	**Chapter 9:**	Summary, discussion and conclusion. Linkages to different parts of the research. Identify areas for further research and unanswered questions. Policy recommendations.

1.5 Use of language

Within this thesis the terms 'we' and 'our' refer to an inclusive approach, which aims to draw in the reader, encouraging them to share the approach so it becomes 'our' approach. The work behind it is of the author only.

1.6 Definitions

The thesis analyses the climate change impact of housing in the United Kingdom from a lifestyle perspective. The term "lifestyle approach" encompasses energy and emissions consumed in pursuit of a lifestyle, i.e. heating and electricity, personal travel, consumables, waste, etc. The approach considers both technological and behavioural dimensions. The term "lifestyle approach' and 'consumer based approach' are here used interchangeably.

The term *direct home energy use/consumption* as used in this thesis includes all energy from fossil fuels directly used in the home for heating, hot water, lighting and appliances. This is the energy delivered to a home and used by its household members. A *household* is here defined as a person or group of people occupying a single dwelling. Because of our chosen wider approach to study the emissions and energy consumption related to households in this thesis the term *household energy consumption* includes both direct home energy (for heating, hot water, lighting and appliances) and all indirect energy from consumables, waste, transport, building materials, etc., which are related to households. The term *household carbon emissions* refers to the carbon emissions resulting from this indirect and direct energy consumed by households. From Chapter 6 onwards the definition for *household energy consumption* and *household carbon emissions* is refined and narrowed down and from then on includes only those emission categories included in the Climate Challenge Tool. This is clearly described again in Chapter 6.

The terms "house builder" and "property developer" are here used interchangeable and both refer to property developers of UK housing developments. Similarly the terms "home" and "dwelling" are used interchangeable and refer to a housing unit such as a house or a flat.

Emissions are quantified as carbon dioxide equivalent emissions: CO_2e. In this thesis the term "carbon emissions" is used as a short version for carbon dioxide equivalent emissions (CO_2e). To calculate CO_2e emissions, greenhouse gases methane and nitrous oxide are converted into carbon equivalent emissions using their global warming potential (GWP) with 100-year time horizon, as adopted by the International Panel for Climate Change (IPCC, 2001), and the Kyoto Protocol (United Nations, 1998). This method was chosen for its transparency and ease of application as discussed by Skodvin and Fuglestvedt (1997) and Fuglestvedt et al. (2003), its accuracy (Fisher et al., 1990) and due in order to be coherent with the above named international organisations (IPCC and

United Nations) and UK national statistics. For sectors where their contribution is less than 1%, they are deemed negligible and have not been included. Due to its significance (Chapter 3) radiative forcing (in terms of the increased climate change impact of greenhouse gasses at altitude) from aviation emissions is also accounted for in the carbon dioxide equivalent calculations. Greenhouse gases other than carbon dioxide, methane and nitrous oxide are considered negligible and therefore were not considered. Carbon dioxide, methane and nitrous oxide together account for over 98% of total UK anthropogenic greenhouse gas emissions other than water vapour (DEFRA, 2001). Where CO_2e emission figures are quoted from other sources and their calculation differs from our method this is clearly indicated.

2. Climate change and the global context

2.1 Chapter overview

The present chapter provides the context for undertaking the thesis research. The importance of climate change as a global problem is established and current and expected future effects are summarised. The global disparities regarding the actors responsible for climate change are stated. Climate science, modelling and the processes used by the Intergovernmental Panel for Climate Change (IPCC) are critically reviewed in order to question the procedure of forecasting and shine a more accurate light on the expected climate change. We discuss various methodologies and evaluate their levels of efficacy in assessing and forecasting climate change. The scale of action recommended by various climate scientists and economists is also evaluated. The appropriate level of global CO_2e emission stabilisation is discussed and conclusions are reached regarding the level of CO_2e emission stabilisation recommended for the UK. The challenge required is exemplified through giving the current emissions resulting from a range of consumer activities.

2.2 Introduction

Many leading UK and international organisations such as Department for Environment, Food and Rural Affairs, (DEFRA, 2006a), the Sustainable Development Commission (SDC, 2006) and the World Economic Forum (WEF, 2006) have stated that climate change is the most important problem facing the world community today. Scientific experts and politicians have also voiced their concerns on the subject. Sir John Houghton, former head of the Met Office and former co-chair of the IPCC science working group, has called climate change a "*weapon of mass destruction*" (Houghton, 2003). The UK Government's chief scientist in 2000 to 2008, Sir David King, has gone further by saying that "*climate change is the most severe problem that we are facing today - more serious even than the threat of terrorism*" (King, 2004); "*it is a threat to civilisation*" (King, 2006).

The UK Government is increasingly adopting this view; for example, in 2004 in a speech on climate change, the then UK Prime Minister Tony Blair remarked, "*It is now that timely action can avert disaster. It is now that with foresight and will such action can be taken without disturbing the essence of our way of life, by adjusting behaviour not altering it entirely*" (Blair, 2004). The Stern Review (Stern, 2007), a government commissioned document on the economics of climate change was considered as a "*landmark review, which will strengthen the political will of governments around the world*" (Mandil, 2006).

Tony Blair commented that the Stern Review into climate change was the most important document about the future he had read since becoming Prime Minister (Blair, 2007).

The Stern Review (*op cit*) highlighted that the seriousness of the threat of climate change has not been matched by equally serious action to reduce the risk of additional anthropogenic changes in climate, either at a global or national level (Stern, 2007). The review states that climate change is the "*greatest market failure the world has ever seen*" (Stern, 2007), and further estimates that if the world fails to act, the cost of tackling the disruption to people and economies would cost at least five per cent of global GDP now and forever - and possibly as much as 20% or more if a wider range of impacts is taken into account. In contrast, at present the cost of action to halt and reverse climate change would cost just 1% of global GDP each year (Stern, 2007).

In order to ensure that environmental disaster is averted, governments need to take action immediately and make a rapid transition to a "low carbon economy". The term "low carbon economy" describes the concept of decoupling economic growth from the burning of fossil fuels, thereby achieving sustainable economic growth, while minimising the impact on climate and the dependence on consuming fossil fuels (DTI, 2003a). In the UK there is the political aspiration to become a low carbon economy: The 2003 Energy White Paper: Our Energy Future: Creating a Low Carbon Economy" focuses on this topic (DTI, 2003a).

2.3 Climate change: the science

Climate change refers to long-term fluctuations in temperature, precipitation, wind, and other elements of the Earth's climate. Natural processes such as solar-irradiance variations, changes in the planet's orbital parameters, as well as volcanic activity can produce fluctuations in climate. The climate system can also be influenced by changes in the concentration of gases in the atmosphere that affect the Earth's absorption of radiation (IPCC, 2001).

The planet naturally absorbs and reflects incoming solar radiation and emits longer wavelength terrestrial (thermal) radiation back into space. On average, the absorbed solar radiation is balanced by the outgoing terrestrial radiation emitted into space. Gases in the atmosphere, however, absorb a portion of this terrestrial radiation. The energy from this absorbed terrestrial radiation warms the Earth's surface and atmosphere, creating what is known as the "natural greenhouse effect." Without the natural heat-trapping properties of these atmospheric gases, the average surface temperature of the Earth would be about 33^{o}C lower (IPCC, 2001).

According to the UNFCCC, the definition of climate change is "*a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability, observed over comparable time periods*." (UN, 1992). Given the UNFCCC definition, in its Second

Assessment Report of the science of climate change, the IPCC concluded, "*Human activities are changing the atmospheric concentrations and distributions of greenhouse gases and aerosols. These changes can produce a radiative forcing by changing either the reflection or absorption of solar radiation, or the emission and absorption of terrestrial radiation*" (IPCC, 1996).

Building on that conclusion is the more recent IPCC Third Assessment Report, which asserts that concentrations of atmospheric greenhouse gases and their radiative forcing have continued to increase as a result of human activity (IPCC, 2001). The current positive radiative forcing tends to warm the Earth's surface (*op cit*). And finally, the fourth assessment report states, "*warming of the climate system is unequivocal*" (IPCC, 2007).

This is backed by various scientific reviews of the evidence that anthropogenic activity is causing climate change (Oreskes, 2004; Doran and Zimmerman, 2009; Anderegg et al, 2010), which conclude that published literature and expert surveys suggest striking agreement among climate scientists that anthropogenic is causing climate change. Anderegg et al (2010) for example used an extensive dataset of 1,372 climate researchers and their publication and citation data to show that 97–98% of the climate researchers most actively publishing in the field surveyed support the tenets of anthropogenic climate change outlined by the Intergovernmental Panel on Climate Change.

Since pre-industrial times (around 1750), carbon dioxide concentrations have increased by just over one–third, from 280 parts per million (ppm) to 380 ppm today, predominantly as a result of burning fossil fuels, deforestation, and other changes in land-use (IPCC, 2001) This has been accompanied by rising concentrations of other greenhouse gases, particularly methane and nitrous oxide.

In total, the warming effect due to all (Kyoto) greenhouse gases (carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sulphur hexafluoride) emitted through human activity is now equivalent to around 430 ppm of CO_2e and rising at around 2.3 ppm per year (Shine and Gohar, 2006). It is noteworthy that the current levels of greenhouse gases are higher now than at any time in the past 650,000 years (Siegenthaler et al., 2005). There is no precedent situation that gives empirical evidence on the effect of such high levels of greenhouse gasses upon climate. Figure 2.1 below illustrates the fluctuation of past and future CO_2 levels.

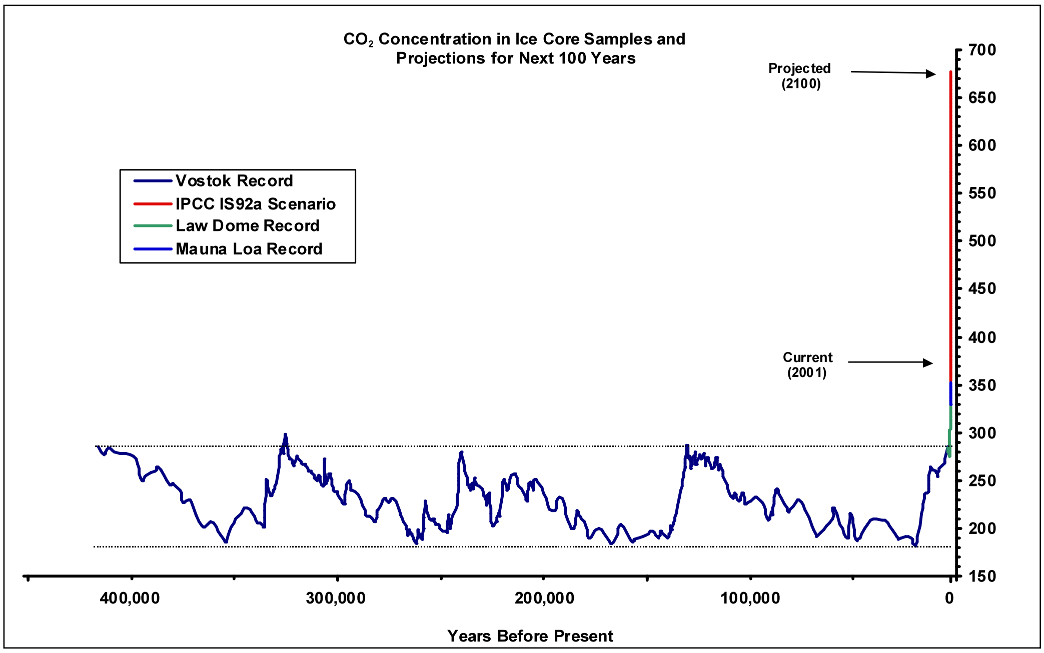


Figure 2.1 *CO_2 Concentration and Projections (Scaife, 2005)*

We can observe that global mean surface temperatures have increased over the past century. The Earth has warmed by 0.7C since around 1900 and, even if all burning of fossil fuel were stopped right now, temperatures would still rise by a further 0.6C as a result of the current greenhouse gas concentration (Stern, 2007). This delay between the time greenhouse gasses are emitted and when their full impact including temperature rise is felt is also referred to as the "*time lag*". Over the past 30 years global temperatures have risen rapidly and continuously at around 0.2C per decade, bringing the global mean temperature to what is probably at or near the warmest level reached in the current interglacial period, which began around 12,000 years ago. The ten warmest years on record have occurred since 1990 (Stern, 2007).

2.4 Climate change impacts

The amount of heating and cooling in the atmosphere is strongly influenced by several other positive and negative feedback mechanisms. Greater understanding of these complex feedback mechanisms is critical to predicting climate change and its impacts on nature and humanity (Bunyard, 2005). Various organisations around the world model global climate predictions using supercomputers and in the UK this is done by the Hadley Centre for Climate Change Prediction and Research (Hadley Centre, 2004). These organisations meet on a regular basis under the international umbrella organisation - the Intergovernmental Panel for Climate Change (IPCC) - in order to share and publish their research findings.

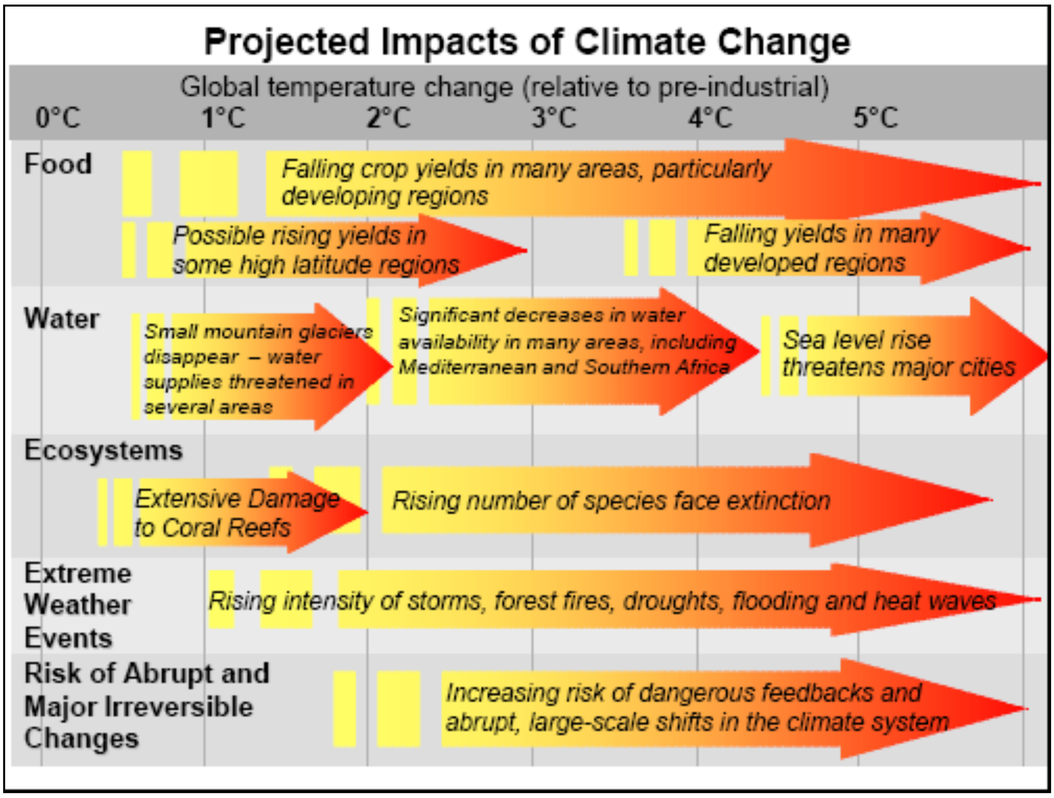


Figure 2.2 Projected Impacts of Climate Change (Stern, 2007)

Figure 2.2 provides a summary of the likely consequences climate scientist forecast at various levels of global average temperature increase. It depicts how climate change threatens the basic elements of life for people around the world – access to water, food, health, and use of land and the environment (Stern, 2007). A temperature rise of 2 to 3C may lead to melting glaciers with rising sea levels, increased flood risk, drought, the likely extinction of 15 to 40% of all species, and increasing Amazon forest destruction (Stern, 2007). Whilst initially there may be some positive impact of climate change such as rising yields in some high altitude regions, as warming increases negative impacts accelerate and positive impacts reduce (Figure 2.2, Stern, 2007).

In recent years greater evidence indicates that most of the warming over the last 50 years is attributable to human activities (IPCC, 2007). How the climate will change and what level of warming will be over the long-term are questions that cannot yet be answered with certainty (IPCC, 2007). Nevertheless, government institutions around the world continue to model global climate in an attempt to forecast the effects of increasing atmospheric greenhouse gas levels. According to Scaife (2005), the global climate and its interaction with oceanic, atmospheric and terrestrial processes are extremely complex and cannot be fully replicated by any of the existing supercomputers.

One uncertainty is the level of greenhouse gas emissions in the future. Using the same assumptions on emissions, different models yield significantly varying forecasts (IPCC, 2007). Figure 2.3 illustrates various forecasts (from the major respected climate change research organisations around the world) on global temperature change under the IPCC A2 emissions scenario of its third assessment report. Global mean temperature is expected to increase to between 1.4 and 5.8C by 2100 (Figure 2.3). The wide disparity of modelling outcomes clearly demonstrates the lack of consensus regarding climate change forecasts.

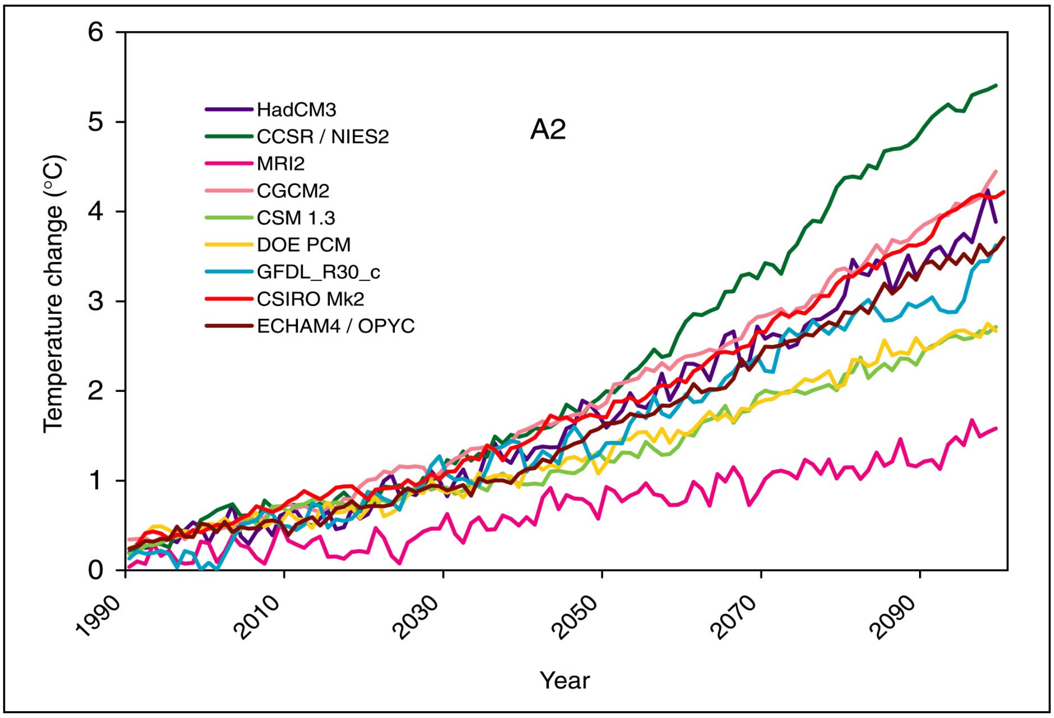


Figure 2.3 Global Temperature change under the IPCC A2 scenario (IPCC, 2007)

When interpreting the forecasts we can observe that the disparities in outcome of different models are caused by the different representations of physical processes in each model (Scaife, 2005). Representation of cloud physics is one important source of difference, as is the spatial resolution of the models (*op cit*). The range of processes included in each model can also lead to disparities in outcome; some institutions ignore processes that others include. Particular examples might be vegetation feedbacks or the proper interaction between sea ice and wind (Scaife, 2005; Cox et al., 2000; Friedlingstein et al., 2006; Plattner et al., 2008).

In order to get clearer about the dangers climate change may pose and what stabilisation target is appropriate it is useful to understand the level of accuracy the models may achieve. When we inquire into the accuracy of climate models it is insightful to investigate whether most of the forecasting models over- or under-estimate changes in climate and temperature. For the purposes of the thesis we suggest that it is important to understand the processes used by the IPCC and the models used in IPCC climate forecasts. For example, the General Circulation Models used by IPCC researchers are complex 3D numerical models of the physics of the atmosphere and ocean (Bunyard, 2005, Cox et al, 2000). However, they generally exclude the feedback between climate and biosphere using static vegetation distributions and CO_2 concentrations from simple carbon cycle models that do not address climate change (Bunyard, 2005, Cox et al, 2000; Friedlingstein et al, 2006).

The limitation of the Circulation Models seems especially stark when we consider climate-carbon cycle interactions. The ocean and land contain significantly more carbon than the atmosphere (about 50 times and 3 times as much, respectively), and they exchange very large fluxes of carbon dioxide with the atmosphere. For example, the annual net land-atmosphere exchange of CO_2 is about 8 times larger than the annual CO_2 emissions from human activities (Scaife, 2005). This means that slight imbalances between the "in" and "out" land-atmosphere and ocean-atmosphere CO_2 (fluctuations/fluxes) can yield significant changes in CO_2 concentration in the atmosphere, and could therefore significantly impact global warming (*op cit*). Furthermore, observations of atmospheric CO_2 inform researchers that the natural carbon cycle responds strongly to natural climate variations such as those associated with El Nino events or volcanic eruptions (Bunyard, 2005).

To exclude the feedback between climate and biosphere may therefore be seen as a significant oversimplification when we analyse the model outputs. However, the IPCC appear to have downplayed the climate-biosphere interaction in their summary for policy makers (IPCC, 2001). The IPCC consists of an international group of approximately 600 climate researchers who are largely required to reach consensus and facts are only included where consensus is reached (Leggett, 2000). This means that uncertainties may often not be included. Due to the fact that, beyond a certain global temperature rise, possibly 2C to 3C higher than preindustrial temperatures, positive feedback processes are likely to outweigh negative ones (Cox et al., 2000; Friedlingstein et al., 2006; Plattner et al., 2008; Sitch et al., 2008), it is likely that most uncertainties not considered in the models will accelerate climate change after a certain warming threshold is reached. As a result the IPCC model outcomes and forecasts are therefore likely to make climate change seem less problematic than it actually is. Despite the fact that this is acknowledged in the detailed technical report, the summary for policy makers omitted this statement and model outputs are presented as their best estimate for global temperature rise (IPCC, 2007). The combined effect of high climate sensitivity and carbon cycle feedbacks is only beginning to be explored, but first indications are that this could lead to far higher temperature increases than currently anticipated (Stern, 2007).

Peter Cox, at the Institute of Ecology and Hydrology, Richard Betts and their colleagues at the UK Meteorological Office (Hadley Centre) are advancing climate models that attempt to incorporate relevant living processes, as expressed through biomass production and decay in different ecosystems (Bunyard, 2005). They witnessed a dramatic effect in their model, in that the climate-carbon cycle feedback was projected to increase atmospheric CO_2 from around 730ppm to nearly 980ppm by 2100. As a result, the global mean warming by 2100 for this particular "middle of the road" emission scenario is 5.5C rather than 4C, with a mean land warming of 8C rather than 5.5C. The reason for this large positive climate-carbon cycle feedback is related to the failure of the land carbon sink, with a weak current day land sink for CO_2 turning into a strong source of CO_2 by around 2050, as global warming accelerates decomposition of the soil and causes "die-back" of the Amazon rainforest (Cox et al, 2000). Figure 2.4 shows some of the areas where greatest warming will occur according to their models. The figure visually displays the locally varying temperature increases by 2100 under the A1B (Business as usual) Scenario, indicating that the temperature rise on land will be greater than at sea and shows that some of the areas already suffering from drought will be severely affected.

Since the study of Cox et al. in 2000, other models have attempted to simulate the 'climate–carbon cycle feedback' (e.g. Friedlingstein et al., 2006; Plattner et al., 2008; Sitch et al., 2008). These studies all find that, at a certain point, the carbon sink switches to a carbon source. While the magnitude of this feedback varies considerably between studies, some indicate a very large effect with major implications for projecting climate change impacts, or indeed, for calculating the level of anthropogenic emissions consistent with achieving stabilisation targets.

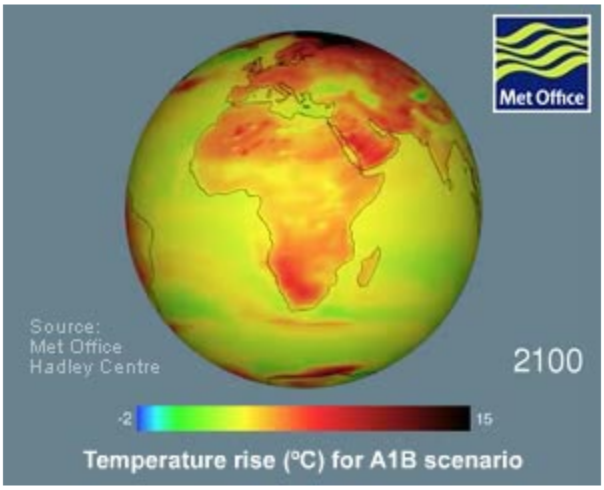


Figure 2.4 Modelled temperature rise for A1B Scenario (Hadley Centre, 2007)

From this analysis we observe that there is a great deal of uncertainty in the effect of rises in anthropogenic greenhouse gas emissions concentration, and that the effect may be worse in the future than we think because of key feedback systems that are not fully understood and are missing from many models. As a result, in order to avoid unforeseeable consequences, emissions may need to be cut further than current policy proposes.

2.5 What emission reduction target is reasonable?

As explained in section 2.4, current scientific understanding cannot accurately forecast the consequences of various levels of emissions on the global climate. Therefore, on the basis of current scientific understanding and uncertainty, a stabilisation level must be decided. The stabilisation levels are described here and a judgement is taken as to which levels are appropriate for the world and the UK.

2.5.1 Avoiding dangerous climate change

Climate scientists advocate an approach of avoiding dangerous climate change (Hadley Centre, 2004; Friedlingstein et al, 2006; Cox et al, 2000). By avoiding dangerous climate change they mean to stabilise greenhouse gas concentrations in the atmosphere at such a level to prevent dangerous anthropogenic interference with the climate system, interference where consequences may be unforeseeable and drastic such as “runaway climate change” (Hadley Centre, 2004; Friedlingstein et al, 2006; Cox et al, 2000).

The term “runaway climate change” describes the following future development scenario: currently, the higher CO_2 levels in the atmosphere are accelerating photosynthesis, leading to a higher absorption rate for carbon dioxide – taking up nearly half of the anthropogenically emitted CO_2, thereby reducing climate change impact. However, as the climate warms, carbon sinks are likely to turn into sources and an overall positive feedback from the natural system may occur (Cox et al, 2000; Friedlingstein et al., 2006; Plattner et al., 2008; Sitch et al., 2008). Global warming may then accelerate, even if at this point no further fossil fuels are burned (Grass et al., 2003; Friedlingstein et al., 2006; Cox et al, 2000; Plattner et al., 2006; Sitch et al., 2008). Pfeiffer (2004) and Lovelock (2006) claim that such a scenario could render the planet or a large proportion of it uninhabitable. This “dangerous” point, where overall carbon sink turns into an accelerating source, is also known as the “tipping point” and the resulting possible climatic condition is called “runaway climate change.”

Climate scientists do not know when the tipping point will be reached. Lovelock (2006) claims that it is already too late. The Climate Task Force (members from business, government, environmental and civic organisations mainly from the US, UK and Australia) and the German Advisory Council for Global Change (WBGU) have put forward the “tolerable window approach”, which sets a global target for maximum warming at a level where dangerous anthropogenic interference with the climate system would be prevented (WGBU, 1997; WGBU, 2003). Based on a normative setting of non-tolerable climate change conditions, the WBGU set the upper limit for total global mean temperature change to 2C and 0.2C per decade. This maximum threshold beyond which climate change would be considered dangerous was adopted by the UNFCCC (Grass et al., 2003; UN, 1992).

The international conference held in 2005: "Avoiding Dangerous Climate Change: A Scientific Symposium on Stabilisation of Greenhouse Gases" aimed to define the link between atmospheric greenhouse gas concentration, and the 2C ceiling on global warming (Hadley Centre, 2005). The conference concluded that, at the level of 550 ppm CO_2e, it was likely that 2C would be exceeded, based on the projections of more recent climate models. Stabilising greenhouse gas concentrations at 450 ppm CO_2e would only result in a 50% likelihood of limiting global warming to 2C, and that it would be necessary to achieve stabilisation below 400 ppm CO_2e to relatively ensure that 2C is not exceeded (Met Office, 2005). This is in line with den Elzen and Meinhausen (2006), who estimate that avoiding dangerous climate change would mean stabilising CO_2 levels at approximately 400 to 420ppm CO_2e. Since then Hansen et al (2008) has called for a 350 ppm CO_2 target (equivalent to approximately 400ppm CO_2e) based on long term climate data stating that the climate is more sensitive than previously thought,

Since the current levels of CO_2e are 430ppm CO_2e rising at 2ppm per year, Lovelock (2006) could be right, it may already be too late. However, the optimistic view is that society may still have a chance if radical changes are made in the near future, and any reduction in emissions now and in the future will reduce the impact of climate change upon humanity and the planet and will also lower the risk of dangerous climate change.

2.5.2 A view from economists

A number of leading economists (Stern, 2007, Nordhaus, 2007, Mendelson, 2007 and Weitzmann, 2007) have analysed the economics of climate change by assessing the scale of actions required and the optimal CO_2e atmospheric stabilisation levels. The question underlying such an analysis is:

> Would it be cheaper to reduce emissions now, or pay at some later point in the future in order to adapt to a changing climate?

If the answer is yes, then the second question Stern (2007) and Nordhaus (2007) have asked is:

> What level of CO_2e stabilisation levels would be optimal in terms of balancing the needs of future generations with those of the current generation? (Figure 2.5).

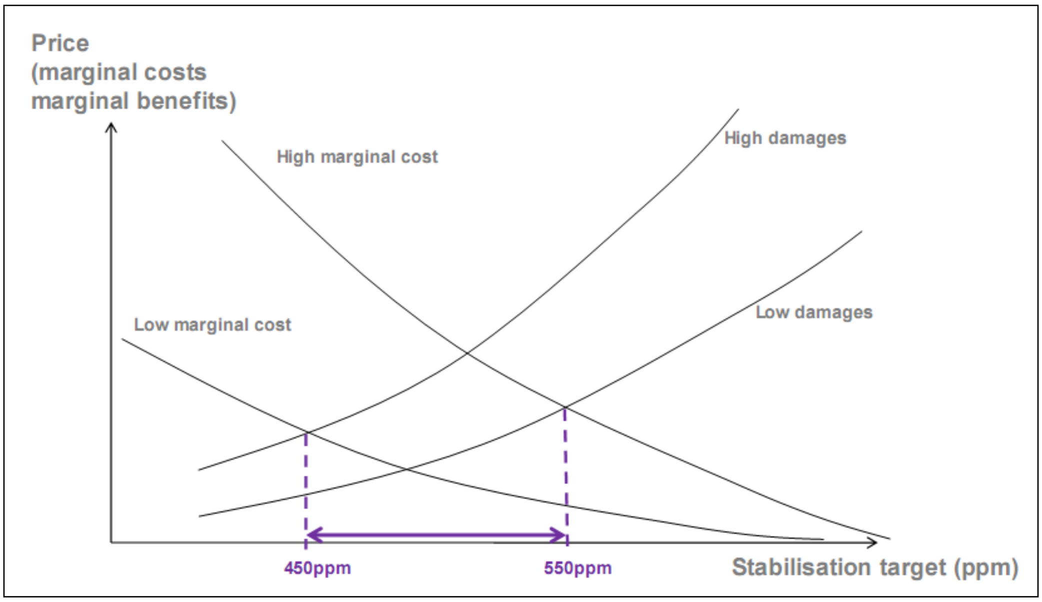


Figure 2.5 Finding the optimal stabilisation point, cost benefit analysis (Hepburn, 2008 adapted from Stern, 2007)

Stern (2007) and Nordhaus (2007) reach dramatically divergent conclusions due to the discount rates they apply, about how much to spend today on goods available to future generations. In "The economics of climate change," (Stern, 2007) Stern's 0.1% discount rate places a relatively high value on the wellbeing of future generations. Nordhaus' 6% discount rate places far less value than Stern on the wellbeing of future generations (Nordhaus, 2007). Stern recommends a greenhouse gas stabilisation level of 550ppm CO_2e, suggesting immediate action and at least a 25% CO_2e reduction target by 2050 over 1990s levels, and an 80% reduction in the long-term (Stern, 2007). Nordhaus meanwhile concludes that action is not urgent (Nordhaus, 2007).

Such an analysis requires the evaluation of the costs of mitigation and adaptation based on climate change science and the cost of CO_2e emission reduction measures. It further requires deciding whether or not future costs should be discounted and if so, by how much. As a result, such an analysis is underlined by a judgement on three major uncertainties:

1. The limited understanding of climate change, including temperature, weather and sea level changes as well as biological feedbacks.
2. The limited understanding of economic and technological development in the future.
3. The appropriate discount rate.

Economists generally value goods received in the future less highly than goods received today. If the discount rate is 6% a year, goods worth £1 million today are only worth about £2500 in 100 years time.

Nordhaus (2007) and other economists such as Mendelson (2007) and Weitzmann (2007), argue for a discount rate is in line with assumptions consistent with today's marketplace real interest and savings rates. It may, however, be argued that using a discount rate based on current interest and savings rates is highly inappropriate when assessing the economics of climate change. Policy on climate change means choosing among paths with very different growth patterns for a whole collection of capital goods, including those relating to natural endowments; thus it seems patently wrong to examine current rates.

The summary in "The Economics of Climate Change" (Stern, 2007) states: "*the review estimates that if we don't act, the overall costs and risks of climate change will be equivalent to losing at least 5% of global GDP each year, now and forever. If a wide range of risks and impacts are taken into account, the damage could rise to 20% of GDP or more*" (Stern, 2007).

Indeed, if these conclusions are anywhere near true, then choosing a negative discount rate may be more appropriate, as such a recession would mean that today's money is worth less than tomorrow's. This would be the case unless economic growth at a similar or higher GDP could counterbalance the loss in GDP described above which is resulting from climate change, which is unprecedented and therefore seems extremely unlikely.

This line of argument permits us to conclude that even Stern's recommendation of a 0.1% discount rate over the long-term to stabilise at least 550ppm may not be enough (translating to at least 25% CO_2e reduction target by 2050 over 1990s levels, and 80% reduction in the long-term). In addition, 550ppm stabilisation levels have been calculated by Murphy et al. (2004) and Wigeley and Raper (2001) and Meinshausen et al. (2006), which nevertheless to lead to a 48%-96% possibility to exceed the 2^{o}C warming limit, i.e. beyond which climate change would be considered 'dangerous' in the context of UNFCCC, Article 2 (UN, 1992).

As a footnote to this discussion a recent study (House et al. 2008) analysed Stern's proposal using latest climate models, which include the biological feedbacks. This study (House et al., 2008) models the implication of two stabilisation targets on CO_2e concentrations and temperature change up to 2300. The models include the interactions with the biological feedbacks. Eleven global climate models in the IPCC (2007) assessment were coupled with carbon cycle models to study the magnitude of the climate–carbon cycle feedbacks in the Coupled Climate–Carbon Cycle Model Intercomparison Project (C4MIP) (Friedlingstein et al., 2006). The models incorporated a range of climate sensitivities, a key uncertainty in climate modelling (Knutti et al., 2008). The models represent a range of CO_2 fertilisation strengths and other differences in carbon cycle processes reflecting uncertainty in the state of knowledge. The study (Knutti et al., 2008) concludes that Stern's proposed cuts remain an effective near-term target on the way to achieving stabilisation of CO_2 concentrations. Based on the evidence presented here for the purpose of this thesis, the greenhouse gas emission reduction targets of Stern have been adopted as most appropriate: a global emission reduction of at least 25% CO_2e below 2006 levels by 2050 over 1990 levels, and an 80% reduction over the long-term. Stern recommends that the high polluting countries (industrialised economies) reduce their emissions by 60 to 80% by 2050 with developing countries taking significant action too (Stern, 2007).

On the face of the evidence presented it seems that based on the economists' literature and most recent and long term climate models which include the biological feedbacks, the greenhouse gas emission reduction target for the developed world should be at least 60% to 80% from 1990 levels by 2050. With this a precautionary approach is chosen in an attempt to minimise the risk of unforeseeable consequences, which could be a threat to maintaining current livelihoods.

2.5.3 What do global targets mean for the UK?

Before discussing the level of CO_2 emission reductions required in the UK, as a contribution to the global target, let us discuss in greater detail the current international emissions scenario. Figure 2.6 shows per capita carbon dioxide emissions for a selection of countries. Each Briton emits about two and a half times the global average carbon emissions from fossil fuels (Marland et al, 2003). If we look at emissions from a historical perspective, the imbalance is even greater. For example, the UK has been responsible for 15% of the cumulative global emissions since 1750, but is responsible for only 2% of current emissions (Marland et al., 2003; Figure 2.6). Note that these statistics do not include carbon emissions from land use changes or from unsustainable use of forests, which also vary considerably by country. Neither are they adjusted to include the full global warming effect of carbon emissions from air travel, or the net effect of imported and exported goods, or greenhouse gasses other than CO_2.

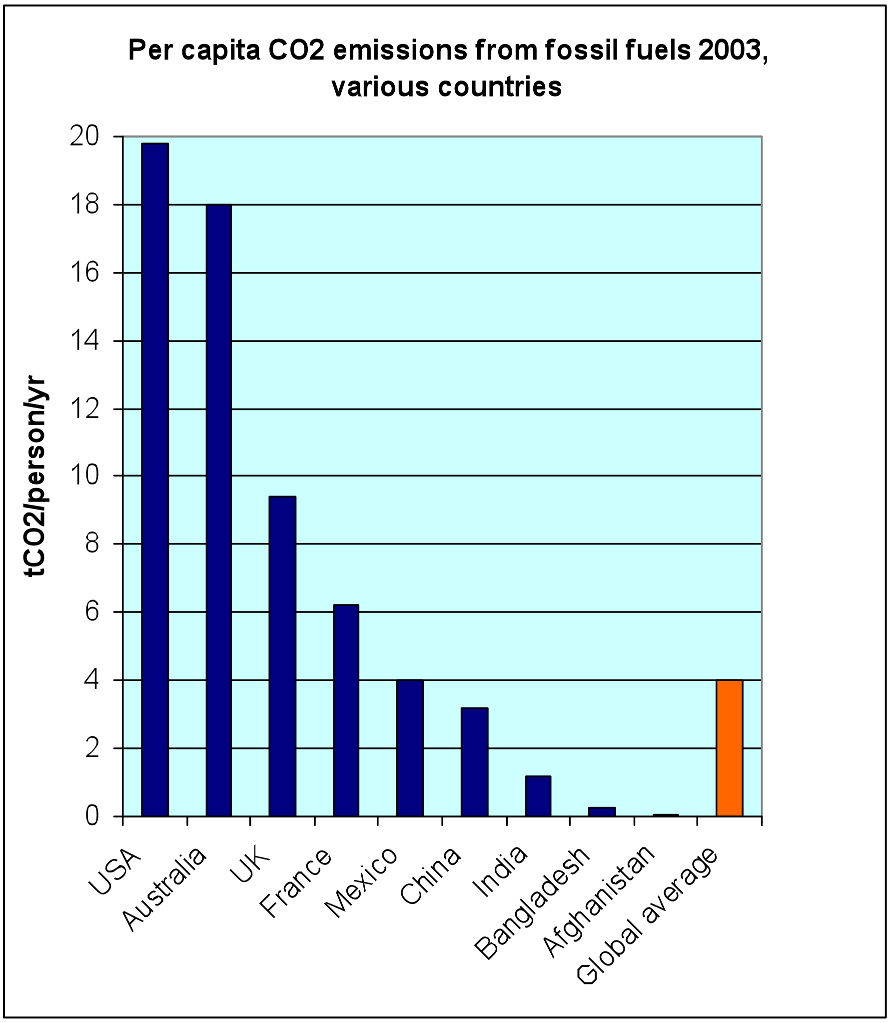


Figure 2.6 Per Capita CO_2 *emissions from fossil fuels for various countries (Data Source: Marland et al, 2003)*

Equity issues are central to the international climate change debate for both principled and practical reasons (IEA, 2002). Inter-generational equity is at the heart of policy on reducing greenhouse gas emissions because emissions have accumulated in the atmosphere for hundreds of years, and today's emissions place a burden on future generations. Moreover, it is widely agreed that without an approach that demonstrates equity and transparency in its application, there can be no realistic prospect of public acceptance or political agreement to introduce the measures needed (IEA, 2002).

However, more than a dozen different equity rules are defined in the literature (IPCC, 2001); they range from egalitarian rules (equal rights are assigned on a per capita basis), to sovereignty rules (allocation is given to governments), to ability to pay rules (varies according to national wellbeing), to polluter pays (abatement costs are distributed in proportion to emission levels), to utilitarian rules (the goal is the greatest happiness for the greatest number), to procedural equity (related to how a decision is made) (IEA, 2002).

In order to address the pertinent questions: who is allowed to suffer how much climate change damage, and who gets to emit how much carbon, it is crucial to select the appropriate definition of equity. Three different interpretations of equity - equal rights, ability to pay and polluter pays - would result in different allocations of responsibility for achieving carbon reductions. Indeed, 'ability to pay' and 'polluter pays' would require a regular re-allocation of responsibility over time as countries' wealth and emissions changed. 'Polluter pays' could encompass either current or cumulative historic emissions - the choice of which would make a huge difference to the UK which as noted above has been responsible for 15% of cumulative global emissions, but is responsible for just over 2% of current emissions (Marland et al, 2003). This thesis concurs with the argument of the Global Commons Institute (Meyer, 2000) that the equal rights interpretation of equity is the most morally defensible option and the only one likely to lead to a successful global carbon control agreement. This solution allows for the largest number of people to benefit, and allows capping emissions at a scientifically sanctioned limit. Therefore, the definition of equity used in this thesis is that of equal rights to use the atmosphere, meaning equal rights to emit where every world citizen has a free carbon budget limited by a global greenhouse gas stabilisation limit. From this equity perspective and current scientific understanding an emission reduction target of approximately 80% for the UK therefore seems appropriate (derived from Beinhocker et al., 2008).

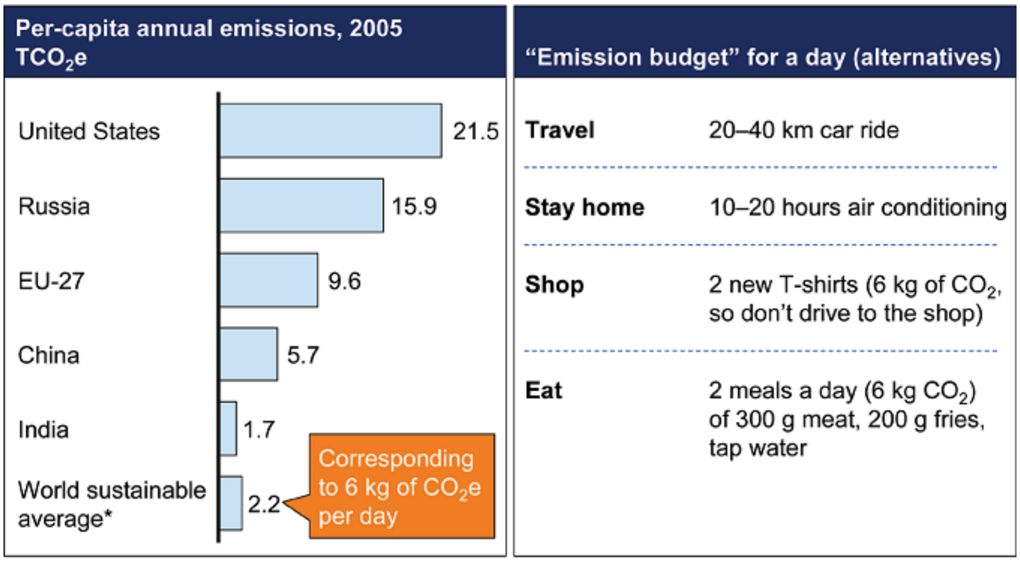
2.5.4 Conclusion

The Stern target is the minimum target to be adopted until 2050 with a long-term view for further reduction. Assuming a world population of 9 billion people by 2050, on an equitable basis this would translate to a per capita emission allowance of 2.2 tonnes of CO_2e per person per year. Current per capita emissions in the UK, according to the UNFCCC accounting methodology, are 11 tonnes of CO_2e per person per year. Therefore, an 80% CO_2e emissions reduction lies in the right order of magnitude. As will be shown in Chapter 3, UK emissions would be much greater using a consumer-based emissions accounting method which includes emissions from international aviation and shipping; therefore, the 80% target based on UNFCCC accounting, as challenging as it seems, may be too small. A long-term strategy is required to work out how the UK can reduce its emissions by this level over the next 40 years and immediate action is required.

2.6 What does the target mean in practice?

To illustrate how much needs to be done Beinhocker et al. (2008) produced a diagram (Figure 2.7) to exemplify emissions from different lifestyle categories and how much they typically contribute to the 2.2 t CO_2e per world citizen per year target based on current levels of carbon productivity. Carbon productivity is a measure of the amount of carbon emissions produced to provide a good or service.

Figure 2.7 shows daily activities that could be included in the per person emissions budget for 2050 at current carbon productivity at 2008 technology levels. It gives alternatives of example activities, which would emit the 6 kg of CO_2e average emission budget per world citizen per day (or 2.2 tCO_2e per year) by 2050. These include a car ride of 20 to 40 km, two meals of 300g meat and 200g fries, or two new T-shirts. Please note that these are alternatives each of which reach the 6 kg CO_2e/day limit. Increased carbon productivity reduces the emissions necessary to produce the same good or service. Figure 2.7 however exemplifies the magnitude of the challenge and necessary changes in carbon productivity we are facing if current consumption patterns are to continue.



* Based on 20 Gt/year sustainable emissions and future population of 9 billion people.

Figure 2.7 Current per capita emissions and world sustainable average emissions for 2050 to meet stabilisation levels of 550 ppm CO_2e (Beinhocker et al., 2008)

2.7 Summary and overall conclusions

Climate change may be the greatest challenge facing humanity today. It is a global problem and to solve it each country has to take responsibility for doing their bit. Currently there are significant disparities in the contributions of the world's countries to the problem. Wealthier countries generally have a much greater per capita emissions footprint than poorer countries. When taking cumulative historic emissions into account, this contribution gap is even wider (Section 2.5.3).

Within the scientific community there is general agreement that the threshold for dangerous climate change (likely to be around the 550ppm CO_2e concentration mark or lower) needs to be avoided. Beyond this threshold, tipping points may be exceeded and the planet may continue warming – even if no further anthropogenic greenhouse gases are emitted (Bunyard, 2005). The IPCC climate change models are likely to underestimate the scale of the problem as they largely ignore (or are unable to model) biological feedback loops (IPCC, 2007). This means that as warming increases the problem could be greater than currently anticipated by the IPCC.

Amongst economists there is less consensus about what emission stabilisation target is reasonable. Stern (2007) supports a 550ppm target (by 2050) whereas others such as Nordhaus (2007) and Mendelson (2007) feel that action is less urgent. In line with the principle of setting the 550ppm target of avoiding serious consequences of climate change it seems sensible to follow the more cautious of the economists: Stern (2007) that we need to act now. This argument is supported by a view that the discount rate chosen by Nordhaus (2007) and Mendelson (2007) which is consistent with today's marketplace real interest and savings rates poorly covers a decision making process for a very long term issue such as climate change.

To reach the target significant changes to carbon productivity and/or consumption changes are required to be made by UK citizens, as currently a 20 to 40 km car journey *or* two meals (300g meat and 200g fries) per day would already reach the average emission quota of a world citizen in 2050, under a 550ppm emission scenario.

Whilst there are still scientific uncertainties about the impacts of climate change and increased anthropogenic greenhouse gas emissions, this thesis supports and builds on a precautionary principle of avoiding unforeseeable consequences, which could threaten people's welfare in the long term.

3. The UK's Contribution to Climate Change

3.1 Chapter Overview

In Chapter 2 the global problem of climate change has been discussed and emission reduction targets for the world and the UK were suggested. It became clear that climate change is a global issue and that to solve it each country needs to take responsibility for keeping their emissions within a sustainable limit. Building on Chapter 2, this Chapter focuses in on the UK and its contribution and current and past response to climate change.

The aims of this chapter are to present key facts about UK energy use and carbon emissions, to analyse recent trends of these, and to describe current UK energy policy and to consider whether this is likely to provide an adequate response to the challenge of climate change. The official statistics on national carbon emissions are reviewed. It is evaluated how successful energy policy has been over the past 40 years in delivering energy savings. Further analysis evaluates the role of international air travel, import and export of products and services, and deforestation in contributing to the carbon equivalent footprint the UK is responsible for, and how including these sources would change the Government reported carbon trend and footprint. The role that energy policy has played and could play in the future shaping of CO_2 emissions is debated.

3.2 UK Energy Use and Carbon Emissions

In the last hundred years energy consumption has increased vastly compared with previous times. For example Smil (2000) estimated that in the year 2000 the world had at its disposal about 25 times more useful commercial energy than it did in 1900. McNeill (2000) suggests that more energy has probably been deployed since 1900 than in all human history before 1900. The very large majority of this energy has come from the burning of fossil fuels. Developed countries in particular depend on these fuels for their energy needs. The UK is typical in this respect, deriving 90% of its total energy requirement from fossil fuels (DTI 2003b). This may be why drastic curtailment of fossil fuel use to prevent further climate change presents such a challenge.

UK CO_2 emissions in 2004 were 556 Mt CO_2 (DEFRA, 2007a), accounting for about 2% of the world's total emissions (Markland et al, 2003). As explained in Chapter 2, each UK citizen is currently responsible for about two and a half times the global average per capita emissions (Markland et al, 2003). In 2004, carbon dioxide accounted for 76 per cent of all greenhouse gas emissions in the UK (ONS, 2008a). Industry, followed by transport and then the domestic sector account for most of this with each of the three contributing to just over a quarter of all carbon dioxide emissions or 29%, 28% and 26%

respectively (DEFRA, 2007a). In the UK, carbon dioxide emissions actually fell by 19 per cent between 1971 and 2003. However, the fall in emissions was not uniform across all sectors. From 1970 - 2003, emissions from industry fell by 48 per cent and domestic emissions by 24 per cent, whilst emissions from transport rose by 89 per cent in the same period (AEA Energy and Environment, 2008).

3.3 UK carbon emissions targets

The UK Government has two carbon emission reduction targets for 2010. These are:

1. The Kyoto target of 12.5% reduction of the basket of six greenhouse gases (carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, sulphur hexafluoride) from 1990 levels by 2010;
2. The UK government's domestic target of a 20% reduction of carbon dioxide emissions from 1990 to 2010.

Contrary to experience in most countries, UK carbon emissions have fallen since 1990 and the UK is on track for meeting its Kyoto emission reduction target (AEA Energy and Environment, 2008) (Figure 3.1). Until 2007 the UK was not on track for achieving its own governmental target of reducing CO_2 emissions by 20% by 2010 compared to 1990 (Figure 3.1). Emissions between 1999 and 2006 did not fall (DECC, 2010a) (Figure, 3.1). However, since then emissions have fallen significantly in 2007, 2008 and 2009 and the UK now appears to be on track for achieving its national 2010 target (DECC, 2010a). Pielke (2009) explains that there is a link between economic growth and emissions. He shows that emission reductions resulting from a downturn in economic activity are not normally linked to a decarbonisation of the economy and that emissions return to previous levels once the economy picks up. At this point in time, insufficient data is available to determine the precise reasons for the recent significant UK carbon equivalent emissions reductions, However it seems likely that the reduction since 2007 is largely a result of the economic downturn rather than a result of climate change policy.

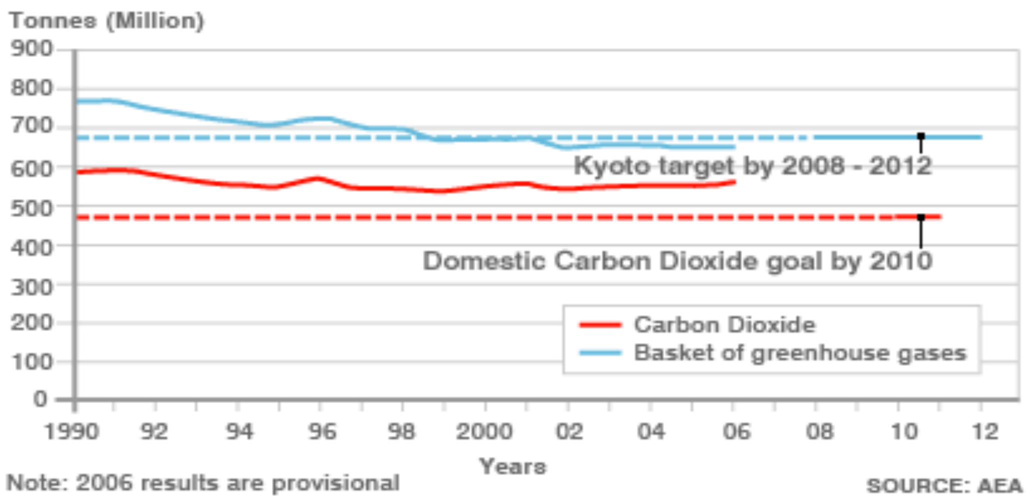


Figure 3.1 UK CO_2 Emissions, 1990 -2006 (AEA Energy and Environment, 2008)

It should be noted that there are two different methods for estimating carbon emissions. Prior to 1990 the UK used the UNECE method (UNECE/EMEP, 2001). From 1990 onwards the IPCC method (Houghton et al., 1996) was adopted. With both methods national emissions have to be calculated rather than measured, and this is because measuring is not possible as carbon emissions are produced from millions of fixed and mobile sources (e.g. homes, vehicles, factories, appliances). UNECE excludes land use change and also international shipping, but includes domestic aviation emissions below 1000 meters to cover take-off and landing cycles (DETR, 2001a). The IPCC methodology includes land use change and all emissions from domestic (national) aviation and shipping, but excludes international marine and aviation bunker fuels. For these reasons national totals reported under the two definitions are slightly different with IPCC emissions 3 to 4% higher than UNECE emissions. Neither methodology includes emissions from international aviation. The implications of this are discussed in more detail in Section 3.6. All CO_2 emissions in this section are given on the IPCC basis unless otherwise stated.

The Climate Change Act 2008 established a new approach to managing and responding to climate change in the UK. The Act created a legally binding target to reduce the UK's emissions of greenhouse gases (GHGs) to at least 80% below 1990 levels by 2050. In order to reduce their levels and meet the 80% target, carbon budgets place legally binding ceilings on the level of allowed UK emissions over five year periods. A 'carbon budget' is a cap on the total quantity of greenhouse gas emissions emitted in the UK (net of credits purchased within the EU Emissions Trading Scheme or other international schemes, e.g. the Clean Development Mechanism over a specified time).(OPSI, 2008). The Climate Change Act (OPSI, 2008) in 2008 specified that the target refers to all six Kyoto gases mentioned above emitted within the national boundaries of the UK minus emissions offset abroad through trading schemes. The IPCC accounting method is used. As a result, emissions offset through land-use change are deducted (OPSI, 2008). Consumables produced abroad and consumed in the UK are not included whereas goods produced in the UK and consumed elsewhere are included (OPSI, 2008). Furthermore emissions from international travel and freight by UK residents and freight of goods consumed in the UK are also not included. These are also not considered in the UK domestic and Kyoto target for 2010 (OPSI, 2008; AEA Energy and Environment, 2008). The first three carbon budgets run from 2008-2012, 2013-2017 and 2018-2022. Government will legislate the level of the fourth carbon budget, 2023-2027 by June 30th 2011.

In the Fourth Budget Report (Committee on Climate Change, 2010) the Government's independent advisory body on climate change, the Committee on Climate Change, recommended that the Government accept the principle that emissions from international aviation and shipping be included in future carbon budgets, and that they intend to make specific recommendations on how to adjust the second, third and fourth budgets to allow inclusion following our review of international shipping emissions, to be published in autumn 2011. In the meantime, the recommended Domestic Action and Global Offer budgets for the fourth period (2023-27) do not include international aviation and shipping, but have been set so as to be compatible with meeting a 2050 total 80% emissions reduction target with international aviation and shipping included (Committee on Climate Change, 2010).

3.4 Recent Carbon Trends

To understand fully how successful UK climate change policy has been in cutting carbon emissions and the extent to which further emission reductions may be achievable, it is worthwhile examining what has driven emission reductions in the past, and whether this trend can continue in the future. It is also worthwhile investigating whether the current way UK carbon emissions are measured truly reflect the trend in emissions for which the UK is responsible.

A move to less carbon intensive fuels has meant that UK carbon emissions have fallen whilst energy use has risen (DEFRA, 2007b). In 1970 carbon emissions were at 678 $MtCO_2$ (UNECE method), in 1990 they were at 605 $MtCO_2$ and in 2004 they were at 556 $MtCO_2$ –that is around a fifth lower than in 1970. Since 1970 total UK primary energy use has switched away from coal and oil, while the share of gas and primary electricity has increased (*op cit*). Due to changes in fuel used for electricity generation and due to more efficient conversion of heat energy to electrical energy, the carbon intensity of electricity has fallen by 60% since 1970, and by 36% since 1990 and stood at 0.53 kg CO_2/kWh in 2005 (DEFRA, 2007b). Carbon intensity is the amount of carbon (by weight) emitted per unit of energy consumed. For electricity the carbon intensity varies as a result of the fuels used, distribution and transmission losses and the efficiency of the power stations producing electricity. The amount in Table 3.1 shows the average carbon intensity in the UK between 2001 and 2005 for domestic sector energy sources. As can be seen natural gas has a lower carbon intensity than coal or oil. Electricity has the greatest carbon intensity, about twice as high as that of the fossil fuels, explained by the fact that it takes about two units of energy of fossil fuels to produce one unit of energy of electricity. In the UK most electricity is currently produced through the burning of fossil fuels (DEFRA, 2007b).

Table 3.1 Carbon intensity of the UK's major energy sources for the domestic sector (DEFRA, 2007b)

Source of direct home energy consumption (heating and power)	**Carbon intensity kg CO_2/kWh**
Coal	0.258
Oil	0.281

Natural gas	0.206
UK grid electricity (average 2001 to 2005)	0.523

The switch towards lower carbon fuels has largely come about for reasons unrelated to climate change (Eichhammer et al, 2001). It has been driven by factors including comparative fuel prices, increasing availability of natural gas, government policy (e.g. liberalisation and privatisation of the gas and electricity markets, reduced support for the coal industry), expansion of nuclear power and changing fossil fuel power station technologies (e.g. efficient combined cycle gas turbines) (Eichhammer et al, 2001). Of the reduction in carbon dioxide emissions between 1990 and 1999, Eichhammer et al. (2001) estimated that just 40% was a result of climate change policy, with the remainder being due to the special circumstances mentioned above. These circumstances made gas (the fossil fuel with the lowest carbon intensity) a more attractive fuel, particularly to electricity producers (Eichhammer et al., 2001).

In addition there as been a continuing trend towards expansion of the service sector and a reduction in agricultural and industrial activity with more and more industrial products and agricultural produce being imported (SEI, 2008). As the service sector is low in energy consumption in relation to its economic activity, and the agricultural and industry sector high in comparison it is possible that whilst the emissions accounted for in Government statistics are reducing, from a global perspective emissions are simply being exported abroad.

Given that most of the changes in the past which reduced UK emissions are either not replicable or may simply be as a result of transferring production to other countries, this raises the question, whether past trends in emission reductions can continue without radical technical advances or shifts in UK policy, and whether the trends in the Government statistics truly reflect the changing contribution of the UK to global climate change.

Before looking in more detail in Chapter 4 into current UK climate change policy and its ability to deliver it is important to understand fully the emissions contribution and the trend of those emissions for which the UK is responsible, but which are currently not counted in the Government statistics. These include emissions from international transport of UK passengers and goods consumed in the UK and emissions for goods services consumed in the UK by UK-residents, but produced abroad (OPSI, 2008). They exclude emissions from good and services produced in the UK and consumed elsewhere (OPSI, 2008). As a result it was decided to look into this issue in further detail. This is presented in the following sections 3.5 to 3.7. We define the term *UK responsible emissions* and interchangeably *consumer based UK emissions* as those emissions for which UK residents are responsible for: this includes emissions related to all good and services consumed by UK residents and transport activity related to those good and services as well as emissions from passenger transport by UK residents.

3.5 Emissions abroad caused by UK consumption

Current national emission figures could be underestimating the UK's true global warming impact, if the UK exports some of its carbon emissions by importing more energy-intensive goods than it exports. There is economic evidence that the UK is likely to be an emissions exporter because the value of imported goods is far greater than that of exported goods (ONS, 2010). The UK has long imported more goods than it exports; the last surplus on trade in goods was in 1982 (ONS, 2006). Energy use in the industrial sector has fallen considerably since 1970, whilst that used in the service sector has risen (ONS, 2008a).

Three recent studies (Druckman et al, 2007, Helm at al, 2007 and SEI, 2008) report an increase in UK CO_2 emissions when calculated according to this consumption perspective, i.e. when imports and exports are accounted for in the emissions calculations. Druckman et al. (2007) estimate a rise of 7.7% in total UK consumer CO_2 emissions between 1990 and 2004, suggesting that the UK is increasingly exporting its more carbon intensive industries. Druckman et al (2007) stress the severe policy implications in conjunction with any emission reduction target, if these industries were accounted for in the UK's carbon target. The second study (Helm et al., 2007) indicates a rise of 19% in total UK greenhouse gas emissions between 1990 and 2003 when consumption based estimations are used. The differing results of the two studies result largely from the inclusion of greenhouse gasses other than CO_2 in Helm et al. (2007). One of the major imported goods in the UK consists of food-products, which contribute significantly to methane and nitrous oxide emissions and to a lesser extend to CO_2. Helm et al. (2007) however does not specify which greenhouse gases were included in the analysis and presents some results for CO_2 only and some results for greenhouse gases.

The third and most thorough study was commissioned by DEFRA and completed by the Stockholm Environment Institute (SEI, 2008). The study considers the production efficiency and emissions intensities of a number of trading countries and world regions in an international trade model, which is globally closed and sectorally disaggregated thereby providing greater accuracy. The study uses full multi-regional input-output framework, including embedded emissions in the UK's trade balance. SEI (2008) found a significant rise in consumer based CO_2 emissions over the period studied: 1992 until 2004. The total UK CO_2 responsible footprint in 2004 was calculated to be 762.4 Mt of CO_2, 206 Mt CO_2 or 37% greater that the UNFCCC reported emissions. They estimate that consumer CO_2 has risen by 18% between 1992 and 2004 (see Figure 3.2).

The most likely reasons for the differences between Helm et al. (2007) and Druckman et al. (2007) and the SEI study (2008) are the use of domestic carbon intensities (single region instead of multi-region assumption[1]) by Helm et al. (2007) and Druckman et al (2007) and the use of out-of-date input output tables by Druckman et al. (2007) (SEI, 2008).

Figure 3.2 shows the development of CO_2 emissions since 1992 comparing UK responsible emissions (as calculated by SEI, 2008) and UK based (UNFCCC reported) emissions, and shows that rather than falling the CO_2 emissions for which UK residents are responsible have been rising, with the most significant rise in recent years driven mostly by increased amounts of imported goods. Because the role of aviation and shipping is reviewed in the next section 3.6, the carbon footprint from aviation and shipping calculated by SEI has here not been included in Figure 3.2.

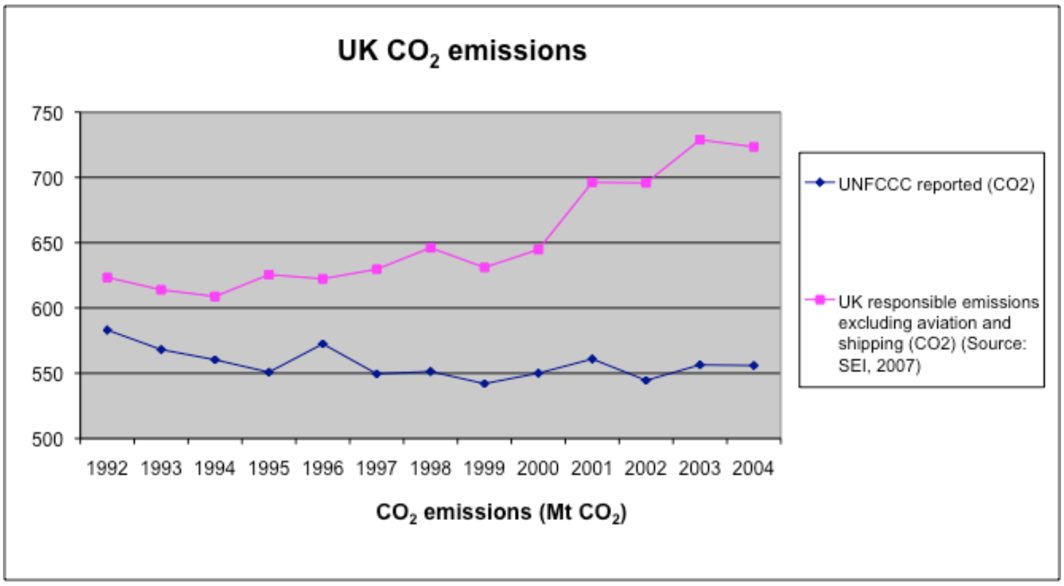


Figure 3.2 Development of UK CO_2 emissions from 1992 until 2004: a comparison of UNFCCC counted and UK responsible emissions compared (Source of data: SEI, 2008)

3.6 Emissions from international aviation and shipping

International aviation is one of the UK's fastest growing sources of carbon emissions (Bows and Anderson, 2007). However international aviation and shipping are not included in the reporting guidelines (OPSI, 2008). Of those studies which have attempted to include international aviation in their estimates of national carbon emissions (SEI, 2008; Helm et al, 2007; Druckman et al, 2007), none has taken into account the increased global warming impact of greenhouse gases emitted at altitude as suggested by IPCC (1999).

[1] *i.e. single region intensities mean that the same emission intensities are assumed for each product regardless where it has been produced. The SEI uses multi region assumption meaning its uses locally specific carbon intensity factors for groups of countries.*

As well as CO_2, the combustion of kerosene also emits:

1. Nitric oxide and nitrogen dioxide, together termed NOx (which forms ozone, a greenhouse gas, at altitude)
2. Particulates (soot and sulphate particles)
3. Water vapour (which leads to the formation of contrails and cirrus clouds at altitude) and
4. Other compounds including sulphur oxides, carbon monoxide, hydrocarbons and radicals such as hydroxyl.

The combined effect of these emissions is to add significantly to the climate change impacts of aviation, over and above those caused by its CO_2 emissions alone. Whilst current scientific understanding is insufficient to accurately quantify the accurate impact, the IPCC (1999) has made an attempt to quantify the overall impact based on a best estimate using current scientific understanding. The IPCC calculated that by 1992 the total radiative forcing caused by aviation was approximately 2.7 times that of the forcing caused by its CO_2 emission alone (IPCC, 1999). The figure varies with altitude and other aspects, however 2.7 multiplier is the best estimate for an overall global average increase in climate change impact from aviation (IPCC, 1999). In contrast to most emission sources on the ground where CO_2 tends to be the greatest contributor the non-CO_2 warming effect from aviation is highly significant. Therefore, using CO_2 emissions, as an indicator for comparative global warming impact of aviation with other emission sources, is misleading, yet conventionally done in government or EU statistics (COMM, 2005; DTI, 2003).

The 2004 White Paper on “The Future of Transport” (DfT, 2004) states that if aviation was defined as all international departures plus all domestic services from the UK then the aviation sector currently contributes about 5.5% of the UK CO_2 emissions. This gives a figure for total CO_2 emissions from international departures and domestic services of 32 Million Tonnes of CO_2. They assume that the UK share of international air travel can be accounted for by just looking at departures, meaning that they allocate 50% of all international air travel to and from the UK to be UK responsible travel. However, Cairns and Newson (2006) state that 67% of all aviation trips to and from the UK are made by UK residents or freight consumed in the UK. They did not calculate the resulting carbon footprint from this assumption. When applying 67% to departures and arrivals the UK contribution to aviation emissions increases the total emissions from UK freight and passenger transport to 41 Million tones of CO_2 for which UK residents are responsible. Using this 2.7 multiplier (IPCC, 1999) the UK’s CO_2e from aviation emissions would then increase to 111 Million Tonnes of CO_2e.

Emissions from international shipping to the UK are estimated at 19.4 Million tonnes of CO_2e (ONS, 2008a). It should be noted that ONS do not give the basis on which this figure is calculated. Taking this figure as read, this would bring the total of CO_2

equivalent emissions from international shipping and air transport to 130.4 Million Tonnes of CO_2e in the year 2004. We also calculate a continuous increase between 1992 and 2004 of 60% over those years. Not only does this show that the climate change contributions from aviation and shipping highly significant, they are also forecast to increase further in the future. The UK's Aviation White Paper (DFT, 2003) sets a policy framework that supports a major expansion in aviation activity, which would enable air passenger movements to increase from about 200 million in 2003 to about 470 million in 2030 (DFT, 2003; Cairns and Newson, 2006), and thus may more than double the already significant climate change impact of aviation for which UK residents are responsible. This is in direct contradiction to the Government's climate change policy (Anderson et al, 2006) and the resulting emissions increase (CO_2e) is likely to be greater than all savings from UK climate changes policies by 2020 forecasted in the 2007 Energy White Paper (DTI, 2007). This conclusion is based on the following assumptions: The White Paper forecasts the carbon emission reductions between 2007 and 2020 resulting for climate change policy to lie in the range of 51 to 121 $MtCO_2e$ (DTI, 2007; Chapter 4). Assuming that the forecasted increased passenger movement is in direct proportion to the increased climate change impact of the UK responsible aviation sector it is here calculated that by 2030 the aviation sector would contribute an additional 150 $MtCO_2e$. It is of course likely that technological change, flight behaviour, plane occupancy, average flight distances and other factors, which effect climate change impact from aviation will change with time and that these changes could both increase or decrease the resulting climate change impact of the aviation sector calculated here. However this calculation provides and indication of the magnitude of the aviation sector in comparison to all improvements resulting from climate change policy listed in the 2007 White Paper (DTI, 2007).

3.7 Emissions from other greenhouse gases

In the UK 76% of emissions in terms of global warming potential result from CO_2 emissions, whereas globally other greenhouse gases play a greater role and CO_2 only contributes 60% (ONS, 2008a; Stern, 2007). This is largely due to the fact that other greenhouse gases (the most important ones being methane and nitrous oxide) result from goods that are largely imported into the UK. Such imports include dairy and beef production, fertilizer production and deforestation (driven by the production of biofuels and animal feed) (Stern, 2007). Because of this when studying emissions from a consumer based perspective the proportional contribution to overall country emissions is likely to change and to show an increase in the UK's contribution to global climate change not shown in previous studies (SEI, 2007; Helm et al., 2008 and Druckmann et al., 2008).

For the purpose of this study the main greenhouse gases methane and nitrous oxide were included in the accounting. Together with CO_2 they contribute to over 98% of global warming potential of all current greenhouse gas emissions (DEFRA, 2001). DEFRA

(2006) figures were used for UK based methane and nitrous emissions. Imported methane and nitrous oxide emissions were calculated using pro rata assumptions for their emissions contribution to each sector depending on the total carbon footprint of each sector and the relative global contribution of other greenhouse gases in each sector as specified by Stern (2007). Methane and nitrous oxide global warming potential were converted into CO_2 equivalents using the DEFRA (2008) recommended global warming potential figures of 21 tCO_2e for 1 tonne of methane and 310 tCO_2e for one tonne of nitrous oxide (DEFRA, 2008a). ONS Environmental Accounts (ONS, 2007) provide information on the contribution of methane, nitrous oxide and CO_2 for the different sectors. The Stockholm Environment Institute study (SEI, 2007) provided data on the net consumer based CO_2 emissions for each sector, after allowing for trade. It was assumed that the relative contribution of methane:NO_x:CO_2 within each sector was the same in other countries as per the UK. Thus, the contribution per sector of nitrous oxide and methane was estimated by multiplying the SEI estimates of CO_2 emissions by the relevant ratios of NH_4:CO_2 and NO_x:CO_2 derived from the UK data (ONS, 2007). Aviation was excluded as the effect of other greenhouse gases from this sector have already been addressed (Section 3.6).

For imported food, the total contribution the UK has upon international deforestation (caused by growing products to be consumed in the UK) was estimated and the resulting contribution to emissions calculated. This was done using global data on deforestation from Stern (2007), assuming that the UK contribution of land use change and agriculture to climate change is proportional to the global contribution, based on the ratio of UK food imports to global food production. Including methane and nitrous oxide emissions both from within the UK (excluding exported goods) and from imported goods, the total CO_2e increase in the UK responsible carbon equivalent footprint was calculated to amount to 206 tCO_2e for the year 2004. This figure was compared with research by Desai (2005) and is broadly in line.

3.8 Discussion

3.8.1 Total CO_2e footprint for which the UK is responsible

Based on the calculations described in sections 3.5-3.7 above, total UK consumer-based CO_2e emissions (including CO_2, CH_4, NO_x, and the effect of radiative forcing) was estimated to amount to 1057 $MtCO_2e$ for the year 2004 (which is the most recent year for which data was available). This compares to reported emissions of 556 $MtCO_2$ and 732 $MtCO_2e$ (ONS, 2008a).

Figure 3.3 illustrates the emission trend of carbon equivalent emissions based on SEI's analysis of UK responsible CO_2 emissions, our analysis of the aviation and shipping sector and our analysis of the additional contribution from methane and nitrous oxide from within the UK and from abroad. Figure 3.3 clearly displays that once we include the effect of radiative forcing and other greenhouse gasses the gap between reported emissions and what we define as UK responsible emissions widens even further than calculated by SEI (2007) (Figure 3.2) and we record a rise in UK responsible CO_2e emissions of 38% between 1992 and 2004.

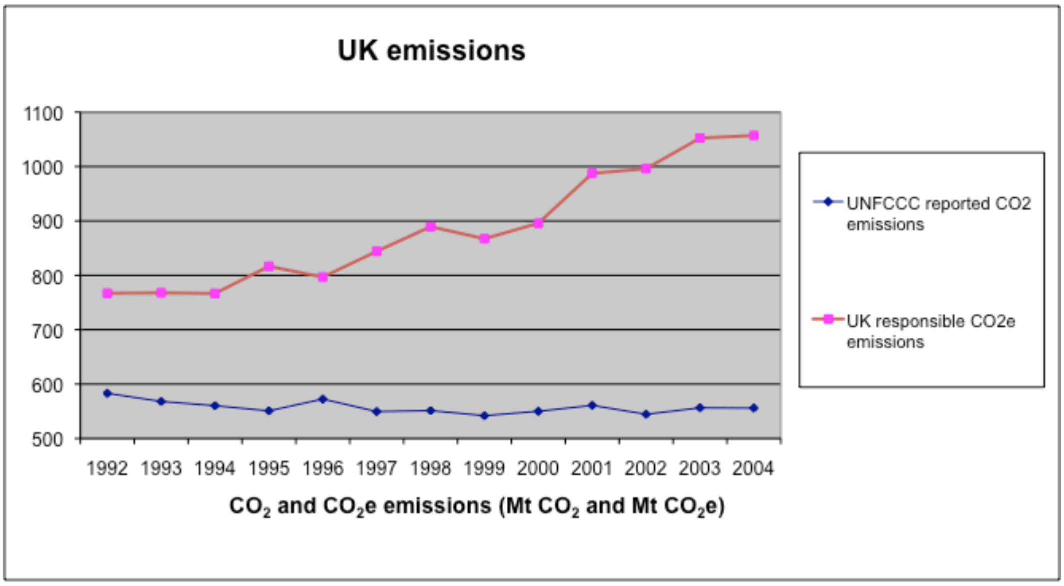


Figure 3.3 *Development of UK emissions from 1992 until 2004: a comparison of UNFCCC counted carbon dioxide emissions and UK responsible emissions carbon equivalent emissions compared (Source of data: SEI, 2008; and calculations from section 3.6 and 3.7)*

Figure 3.4 shows the contribution from the various sectors using the consumer based accounting method described above. This compares to Figure 3.5, which shows the contributions when using government reported (IPCC method) CO_2 statistics only.

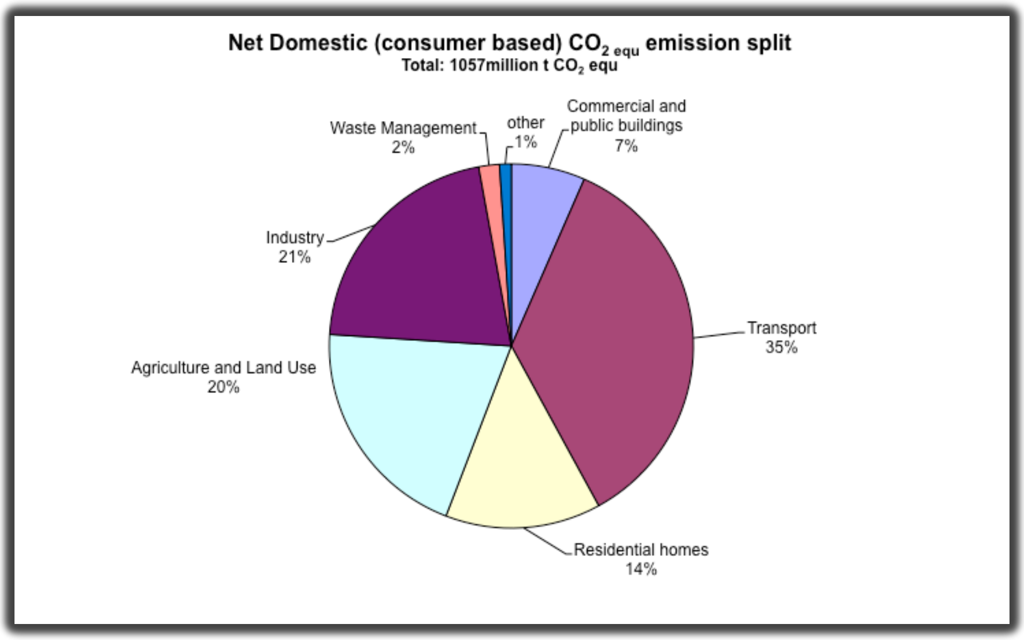


Figure 3.4 Net Domestic CO_2e emissions split calculated using consumer-based accounting method

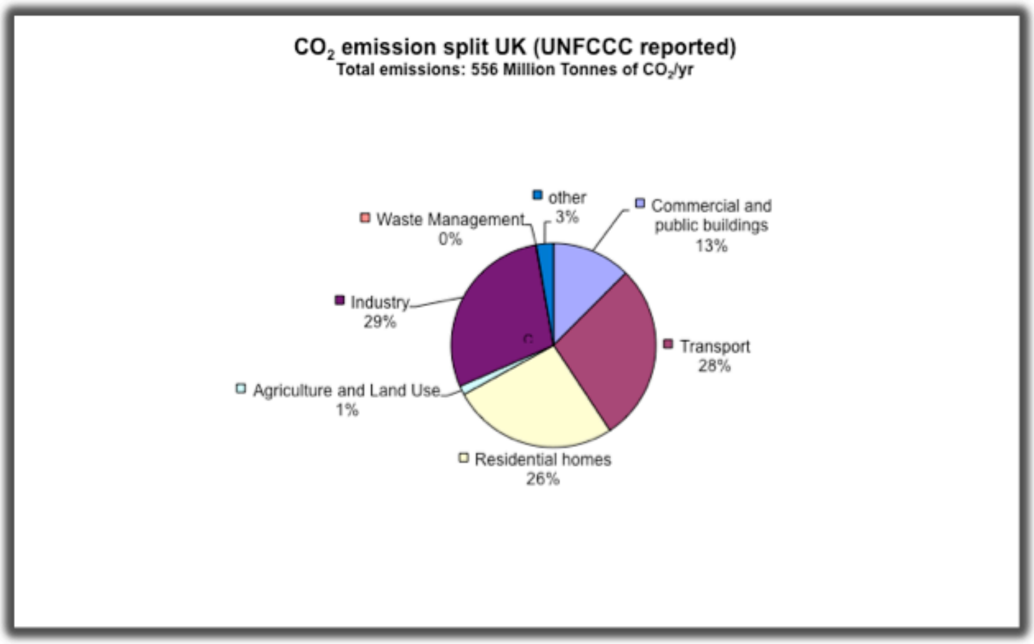


Figure 3.5 Sectoral emission contribution calculated using the IPCC method

Employing our accounting method the transport sector is the largest sector (Figure 3.3). This splits in to: 32% aviation, 25% shipping, 14% road haulage, 27% personal road transport and 2% other transport (including public transport).

The proportion of emissions arising from the domestic sector changes significantly when including emissions from abroad, methane and nitrous oxide emissions and the uplift from radiative forcing. Using the Government's accounting method and counting CO_2 only, residential homes (domestic sector energy) contributed 26% to overall emissions in 2004; whereas including the other contributors mentioned to calculate CO_2e, the total contribution from the domestic sector reduces to 14% and the role of agriculture and transport as emission sources increases drastically from 1% to 20% and 28% to 35% respectively (Figure 3.3 and Figure 3.4).

3.8.2 Critique

The consumer-based carbon accounting method developed here is a way to estimate the true climate change contribution that UK residents are responsible for. The reasons that this has not been done in the past is due to scientific uncertainties and lack of available data. To understand the validity of these results we therefore here set out to discuss its main uncertainties. The present work therefore set out to quantify the error margins associated with the results.

The uncertainties here investigated are:

1. The scientific uncertainty around the 2.7 radiative forcing factor.
2. Emission change if the assumption about the percentage of air travel to and from the UK that is the responsibility of UK residents was changed from 67% to only 50%.
3. Uncertainty around the net emissions abroad cause by UK consumption.

<u>Radiative Forcing Factor</u>

The IPCC (1999) Special Report on Aviation and the Global Atmosphere calculated that by 1992 the total radiative forcing caused by aviation was between two and four times that of the forcing caused by its CO_2 emission alone. 2.7 was the best estimate for the overall effect. Due to the scientific uncertainty surrounding the 2.7 factor radiative forcing, this is often not included in CO_2e calculations. As this factor has significant climate change implications, rather than ignoring it, we decided to include it, however with recognition of the underlying uncertainties. Were we to use the IPCC's (1999) minimum radiative forcing factor of 2 or the maximum factor of 4 to total UK consumer based CO_2e emission footprint would change to 1046 Million t of CO_2e or 1117 Million t of CO_2e respectively, a margin of error of – 2.9% and +5.6% on the overall UK CO_2e emission footprint.

<u>Air travel contribution by UK residents</u>

Whilst in our study we have considered the air travel contribution of UK residents based on the percentage of UK passengers occupying aircrafts that leave and arrive in the UK, other studies have defined the aircraft emission contribution of the UK as 50% of the emissions from planes leaving and arriving to the UK. If we had used this assumption then the total consumer based UK emission footprint would reduce by 40 million tonnes of CO_2e or 3.8% of total UK consumer based emissions.

Emissions abroad on behalf of the UK

The SEI and the University of Sydney (2008) conducted a sensitivity analysis of the SEI (2008) study. They used a comprehensive Monte-Carlo analysis of the uncertainties on their global multi-regional input-output model. Uncertainty functions were determined for all input variables to the model. The IO tables' uncertainties were estimated from constraint uncertainties and matrix balancing, 5000 simulation runs were carried out to determine the multiplier uncertainties and the error propagation for embedded emissions was calculated. For aggregated results of CO_2 consumer emissions the error margin was shown to be between 3.3% and 5.5%. Therefore the estimate of total embedded emissions can be regarded as robust and reliable. On an individual sector level however these errors are generally higher.

Overall error margin and conclusion from the uncertainty analysis

Assuming that all uncertainties investigated here would work in our favour, i.e. we account for only 50% of air transport entering and leaving the UK, we assume that radiative forcing is only a factor 2, and emissions abroad are 5.5% lower than estimated in the SEI study (2008) then the total UK consumer based CO_2e footprint would amount to 942 Million t of CO_2e, a 10.9% drop of the calculated overall figure of 1057 Million t of CO_2e.

Assuming all uncertainties would prove to be more emission-intensive than estimated, i.e. aviation radiative forcing amounts to 4 and emissions abroad are 5.5% greater than estimated by SEI (2008) then the total consumer based UK emissions would amount to 1170 Million t of CO_2e, a 10.7% increase over the calculated figure.

Taking into account the uncertainties discussed above the overall error margin may lie in the region of ±11%. The results suggest that the calculations developed here may be robust enough to provide a reliable indication of CO_2e emission trends for the UK economic activity, including trade to and from the UK and international passenger travel. There are other assumptions not tested which may make error margins bigger or smaller, but the current findings provide a sufficient basis for the research presented in the following chapters.

3.9 Conclusion

A consumer-based accounting method, which more accurately accounts for all emissions caused by UK residents' shows that emissions are unlikely to have fallen for the UK, but may have risen steadily and significantly.

Over the past 20 or more years the UK exports of low carbon services such as financial services have increased and imports of carbon intensive goods (industrial and agricultural produce) have increased too. Not only has this lead to an overall increase of worldwide transport emissions, it has also meant that the UK has increasingly "exported" its emissions abroad.

The analysis of Section 3.3 shows that:

1. Whilst the UK's total reported carbon emissions have fallen since 1990, much of the reduction was fortuitous rather than as a result of deliberate shifts to a low carbon economy.
2. When including international aviation and shipping and the effect of radiative forcing in aviation emissions the total carbon emissions increase by 130 tonnes of CO_2e.
3. When excluding emissions from goods exported consumed outside the UK and including emissions from good consumed in the UK but produced abroad the UK emission footprint increases by a further 168 million t CO_2.
4. When including methane and nitrous oxide the UK consumer based emission footprint increased by a further 206 tonnes of CO_2e.
5. The total consumer based CO_2e emission calculated here amounts to 1057 Mt CO_2e, only slightly more than half of this (556 Mt CO_2 in 2006) is reported to the UN and currently used to measure success against national climate change targets.

In sum the total calculated consumer based CO_2e footprint of 1057 Mt CO_2e (with an approximate margin of error of ±11%, based on testing the major assumptions) compares to the UK Government reported figure for UK CO_2 emissions of 556 Mt CO_2 and 732 Mt CO_2e[2] against which the 80% 2050 reduction target is set (OPSI, 2010).

The evidence indicates that rather than falling, those emissions that the UK is responsible for have risen significantly by nearly 40% between 1992 and 2004. In the future without significant change, they are likely to increase further, to a large extent driven by a forecasted increase in international air travel, and growth in imports of agricultural and industrial products.

The important role of imports and international air travel (including freight) makes it vital that these emissions are included in greenhouse gas reduction targets. Secondly the important role that UK consumers play in causing emissions internationally should also be recognized in the UK's climate change policy and overall emissions reduction targets. Without this, Government may continue to show a decreasing trend in UK carbon emissions whilst in actual fact all that has happened is that the country is increasingly "exporting" its emissions rather than reducing them.

It has been shown that the UK is a significant contributor to the global climate crisis, and that the contribution UK residents are responsible for is far greater than reflected in

[2] *Using the Government's calculation method without accounting for radiative forcing and emissions outside the UK national boundaries.*

Government statistics. Past climate change policy has played a limited role in reducing emissions. However it is now necessary to look in detail into current policy in Chapter 4 in order to judge whether the presently planned response of the UK Government provides a sufficient response to the challenge. Because this Chapter (3) has revealed that one of the problem in solving climate change may be the lack of each country and each citizen and to accept full responsibility for their global contribution to climate change, it now makes sense in Chapter 4 to focus in on those policies, which directly affect the UK consumers, their choices and the resulting emissions implications.

We have chosen to focus on households, which are individuals or groups of people occupying a dwelling. This grouping of consumers seems to make sense in this context because many choices that individuals can make which influence their emission footprint are decisions made by a whole household. Some example are: the purchase of a car, food choices, recycling behaviour, energy efficiency and renewable energy measures of their homes, eco-product purchases for their homes (appliances, eco-paint, furniture, etc). In addition many climate change policies target households rather than individual. Further detail of this is provided in the next chapter.

4. Can the Carbon Target be achieved? – Existing Policy versus a Lifestyle Approach

4.1 Chapter overview

The aim of this chapter is to review whether UK energy policy affecting household emissions is sufficient to provide an adequate response to the threat of climate change. Energy policy is reviewed with a focus on demand-side measures affecting household emissions from direct home energy consumption, carbon embodied in building materials, carbon embodied in goods consumed by households, transport emissions related to household location and infrastructure links, and carbon emissions savings from waste treatment options.

The likelihood of achieving the 2050 80% carbon emission reduction target as well as the intermediate 2020 26% target (over 1990 levels) under the current policy framework is reviewed. The role of technical solutions and lifestyle change in current policy is reviewed, and the potential for a greater use of behaviour as contributors to the targets is discussed.

A lifestyle focussed approach includes behaviour change and lifestyle choices significantly affect carbon emissions. Opportunities which such a lifestyle focussed approach presents are discussed. We find that new housing design influences lifestyle and conclude that the extent to which this can be drawn upon to foster carbon emission reduction warrants further investigation.

4.2 UK Energy policy

Energy policy encompasses both supply and demand side issues. National supply side issues include the future of nuclear energy, support for the local coal industry, renewable energy policy, oil exploration and liberalisation and regulation of the privatised energy industries. Demand side issues include energy efficiency, building integrated renewables and combined heat and power schemes. Some factors, which determine patterns of energy use, such as international energy prices, are difficult for national governments to influence and thus exceed the traditional boundaries of energy policy. This thesis primarily focuses on demand side energy policy.

UK policy regarding carbon emissions from the built environment is part of a wide ranging and complex legislative and policy matrix, which extends across Government. The Department of Trade and Industry (DTI) provides input regarding energy generation: the Department for Environment, Food and Rural Affairs (DEFRA) considers the environment; and the Department of Communities and Local Government (DCLG) concentrates on the buildings themselves. The Department for Business, Innovation and

Skills aims to drive economic growth and a competitive environment for businesses. In 2008 a new Government Department was created specifically focussed on energy and climate change, the Department of Energy and Climate Change (DECC), which brings together energy policy and climate change mitigation policy.

The Programme for Climate Change (DEFRA, 2006a) sets an overall framework for moving towards carbon emission reductions in all sectors, including the Built Environment. An Office of Climate Change has been established to coordinate work towards climate change reductions across government departments (DECC, 2009b). The Climate Change Act 2008 makes the UK the first country in the world to have a legally binding long-term framework to cut carbon emissions (DEFRA, 2010). The Climate Change Act (OPSI, 2008) commits the UK to reducing carbon emissions to 80% of their 1990 levels by 2050, setting staged carbon reduction targets, backed by a transparent reporting system overseen by an independent advisory committee. The Act includes other greenhouse gases also to be reduced by the same amount, but does not consider emissions outside national boundaries, nor does it account for the radiative forcing effect of aviation emissions at altitude.

Similarly, the 2007 Energy White Paper (DTI, 2007) sets wide ranging policy aims to achieve carbon reductions in the built environment from energy efficiency measures and cleaner energy sources. These aims are further expanded on in the Energy Efficiency Action Plan 2007 (DEFRA, 2007c) published in compliance with Directive 2006/32/EC (Energy End Use Efficiency).

4.2.1 Conflicting goals of UK energy policy

In 2003 the UK government published the Energy White Paper *Our energy future: creating a low carbon economy,* which represented at that time, the first major energy policy document for many years (DTI, 2003). This White Paper identified four goals for energy policy:

1. To put ourselves on a path to cutting UK carbon dioxide emissions - the main contributor to global warming - by some 60% by about 2050, rising to 80% in the 2007 Energy White Paper, with real progress by 2020;
2. To maintain the reliability of energy supplies;
3. To promote competitive markets in the UK and beyond, helping to raise the rate of sustainable economic growth and to improve our productivity; and
4. To ensure that every home is adequately and affordably heated.

The first goal clearly demonstrates governmental concern about climate change, and promises to shift to a low carbon economy. The commitment was widely welcomed by a broad range of organisations from Greenpeace to British Nuclear Fuels (ENDS, 2003). The second goal concerning reliability or ‘security of supply’ is a traditional concern of governments. Most households now depend on centralised supplies of gas and electricity, which cannot be stored at household level (compared with 1970, when most heating fuel could be stored in some quantity by UK households (Shorrock and Utley, 2003). Reliability of energy supply has therefore become more important over time: an increasingly centralised energy system makes reliability of supply critical to citizen wellbeing. The third goal makes explicit the UK Government view of the link between energy and energy prices and economic growth. The fourth goal puts elimination of fuel poverty at the centre of Government energy policy.

These goals may at times conflict with each other. In fact, it has been recognised that trade-offs will have to be made (House of Commons Environmental Audit Committee, 2003). The most likely conflict is between the first and third goals. All other things being equal, a competitive energy market leading to higher economic growth is likely to counteract the goal of reducing carbon dioxide emissions. The issue is whether 'sustainable economic growth' is a sufficient response to the problem of climate change (Jackson, 2009).

The 2007 Energy White Paper: Meeting the Energy Challenge DTI, 2007 sets out the Government's international and domestic energy strategy as a response to changing circumstances, and also addressed the long-term energy challenges inherent in the four energy policy goals outlined in 2003. The White Paper of 2007 shows how the UK began implementing the measures in the Energy Review Report in 2006 (DTI, 2006), as well as those announced since, in the Pre-Budget Report in 2006 and the 2007 Budget (DTI, 2007).

The 2007 White Paper (DTI, 2007) restates that energy is essential in almost every aspect of life and for the success of our economy. It states that the UK now faces two long-term energy challenges:

1. To tackle climate change by reducing carbon dioxide emissions both within the UK and abroad; and
2. To ensure secure, clean and affordable energy as the UK is becoming increasingly dependent on imported fuel.

It is interesting to note that, in contrast to the 2003 Energy White Paper (DTI, 2003), the 2007 White Paper does not specifically state the promotion of competitive energy markets as a main goal. Tackling climate change is here listed as one of two challenges rather than one of four challenges in the 2003 White Paper (*op cit*).

The two goals may, however, still conflict with each other. For example, most low carbon (renewable and nuclear) energy sources cost more than their fossil fuel equivalent per unit energy produced, and are either intermittent (some renewables) or bring security risk (nuclear), thus less affordable and secure. However, the removal of the competitive energy market goal may make it easier to implement policy to enable a greater proportion of energy generation from low carbon sources, as long as fuel poverty aims and security issues can be addressed at the same time.

The 2007 Energy White Paper was followed by the UK Energy Efficiency Action Plan (DEFRA, 2007) to comply with the EU Energy Services Directive (EU, 2006). The Action Plan discusses the reductions to be made against hypothetical, undisclosed expected levels of growth as if no new policy had been introduced. This makes it particularly difficult to assess how reliable the expected forecasts are, and demonstrates the difficulty of simultaneously trying to work with top-down econometric modelling (as used for the Government's projections of the whole economy) and bottom-up policy proposals (that are independent and specific). Nevertheless, in the following analysis in this Chapter we review the means by which the Government aims to achieve these goals, and whether they are likely to deliver the UK's intermediate (2020) and long-term (2050) emissions reduction targets. Our focus is on UK households, the focal point of this thesis.

The 2007 Energy White Paper (DTI, 2007) states that the net effect of all policies announced prior to and including the Energy Review 2006 (DTI, 2006) are only expected to be sufficient to offset the projected carbon impact of growth in the whole economy up to 2020. By then, despite all efforts, carbon emissions are projected to be 554 $MtCO_2$, the same as in 2006 (DTI, 2007). The policies announced since the Energy Review 2006 and the Energy White Paper 2007 are estimated to reduce this to somewhere in the range of 433-473 $MtCO_2$ (DTI, 2007). It is important to note that only the most optimistic estimate for total projected reductions (433 $MtCO_2$) will deliver the Government's 2020 intermediate carbon emissions reduction target of 26% (DTI, 2007).

Furthermore, in the past, early predictions of possible savings have had to be revised downwards. For instance, the projected savings from the first two rounds of the Energy Efficiency Commitment were expected to be 3.7 $MtCO_2$ (DEFRA, 2006). Half way into the programme the forecast was revised downwards by 20% to 2.9 $MtCO_2$ (DTI, 2007). A second example is the Climate Change Levy where carbon savings estimates were reduced by more than a third by the National Audit Office, from 10.6 $MtCO_2$ to 7.0 $MtCO_2$ (Boardman, 2007). Some of these differences result from the difficulty of predicting people's responses to a policy, including those who would spend the money saved on energy on other goods and services or to consume more energy for example to keep their homes warmer now that they can afford it. This is known as the *rebound effect*, and is likely to be less than 30% (Sorrel, 2007) in the residential sector, but higher where at present people live in cold homes (Milne and Boardman, 2000): as they want to be warmer. There are signs that Government predictions are improving as the rebound effect is now included (HM Treasury and DECC, 2010).

Boardman (2007) reviewed the 2007 Energy White Paper targets to assess whether or not the forecasted savings for the domestic sector were realistic. She found that, in the absence of essential detail, there can only be limited confidence in the proposed policies to deliver within the given range. Table 4.1 below displays the forecasted savings and the conclusions against each carbon savings category from Boardman's (2007) report.

Table 4.1 Carbon emissions reductions from direct home energy consumption between 2007 and 2020

Measure	**Government forecast of carbon reduction between 2007 and 2020 (Mt CO_2e/year[3])**	**Independent review by Boardman (2007): findings on likelihood of meeting the target**
Continued obligation for energy suppliers to make carbon reductions in the household sector (CERT and follow-up schemes)	11.0 -14.7	Could be achieved with the same level of output as CERT over 10 years. However, measured savings would have to equal estimated savings, which is unlikely due to rebound effect.
Information on bill statements and free real time display of electricity meter	0.0 - 1.8	Strong response expected when first introduced. Forecast judged realistic.
Energy performance certificates for homes	0.7 - 2.6	Label alone is unlikely to achieve the forecasted savings. Other new policies and incentives would need to be specified alongside.
More energy efficient products (e.g., light bulbs, electrical goods, windows)	1.5 - 4.4	These savings could be achieved from lighting alone, but in the absence of other policies, is likely to be offset by growth in additional appliance purchases.
Carbon neutral new homes by 2016, 25% reduction by 2010, and 44% reduction by 2013	4.0 - 4.4	New homes are additional, so the carbon savings are in comparison to what would have happened if they had been built to a less demanding target. In the absence of a clear baseline it is not possible to confirm these projections.
Total	17.2 - 27.9	

The analysis by Boardman (2007) as summarised in Table 4.1 shows that without further policy and incentives the savings forecast in the 2007 White Paper for the domestic sector are unlikely to be achieved, and runs the danger of being compensated for by a

[3] Please note that these were calculated by the Government and do not include the effect of radiative forcing. However, as aviation emissions are not part of the measures included, this is unlikely to make a difference to the figures.

general trend of an increase in energy consumption. Without assessment of the forecast of savings in other sectors it is impossible to conclude whether or not the overall White Paper forecast is realistic. However, the above review clearly puts the Government forecasts into question, and particularly shows that for the domestic sector a number of challenges need to be overcome for the sector-specific target to be achieved.

In sections 4.2.2 and 4.2.3 the major policies aiming to reduce carbon emissions in households are described and discussed, and some gaps are identified in section 4.2.4.

4.2.2 Energy policy for the domestic sector

Energy policy for the domestic sector can be split into policy that targets new homes and policy targeting existing homes. Most policies target either category with a few overarching ones here listed under *other key domestic sector policies*.

Domestic sector energy policy focuses on reducing the energy used directly in homes, such as electricity and fossil fuels consumed in the home, or through generating energy using building integrated renewable energy sources. Carbon emissions reduction policy for the domestic sector is limited to reduced emissions from direct energy use, rather than emissions used to produce building materials, construct and/or demolish homes, energy embodied in the products consumed in the home, or the transport of energy associated with the location of the home. The policies, which target carbon emissions reductions in these other areas (with significant carbon emission footprints related to households) are described and discussed in section 4.2.3.

UK Government carbon targets for the domestic sector are in the range of 17.2 to 27.9 $MtCO_2e$ by 2020, over 2006 levels of about 147$MtCO_2e$ (DTI, 2007), which represents an 11% to 18% cut from 1990. Were the government to be on a trajectory to reach an 80% reduction from 1990 by 2050, the required reduction would have to be in the region of 40%.

Individual policies are discussed below and assessed on their likelihood of delivering the required savings. This assessment is, however, restricted by the limited detail given in the 2007 White Paper (DTI, 2007).

New homes

The major policies and regulatory mechanisms affecting carbon emissions of new homes in their future use are:

A. <u>Building Regulations: Part L</u>
The Building Regulations define a minimum standard for new homes and Part L deals with the energy efficiency of the fabric, the boiler and a few dedicated low energy light fittings (ODPM, 2006). Part L also deals with existing homes, however, in contrast to new homes there is no minimum standard which existing

homes have to meet by law. However standards have to be met when replacing windows or building extensions. Before a dwelling is built the developer must apply for building regulation approval, and as part of this must pass Part L on energy efficiency. The scope of Part L has risen over the years with increasingly challenging standards being introduced, and significant step changes introduced in 2002: Part L 2002, and a further step change in 2006: Part L 2006. The Government has committed to a further stepped increase for Part L in the near future, requiring 25% lower carbon emissions than 2006 regulations by 2010, 44% lower by 2013, and 100% by 2016, also referred to as zero carbon homes (DCLG, 2007a).

The auditing method behind the calculations is called the Standard Assessment Procedure (SAP), which has a strong emphasis on the building fabric and heating systems (derived from ODPM, 2006). Energy use from appliances and some lighting are not included. Therefore, more energy efficient equipment would not contribute towards good ratings. This is important, as appliances comprise a significant proportion of energy use in new homes (DCLG, 2007b), and this proportion is likely to increase, as building fabric and heating systems will increase in efficiency with increasingly stringent regulation. The government recognises the issues and plans to include appliances and all lighting in the zero carbon homes policy (DCLG, 2007b), but in the meantime, policy is framed around a tool with limitations.

A second major issue is that SAP is a design stage assessment. This makes it relatively easy for the Government to ensure that a design complies with the building regulations, but much more complicated to ensure that it is actually built to the design specifications. A study by BRE (2004), for instance, found that a third of new homes failed the pressure test and had higher air leakage than specified in their SAP assessment. They also found that in 20% of the properties checked, the energy efficiency of the boiler that was actually installed was less than the one on which the original permit was based. These findings therefore cast some doubt on the predicted savings from new construction.

Future Energy Solutions (FES, 2006) has identified a number of issues, which may be responsible for the lack of sufficient enforcement of building regulations. These include under-resourced and overstretched building regulation inspectors, an incentive structure which disincentivises them from being stringent, cost-savings from non-compliance processes that are difficult to detect by building inspectors, and the general perception that Part L is trivial compared to other issues such as health and safety.

In theory Part L for new homes results estimated savings from energy used in the home at about 30 to 50% lower than the average existing home in the UK

(Johnston et al., 2005). It must be noted however that no studies could be found which provide evidence that this has indeed been the case in practice.

B. The Code for Sustainable Homes (CSH), zero carbon homes and the Ecotown Initiative

The Code for Sustainable Homes (CSH) is a national standards aiming to indicate the sustainability of a home. It uses a sustainability star rating system to communicate the overall sustainability performance of a home. Ratings rank from one to six stars also referred to as levels. Amongst a number of scoring categories the most challenging and costly scoring category is the energy score for the direct energy used in the home (Cyril Sweet, 2007). This is also the only score which effects domestic sector or direct home energy consumption. Here the CSH has minimum standards for carbon emissions from direct home energy use at every code level, which are raised beyond the standard of the building regulations up to a maximum of zero net carbon emissions for the highest Code Level: 6 (CLG, 2009). Code Level 3 (which requires 25% carbon emissions reduction beyond building regulations requirements) is now achieved by most new build social homes, as it is a condition for being awarded housing corporation funding. Since April 2008 all homes must display a code rating. However, failing to comply with any rating, or failing to conduct a code assessment, stipulates that a zero star rating can be displayed (CLG, 2009). The Government is planning to step up the minimum rating that must be achieved by all new homes. It is proposed that by 2010 all new homes should achieve Code Level 3, which has a 25% carbon emissions reduction mandatory requirement beyond current building regulations, i.e. for direct energy used in the home. By 2013 by Code Level 4 with 44% requirement is planned to become mandatory and by 2016 all new homes should be Code Level 6 including carbon neutral for direct energy used (DCLG, 2007c). Some local and regional authorities have already, or are in the process of, setting their own code requirements for housing developments in their localities, ahead of government legislation (EST, 2009).

Exemplary housing developments are currently planned under the Ecotown Initiative, which are to deliver a number of zero carbon home communities prior to 2016 in different parts of the country (CLG, 2007;Warren, 2007; TPCA and Lock, 2007). Ecotowns are part of the continuing programme to help achieve the step change in the quantity and quality of housing for England (CLG, 2007b). The Ecotown Prospectus (CLG, 2007b), launched by Communities and Local Government (CLG) on 23 July 2007, describes Ecotowns as:

> *"small new towns of at least 5-20,000 homes. They are intended to exploit the potential to create a complete new settlement to achieve*

zero carbon development and more sustainable living using the best new design and architecture." (CLG, 2007b).

The terms: *carbon neutral*, *zero carbon homes* or *zero carbon developments* are defined as "where the net carbon dioxide emissions resulting from all [direct] energy used in the dwellings of the development are zero or better" (CLG, 2007b). The same definition is used as the standard that all homes are supposed to achieve after 2016 under an upgraded SAP rating system (TCPA and Lock, 2007; CLG, 2009). This means that whilst this may be an ambitious goal, the so-called zero carbon homes and developments are only zero carbon in the direct energy that is consumed in the homes (for heating, hot water, lighting and appliances). Embodied and indirect emission sources of the household are not considered. We will analyse implication of this further both in this chapter (section 4.2.3 and in Chapter 6).

C. Town and Country Planning

Town and Country Planning is the land use planning system used by governments to balance economic development and environmental quality. Each country within the United Kingdom has its own town and country planning system - devolved to the Northern Ireland Assembly, the Scottish Parliament and the Welsh Assembly (Cullingworth and Nadin, 2006). Each local authority produces a local plan, which follows country guidance but has a degree of flexibility regarding locally specific targets (Cullingworth and Nadin, 2006). Typically, developers must comply with certain fixed rules but there are desirable criteria which a developer can propose and use to negotiate flexibility elsewhere (*op cit*). The house builder has to apply for planning permission and explain in their application how they will meet and contribute to the objectives of the local plan (*op cit*). There are also particular locations where buildings are to be built to higher standards for carbon emission from direct energy used than current building regulations require. These may be enforced through specific SAP targets, through the Merton Rule (see below) or through imposing a specific rating on the Code for Sustainable Homes. One example of these is the Ecotown Initiative, which as described above requires all home in the new ecotowns to be net zero emitter of direct home energy use (CLG, 2007b).

D. The Merton Rule

The 'Merton Rule' is a planning policy requiring the use of renewable energy onsite to reduce carbon dioxide (CO_2) emissions of direct home energy use (Merton Council, 2010). Pioneered by the London Borough of Merton, it has now been adopted by a number of local authorities (Merton Council, 2010). CO_2 emissions reduction targets required in most Local Authorities with this policy are usually 10%, however, some pioneering sites have gone as high as 40% (*op cit*).

Collectively, the London Borough of Merton and its neighbouring Borough of Croydon have implemented the policy on 60 developments, and over 30 other local authorities require the Merton Rule to be met on all or some of their developments (EST, 2007; Merton Council, 2010). By 2007 the Merton Rule had been adopted or was being considered by over 165 Local Planning Authorities (The Merton Rule, 2007). The UK Government now requires all boroughs to adopt a policy in their local development framework that expects a proportion of energy in new developments to come from renewable and low carbon sources (Energence, 2010).

With the Merton Rule, Local Authorities face the problem that they lack the power to enforce the operation of the renewable energy installation post-completion of the housing development (Aplin, 2007). They can give planning application and building regulation approval on the basis that the renewable energy capital installation takes place; however, what happens post construction is not in their control. This could lead, for example, to the installation of a biomass CHP unit with gas back-up boilers. In practice, it would be cheaper to run the whole site on the gas boilers rather than use the more expensive wood fuel, so that once the plants are installed to the local authority's requirement it would be cheaper not to use the renewable fuel but to maximise the use of the backup boilers instead. Since the introduction of the feed-in tariff in 2010 the economics for the renewable sources are more favourable and therefore this may now pose less of a problem (Mendonca et al, 2009).

Existing homes

At present, the main domestic sector sustainable energy policies for existing homes in the UK are:

A. <u>Carbon emissions reduction target (CERT)</u>

   CERT is the current obligation of gas and electricity retailers to achieve energy savings. The government describes it as "the principal policy mechanisms driving increases in the efficiency of existing homes" (DEFRA, 2004). Savings are achieved most commonly by subsidising consumer purchase of efficient light bulbs, appliances, and loft and cavity wall insulation. The savings each gas and electricity retailer needs to achieve are in direct proportion to their overall gas and electricity sales. There is a fuel poverty alleviation component to this policy in that at least 50% of the savings have to be achieved in low-income households (DEFRA, 2004). Based on concrete targets, this policy has been relatively successful at saving carbon emissions and improving the existing housing stock (Boardman, 2007); and the Government projects that more than half of the overall carbon savings between 2007 and 2020 resulting from domestic sector policy will be delivered this way (DTI, 2007). However, due to the rebound effect, savings so far have been about 30% lower than previously expected (Sorrell, 2007). Even taking this into account we judge that CERT has been an effective policy for delivering carbon savings and reducing fuel poverty.

B. Warm Front

Warm Front is a programme in England designed to improve efficiency and home heating systems of citizens on low incomes, with the dual aims of reducing fuel poverty and improving health (NAO, 2003). Warm Front provides grants for specific measures up to a defined maximum value per household. There are similar approaches in all devolved administrations. The coverage was originally just draught-proofing and loft insulation, but has been extended over the years. The most recent addition has been the installation of oil-fired central heating where there is no gas, but this is both expensive and carbon-intensive. NAO (2003) found that the Warm Front Scheme has also delivered less carbon savings than initially anticipated: Over 50% of Warm Front grants lifted a treated home up by less than 10 Standard Assessment Procedure (SAP) points, and for 20% of homes there was a SAP improvement of 1 SAP point or nil (NAO, 2003). 10 SAP points are roughly equivalent to theoretical savings of ½t CO_2 per year or a financial savings of £100 on energy costs (*op cit*). It is likely also that similarly to CERT the rebound effect would have curtailed the real carbon savings further.

C. Energy Performance Certificates

An important policy, which came into force in January 2006, is known as the EU Energy Performance of Buildings Directive; it requires that all buildings at point of sale or rental must obtain the supply of energy performance certificates which estimates the annual energy consumption and emissions from the home (DEFRA, 2004). Part Lb for existing buildings is used to calculate the annual consumption and emissions. The aim of energy certification is to build on the success of labelling white goods (which has effectively transformed the market), and significantly increased the average energy efficiency of all white goods sold (EST, 2008). It is yet to be seen if the energy performance certificate will in future affect the value and saleability of homes. So far, no evidence could be found in the literature review, which shows this to be the case.

D. Billing information and real time display

In order to raise awareness on energy efficiency, the government is also obliging energy suppliers to provide information as part of their billing (real time energy use displays to households for free) (DTI, 2007). This and the Energy Performance Certificates are the only planned policies listed in the 2007 Energy

White Paper, which specifically targets behaviour change and consumer behaviour.

It is interesting to note that none of the energy policies for existing homes bring the energy performance of existing homes anywhere near matching the energy and carbon performance which new homes must achieve under the building regulations (Boardman, 2007).

Other key domestic sector policies

Other key policies affecting carbon emissions from direct home energy consumption are:

A. Energy efficiency standards for windows, light bulbs and electrical goods

Since 2002 there are minimum requirements for replacement windows (Boardman, 2007); and a voluntary agreement between retailers, the energy industry and government has been made to phase out inefficient light bulbs with gradually increasing efficiency standards set up to the year 2016 (*op cit*). Industry voluntary agreements are also in place to reduce the overall energy consumption of electrical goods (DIF, 2009). This affects both the missing legislation for energy efficient white good and lighting in new homes and the lack of legislation for minimum standards in existing homes. Any replacement or repair is therefore (unless reclaimed products are used) ensured to meet a minimum energy efficiency standard (Boardman, 2007). Whilst these policies and voluntary agreements are judged to be able to reduce energy consumption from electrical goods and lighting by more than 10% between 2007 and 2020, it is unclear whether this saving will be wiped out by an increase in the use of appliances, particularly consumer electronics (Boardman, 2007).

B. Renewable and Zero Carbon Technologies

The Community Sustainable Energy Programme is a programme encouraging the use of microgeneration technologies through providing part government funding (BRE, 2010). Other programmes such as Clear Skies, the Low Carbon Building Programme, and the PV demonstration field trials, have in the past provided part funding for renewable energy installations (EST, 2005). Funding tends to be allocated on a competitive tender basis requiring the bidder to demonstrate capability and commitment to sustainable building practices in general. These funding programmes have targeted both existing homes and the new build sector. By 2005 there were a total of 107,200 low and zero carbon technology installations, the majority in households and through grant aided funding programmes (*op cit*).

The aim of the European Commission is for 20% of European energy (not just electricity) to come from renewables by 2020 (EU, 2009). With only 2% renewable energy contribution, the UK is currently the third lowest contributor towards meeting the target (CEC, 2007). Only Malta and Luxembourg produced a lower percentage (*op cit*).

The slow rate of renewable energy installations in the UK to the grid results from several interlocking causes and the low rate of payment for exported electricity until 2010 was likely to be one of them (Boardman, 2007; Mendonca, 2009). For example, under the current renewable support mechanism the Renewable Obligation (RO), the financial support to a householder with a 1 or 2 kW PV system would outweigh the administrative costs of claiming the funding (Davenport, 2008). At this price, and without additional subsidies, building integrated renewable energy sources is not economically viable.

Since April 2010 feed-in tariffs have been introduced (DECC, 2010b). This is a step change in UK renewable energy policy. Feed-in tariffs are a recognised and influential method of encouraging the installation of electricity from micro-generation; they provide the householder with a guaranteed price for the generated kWh that are supposed to reflects the true costs of installing the equipment (Mitchell et al., 2006). The feed-in tariffs have been used extensively in Germany and Spain and have resulted in substantial growth in renewable energy contribution to electricity production (Mitchell et al., 2006). It is, however, too early to judge the uptake of the feed-in- tariffs by UK households, but this appears to be a promising policy due to the example of large-scale impacts in other countries.

4.2.3 Other policies affecting household carbon emissions

The UK Government reports CO_2 emissions on a sector basis (ONS, 2008a). Four main sectors are used: domestic, commercial, transport, and industry. Domestic energy covers all energy directly consumed in households for heating, lighting, electric appliances and hot water and domestic sector policy as discussed in Section 4.2.2 focuses on reducing emissions in these categories. Here we also include indirect emissions from households. It makes sense for households to view such emissions from a consumer-based perspective, i.e. consumer categories rather than the four sectors the Government is using. Desai (2005), in an analysis of carbon emissions from a consumer perspective, has constructed the following split, as displayed in Table 4.2.

Table 4.2 Carbon impact for an average person living in a home built to 2005 building regulations (Desai, 2005)

	UK average % of total CO_2 emissions
Energy used in dwelling/home (built to Part L of 2002)	11 %
Building materials	3 %
Personal transport	18 %
Food	23%
Waste and consumer items	13 %
Shared services (Total energy for running schools, hospitals, financial services, etc)	12 %
Shared infrastructure (Energy for constructing schools, hospitals, roads, airports, etc)	20 %
Total UK responsible emissions	**100%**

Table 4.2 includes emissions from aviation and emissions emitted abroad (personal transport) on behalf of the UK. It does not, however, use a multiplier to account for the greater impact of aviation emissions at altitude as discussed in Chapter 3.

Desai's research indicates that the contribution of direct home energy use to carbon emissions in a new home (space heating, hot water, and appliances) represents about 11% of the total emissions of a UK resident. Some categories, such as shared infrastructure and services, cannot be (or are only to a minor extent) influenced by decisions of a householder or developer of a new housing development. Other areas such as the building materials used, products consumed, the household waste disposal option, and mode of transport to commute to work can, however, be under the householder's control. Desai (2005) provided too few data sources to fully verify his findings. However, comparing his analysis with ours in Chapter 3, such as SEI (2008), Druckmann et al. (2007), Helm et al. (2007), ONS (2008), DTI (2004), Cairns and Newson (2006), ODPM (2006), and Audley et al. (2009), we can verify that the weighting lies in the right order of magnitude. This is sufficient to understand that household categories other than direct energy use are significant carbon emissions contributors.

For the purpose of this research we therefore define household carbon emissions to include categories that have significant potential to reduce carbon emissions through the choice of householders/residents and developer. Looking at each of Desai's categories in turn, we now discuss the extent to which they can be influenced by housing developers. We here look more widely at choices the property developer/housing provider can make to take responsibility to influence the carbon footprint of the development and its future residents. Herein we recognize that the property developer has to work with the local planner to gain planning permission and that some of the actions that a property developer can propose to provide sustainable solutions may support what the planners are looking for and therefore help gain planning permission.

1. **Energy used in dwelling/home:** This is the direct energy used by households and can be influenced by the developer through building energy efficient homes and building integrated renewable energy systems. Policies to encourage these have been discussed in Section 4.2.2.

2. **Building materials**: This is the carbon generated in the production, transport of building materials, on-site construction, and disposal of the building at the end of its life. Whilst this is a small percentage of emissions the developer has full say over the choice of building materials providing they meet the building and planning regulations. A developer can influence this through choosing locally produced materials, building materials that require little energy to manufacture (e.g., timber), by recycling construction waste or by not generating waste through the construction process. (Anderson and Howard, 2000; Anderson and Shiers, 2002; Larus, 2003a).

3. **Personal transport**: Carbon emitted from cars and public transport can be minimised if house builders choose sites where people can live close to workplaces and key services (Larus, 2003b; Aplin, 2007). The provision of low carbon transport solutions (car sharing, public transport) is another option, as is carbon-free transport provision (attractive cycling paths and walkways), and by local job creation, for example, through building offices.

4. **Food**: The embodied carbon (CO_2e) in food from the manufacture of fertiliser, livestock, CH_4 and NOx, agricultural machinery, transport, packaging materials, storage and sales process (e.g. transport and supermarket energy), can be influenced by the housing developer or provider by integrating food production and supply with housing developments or ensuring that the development is close to local and low carbon food sources (Gill, 2005). For example, through provision of allotments to grow food and market stalls where local produce can be sold, through promoting low carbon/ethical food, and by creating local amenities that offer local and ethical produce. At the eco-development Bedzed in London, an estimated 7% of total resident food emissions were saved through the opportunity for people to grow their own food and through the promotion of a local organic vegetable box scheme (Bioregional, 2009).

5. **Waste and consumer Items**: Recycling and composting facilities reduce the amount of waste sent to landfills, thus curtailing the production of methane, a very strong greenhouse gas (DEFRA, 2007d). Moreover, replacing virgin resources with recycled products often means a lower carbon footprint in the manufacture of the product (DEFRA, 2007d). A house builder or Local Authority can influence recycling rates of households by offering good recycling provision

and by raising awareness among residents (Robinson and Read, 2005). There is little evidence that the developer or housing provider can influence general consumption to a significant extent.

6. **Shared services and infrastructure:** Again there is little evidence could be found that shared infrastructure and services can be influenced significantly by the house builder or housing provider.

Concluding from this analysis we have four additional categories, which may significantly contribute to household carbon emissions and can be influenced by the developer or housing provider. These are building materials, personal transport, food and waste in addition to direct home energy consumption. We will now look at policies relating to these categories and their impact on climate change.

The 2007 Energy White Paper (DTI, 2007) quantifies the carbon emissions reductions that will result from Government policy between 2007 and 2020. The policies and related emissions reductions relevant to the four selected areas of household carbon emissions (building materials, transport, consumables, and waste) have been extracted from the White Paper (DTI, 2007) and are discussed below.

Building Materials

There are a number of general policies, which are likely to effect the carbon emission of building materials slightly. These include the EU Emissions Trading Scheme and carbon related taxes as well as building regulation changes other than Part L, which change the housing standards and related emissions. In addition there is one mechanism, which is Part of the Code for Sustainable Homes (CSH), which directly targets the reduction of environmental impact of building materials. These are here described including a more detailed review of the effectiveness of the direct mechanism: the CSH in delivering carbon savings to embodied energy in building materials.

The EU Emissions Trading Scheme (EU, 2010) and other energy and carbon-related taxes are possible mechanisms which will indirectly affect energy embodied in building materials, as they will raise prices for fossil fuel energy and, as a result, act as a market driver for lower carbon products (DTI, 2007). These policies are UK and EU-specific and do not apply to building products imported from outside the EU. More stringent building regulation standards, for example, on noise and fire (ODPM, 2003; CLG, 2006) may have the opposite effect and increase the carbon content embodied in building materials.

Despite the fact that Part L of the UK Building Regulation limits the theoretical emissions resulting from direct home energy consumption, there is no policy listed in the White Paper, (DTI, 2007) in place to regulate the carbon emissions embodied in the building materials themselves. The only policy mechanism which may directly influence the choice of building materials is the Code for Sustainable Homes (CSH). As explained in Section 4.2.2 the CSH is a standard for which a particular star rating has now become mandatory in a number of Local Authorities (EST, 2009). The rating is achieved by choosing from a list of sustainability scores, the total of which must add up to the required rating (CLG, 2009). Each scoring section is labelled by the overall theme they are part of and by a number. Ene 1, for example, stands for the first scoring category of the energy theme, Mat 3 for the third scoring category of the Materials Theme. Scores are available for a number of sustainability areas, including use of sustainable and low carbon building materials in the Mat 1 score (CLG, 2009). Therefore, whilst achieving a Code for Sustainable Homes (CSH) rating will not ensure that sustainable materials are used, a home, which meets a CSH rating, may have specifically selected low carbon building material to increase their score.

In order to understand the importance of the CSH in this respect, we will examine more closely the detailed calculation methods and their assumptions. Ratings are given for choosing particular construction types for roof, external walls, internal walls, upper and ground floors, and windows (CLG, 2009). In order to assess the score the *Green Guide to Housing Specification* (by Anderson and Howard, 2000) is used. It lists a large range of typical construction elements and rates these according to their environmental performance. For example, timber windows score higher than PVC or Aluminium windows and timber stud partition walls score higher than concrete brick walls (Anderson and Howard, 2000). The score in the Green Guide (*op cit*) results from a life cycle assessment methodology described in the *BRE Methodology for Environmental Profiles of Construction Materials, Components and Buildings* (Howard et al., 1999). In this document different environmental impacts are rated at different weightings, with carbon equivalent emissions-related impacts (emissions and fossil fuel resource consumption) being given a total weighting of 38% (*op cit*). Therefore, the CSH score is influenced (but not solely related to) the climate change impact of the building materials. This is an important factor in understanding the total weighting that carbon emissions from building materials used are given in the overall CSH rating. This may in turn provide a clearer picture of the level to which the current policy of the CSH actually encourages the use of low carbon building materials.

The other information required to assess the role emissions embodied in the building materials play in the overall CSH rating, is the relative contribution of the Mat 1 score to the overall CSH rating. The Mat 1 score is 4.5% of the overall Code rating (derived from CLG, 2009). If we multiply this by the 38% carbon equivalent emissions-related weighting, the total contribution for carbon embodied in building materials in the CSH is only 1.7%. This compares to a weighting of 32.6%, which is the total weighting of the Ene1 to Ene7 scores (derived from CLG, 2009), all of which are directly related to home energy use. The balance of the direct energy used in a home over its lifetime, compared to the energy embodied in its materials is typically about 80% (energy used) to 20%

(embodied in building materials); and in new efficient homes, the balance is more like 70%: 30% (Edwards, 2007; Adalberth, 1999). This shows that the CSH undervalues the relative contribution of building materials to climate change when compared to energy used in the home. Rather than giving it a weighting of roughly a third of the energy in use weighting, embodied carbon in building materials is weighted at approximately 5% (1.7%/32.6%) of the energy in use rating. Moreover, minimum ratings for energy use in the home are mandatory for each code rating, whereas any code rating can be achieved without scoring on Mat 1 at all.

To conclude, whilst there are many opportunities to reduce carbon emissions through building material choices (Morrell, 2010) there is currently little policy incentive and no regulation in place to reduce carbon emissions in building materials (Morrell, 2010 and above analysis).

Personal Transport

The Energy Review Report (DTI, 2006) sets out that the government is working to tackle emissions from transport by:

A. Reducing the carbon content of fuel
B. Reducing the carbon emissions of vehicles
C. Encouraging the shift towards environmentally friendly transport and, where appropriate, using emissions trading schemes and carbon pricing (e.g. through fuel taxes).

It is interesting to note that reducing the need for transport is not mentioned in the report. Yet, this has been recognised as the first priority for sustainable transport systems for decades (Whitelegg, 1993).

Indeed, planning policies PPG13 (CLG, 2001a) and PPS1 (CLG, 2005) do provide guidance to planning authorities on the need for reducing travel. In addition, the CSH awards credits for various sustainable transport categories (CLG, 2009).

A. <u>Planning Policy: PPG13 and PPS1 and the CSH</u>

   PPG 13's (CLG, 2001a) objectives are to integrate planning and transport at the national, regional, strategic, and local levels and to promote more sustainable transport choices both for carrying people and for moving freight. It also aims to promote accessibility to jobs, shopping, leisure facilities, and services by public transport, walking and cycling, and to reduce the need to travel, especially by car (CLG, 2001a). To deliver these objectives, the guidance suggests that local planning authorities should actively manage the pattern of urban growth, locate facilities to improve pedestrian and cycling accessibility, accommodate housing principally within urban areas, and recognise that provision for movement by walking, cycling and public transport are important but may be less achievable in some rural areas (CLG, 2001a).

PPS1 sets out the Government's overarching planning policies on the delivery of sustainable development through the planning system (CLG, 2005). A supplement to Planning Policy Statement 1: Planning and Climate Change sets out how planning in the provision of new homes, jobs and infrastructure for communities, should help develop areas with lower carbon emissions that are resilient to climate change (CLG, 2007).

As PPG13 and PPS1 are not mentioned in the 2007 Energy White Paper (DTI, 2007), we assume that the Government is not expecting these policies to lead to overall carbon saving, although they might counteract baseline growth in carbon emissions. Unlike direct energy used in the home – regulated and limited through Part L of the building regulation (ODPM, 2006) – no such measure is in place requiring developers to quantify carbon emissions from transport emissions from their development (CLG and DTI, 2007). Although for large-scale developments developers are required to assess the impacts of commuter trips on traffic flow, there is no specific requirement to convert their findings into the implications for carbon emissions or a target maximum increase per household that should be achieved (CLG and DTI, 2007). The decision to permit a development to go ahead is therefore based on an assessment of the highway agencies and planning officers, which in turn need not report or meet specific targets on the carbon emission footprint in their confines (Aplin, 2007). This may be a significant limitation on the ability of PPG13 and PPS1 to deliver carbon emission reductions.

In a similar way to the material sustainability rating, the CSH also give credits for two sustainable transport options: cycle storage and home office (CLG, 2009). Again, these are not mandatory credits, but some may be chosen by developers as a way to achieve a target overall rating, where a mandatory CSH overall star rating must be met. A home office is defined as a desk of a minimum size in a room with a window and requires electrical and telephone sockets (CLG, 2009). A bedroom could suffice, thus any householder could choose either to use it, or remove the desk and use the space for other purposes. In addition, the jury is still out on whether teleworking makes an overall difference to the amount of travel undertaken (Christodoulou et al, 2006) and to carbon emissions.

The only other transport score within the CSH, cycle storage is specified as a minimum amount of secure (lockable) storage space for bikes per bed space in the development (CLG, 2009). The CSH does not specify how close the cycle store has to be to each house; the developer can therefore create potentially cheaper centralised cycle storage, which would be less accessible than cycle storage at each home (CLG, 2009). These two options (cycle storage and home office) seem like a significant step towards simplifying sustainable living. However, the tick-list approach of the CSH may hinder an overall logical approach. It is also interesting to note that the CSH shies away from awarding credits for other sustainable transport criteria, such as access to local amenities and jobs, integration of pedestrian and cycle paths in the development, and mixed-use developments which by default are set up to reduce transport impacts through reducing the need for carbon-intensive travel (Banister, 2005). Without these, the difference that a home office space and cycle parking provision could make is significantly limited.

In addition to the above planning policies, which effect transport emissions for new homes, there are other more general transport policies which effect carbon emissions from all households who use cars. These are reviewed below.

The transport measures recognised in the 2007 White Paper (DTI, 2007), expected to contribute to transport emissions reduction by 2020 that are relevant to households are fuel efficiency standards and the Renewable Transport Fuel Obligation (RTFO).

B. Fuel efficiency standards

These standards set reduced average emissions per vehicle km to 130 gCO_2/km by 2011 through voluntary agreements or regulations for vehicle manufacturers; they are supported by a tax regime (such as the fuel duty escalator and graduated vehicle excise duty based on CO_2 emissions bands) (Bonilla, 2009). The standards are to be implemented through a successor to the EU Voluntary agreements on new car fuel efficiency (DTI, 2007; DFT, 2009).

In order to review the reliability of the forecasted savings through this measure of 1.8 to 4.1 Mt CO_2e/year (DTI, 2007), we have here reviewed the success of the previous voluntary EU agreements in 1997. A 140 gCO_2/km sales weighted average target was set to be met at European Level by each motor manufacturing association between 1998 and 2008/9 (Bonilla, 2009). This represents a 25% cut over 1995 levels (*op cit*). The UK is likely to be one of the countries with higher average emissions per kilometre. The average emissions footprint for new cars sold in the UK in 2006 was 167.7 gCO_2/km (DfT, 2007a). Bonilla (2009) found that on-road fuel economy in 2005 is no better than in 1988 (litres per km). Among the reasons are: driving at less than optimal speed, consumer choices for larger vehicles increase in market share of larger and more powerful cars, among others. Whilst in 2005 the theoretical gap between on-road and new car fuel economy (petrol) is 24% less fuel of new against fleet]], the real fuel use and emissions differ, as they are influenced by driver behaviour (*op cit*). Although actual fuel economy of new cars has improved, this improvement falls short of meeting the EU voluntary agreement of which the UK is a signatory. The UK is on course to fail to meet the agreed targets. For improvements to be made, policy should more closely target consumer choice, and use of cars (Bonilla, 2009).

No specific mention is made of any reform or new support mechanism to improve progress in the UK in order to increase the probability of meeting the EU voluntary agreement the second time around (DTI, 2007). The absence of reform or support puts the forecasted progress into question.

Since the Energy Review Report (DTI, 2006) two policies have been introduced which do encourage consumers who can afford new vehicles to choose vehicles with lower emissions. These are the road tax banding where cars with lower emissions pay less road tax (Directgov, 2010) and the vehicle scrappage scheme (BIS, 2010) aimed at boosting the economy in the recession, by subsidising the purchase of a new car when at the same time as an old car with typically higher emissions is scrapped. Ryan et al (2007) shows that road tax banding has a small positive effect on consumer behaviour towards choosing to purchase vehicles with lower emissions. For the vehicle scrappage scheme however, without considering the full emissions implication of this scheme (including the embodied emissions of the new car to be purchased) it is unclear whether or not and to what extend it will influence overall emissions. Whilst the environmental impact of the UK vehicle scrappage scheme has not been investigated, a study (Hopfner et al, 2009) commissioned by the German government invested the environmental impact of the German equivalent of the UK car scrappage scheme: Umweltpraemiere. Hopfner et al (2009) found that when the embodied carbon and user behaviour is taken into account it is unclear whether or not the scheme results in overall emission reductions or not. He criticises the lack of maximum emissions criteria for the subsidized cars that could have been linked to the scheme. Like the German scheme the UK scheme also does not have emission limits attached to it (BIS, 2010). Again this is another example where climate change policy seems to have been placed without consideration of their full emissions implications.

C. <u>The Renewable Transport Fuel Obligation (RTFO)</u>

The Renewable Transport Fuel Obligation (RTFO) is the UK's main policy mechanism for meeting the EU Biofuels Directive (European Commission, 2003). The 2007 Energy White Paper forecasts an annual carbon emissions reduction from this policy of 0.5 to 1 Mt CO_2e per year between 2007 and 2020 (DTI, 2007).

The RTFO places an obligation on transport fuel suppliers to ensure that by 2010, 5% by volume of all road vehicle fuel will be supplied from renewable resources (DfT, 2006). Median estimates for the amount of UK arable land required to meet this policy target through UK production alone, range from 10% (for sugar beet ethanol) to 45% (for wheat straw ethanol) (Royal Society, 2008). Both due to the lack of available agricultural land in the UK and for cost reasons, it is likely that by 2010 a significant proportion of biofuels used in the UK will be imported. In order to ensure that biofuels deliver carbon savings and meet 'minimum' environmental standards, a carbon and sustainability assurance scheme has been developed for the first phase of the RTFO, which runs from 2008 to 2011 (DfT, 2008).

Obligated companies will be required to report on the carbon savings of their fuels, using a carbon calculation methodology based on a well-to-wheels approach, and on broader aspects of the sustainability of biofuels (DFT, 2008). Companies are to report on carbon calculations using a consistent methodology that has been developed by the Department for Transport (DfT). This methodology includes default values that allow the carbon intensity of the fuel chain to be estimated where figures are unavailable (DfT, 2008). It is envisaged that carbon reporting will enable market actors to distinguish between fuels on the basis of carbon intensity, in addition to allowing the government to monitor any carbon savings resulting from the RTFO (Wallis and Chambers, 2007). Sustainability reporting is required in addition to carbon reporting, and focuses on the farm or plantation level rather than on the full production chain.

Suppliers are obliged to produce monthly and annual reports on carbon and other aspects of biofuel sustainability. Company reports will be independently verified by the RTFO Administrator, who will compare and rank individual companies' performance and report to Parliament. To begin with, it is possible to report 'not known' responses, and no date has yet been given for ending this concession, providing a threshold percentage of available data is reported. There will also be no initial exclusion of particular types of biofuels, and suppliers will receive a certificate, provided that qualifying standards and minimum GHG savings have been met (DFT, 2008). The RTFO therefore currently relies on stakeholder pressure to incentivise the production and purchasing of the most sustainable biofuels. As of late 2008, biofuel accounted for 2.7% of transport fuel supplied in the UK; of this, 84% was biodiesel and 16% bioethanol (RFA, 2010). The most widely reported biodiesel feedstock is currently Argentine soy and only 23% of the supplied biofuel met an environmental standard (RFA, 2010).

Averaged across the first five months of the RTFO, the GHG saving of biofuel supplied to the UK market (excluding indirect land use change) is stated as 44%

of the fuel it displaced; however, the previous land use is also reported as 'unknown' for 11% of biofuel supplied to the UK for the same period (RFA, 2010). This 'unknown' is highly significant in this context, especially as the majority of biofuels are not supplied with an environmental standard, as some sources of biofuel are highly significant carbon sources rather than sinks. For example, biofuel from soy from Brazil grown on converted forestland causes an increase of up to 25.5 as much carbon in the atmosphere as would be emitted when burning fossil fuels instead of this biofuel (DfT, 2008). And the main current source: Argentine soy can cause an increase of up 11.3 times as much carbon as burning fossil fuels would (*op cit*). This shows that, depending on their source, biofuels can be net emitters rather than sinks, and some sources will cause for more climate damage than benefit. As a result, the figures here show that biofuels used in the UK may actually be increasing, rather than reducing, global emissions. The degree to which this happens is unclear due to the lack of reported sources (DfT, 2008). It is clear, however, that this further illustrates how the UK Government has ignored its responsibility and contributed to climate change outside its national borders, as outlines in Chapter 3.

The above analysis indicates that it is unlikely that the UK will achieve the 2007 Energy White Paper targets set for transport emissions reduction in policies directly affecting households. Whilst it is likely that shifting towards more efficient vehicles will go some way towards reducing emissions, that changing to alternative fuels could also potentially make a difference if appropriate sourcing can be enforced, and that town planning and the CSH may play a role in limiting extra traffic originating from new developments, various studies have shown that these alone are unlikely to offset increases in traffic growth, nor will they deflect the trend away from purchases of heavier cars loaded with more energy-intensive equipment, let alone actually lead to a downward trend in UK transport emissions (IPCC, 2001; CfIT, 2007; CfIT, 2009; Tight et al., 2005).

Food

Before discussing the specific policies relating to carbon emissions from food, it is important to understand the contribution of food to the overall UK carbon footprint and the contributing emissions sources relative to food distribution.

Audsley et al. (2009) have estimated the total direct emissions from the supply of food and drink in the UK, including emissions caused abroad, to be 152 $MtCO_2e$. A further 101 Mt CO_2e from land use change is also attributable to UK food. In their calculation they accounted for methane and nitrous oxide, however, they do not account for the uplift factor of radiative forcing. Garnett (2003) estimated that only about 1.6% of food was imported by air, and the overall transport emissions from food accounts for about 8% of total food emissions. On the basis of this data, and in the absence of available data that quantifies carbon emissions from aviation food transport, if we judge the effect of radiative forcing on overall CO_2e emissions of food to be negligible, then the total contribution of food to the overall UK responsible CO_2e emissions footprint is 24%. This was calculated using the total UK carbon footprint calculated in Chapter 3 and the UK food footprint calculated by Audsley et al. (2009) and includes carbon emitted due to land use change. Out of this total food carbon (CO_2e) footprint, about half is emitted within and the other half outside the confines of the UK (*op cit*). The total UK food carbon equivalent footprint can be divided into three parts: primary production to the regional distribution centres: 34%, the regional distribution centre to consumption (including transport, storage, cooking, waste): 26%, and land use change: 40% (*op cit*), with the latter emissions from land use change all happening outside the UK national boundaries.

The 2007 White Paper (DTI, 2007) neglects to mention carbon emissions reduction measures targeting the food and agricultural sector. In the absence of policy, the only policy capable of impacting on the food sector is the general decarbonisation of the energy supply, e.g., through renewables, and to some extent through emissions trading affecting production of agricultural products such as fertiliser. To compound the absence of emissions standards in the agricultural sector, about half of the emissions from food happens outside of UK national boundaries, therefore the emissions related to imported goods will not be significantly influenced by UK policy, although emissions trading schemes which are multinational could play a small role (Pretty and Ball, 2001).

As discussed above, there is no policy, which directly targets food consumed in households. A very large amount of food is imported into the UK; therefore renewable energy supply and energy taxes are likely to have little impact. We assume that in the absence of newly emerging policy, the UK food carbon footprint is unlikely to change significantly from business-as-usual by 2020. To understand this business-as-usual current trend scenario, we not only need to examine what is happening in the UK but also look at world food and competing commodity markets, both in terms of direct emissions and land use change.

Greenhouse gas emissions from UK agricultural production have fallen since 1990 (HM Government, 2006). It is difficult to assess trends in greenhouse gas emissions for the food economy as a whole, as they are the result of a number of counteracting and poorly understood activities (Audsley et al, 2009)– for example, rising commodity consumption is counteracted by increased production efficiency in Europe, and increased energy efficiency in manufacturing is counteracted by increased car use in shopping. Overall, further but modest reductions in emissions from primary production are expected up until 2010 (DEFRA, 2008; HM Government, 2009). DEFRA (2008) thereafter expects UK agricultural emissions to rise by 6.5% between 2010 and 2020.

An estimated 18% of global greenhouse gas emissions arise from land use change through deforestation (Ramankutty et al., 2007). Drawing on FAO statistics (FAO, 2007), 58% of deforestation is driven by commercial agriculture. The role of agriculture as a driver can be complex due to its interaction with other factors such as road building, biofuels, logging and population growth. Accepting the uncertainty in estimates and drivers, it remains clear that land use change is connected to agriculture and this is a significant cause of emissions attributable to the global food economy.

Most UK public debate on food and deforestation highlights the direct link between land use change and the UK food system (Audsley et al., 2009). Considering the dominance of the tropics in land use change (FAO, 2005), we can observe the production of particularly soy and beef from South America and palm oil from South-east Asia. This approach to the problem regards deforestation as attributable to UK food consumption when UK consumed food is grown on recently converted land. For example, if the UK consumes palm oil and a proportion of this demand is met by converting forest to palm oil plantations, the emissions from the conversion of forestland to plantation are allocated to the palm oil produced on that land. However, it is possible that switching to consumption of foods grown on existing agricultural land (to reduce direct land use change) will displace the production on that land to other areas, some of which will be converted from other land use types (causing indirect land use change). Therefore, there are direct connections to land use change, and there are indirect connections via global commodity trading. If we accept that the global food system is highly connected and indirect effects must be considered, then the boundary between agricultural land and other land use can be regarded as a frontier. As the global demand for food or other agricultural products increases, global agricultural output expands. Over the last 50 years, much of this production expansion has been achieved through increases in yield rather than area (Bringezu, 2008). However, the relative growth in yields has declined steadily and is now lower than the growth in population, and further pressure for land arises from biofuel legislation internationally, such as the RTFO in the EU (Bringezu, 2008) (as already discussed in this section). This is a strong pointer towards increased pressure on land use change.

We can conclude that in the absence of further policy, greenhouse gas emissions from UK food are unlikely to decrease by 2020. In fact, DEFRA (2008) forecasts an increase of direct food emissions from UK sources. For indirect emissions (from land use change through deforestation), despite RTFO policy mechanisms dictating that biofuels increasingly come from more sustainable sources, the RTFO is nevertheless indirectly exerting international pressure on agricultural land use. This means that even if at one point all RTFO accredited biofuel were to come from sustainable sources, the RTFO policy mechanism could indirectly cause deforestation to occur for land used for food production, thereby either increasing the UK food carbon footprint, or the food carbon footprint elsewhere, or possibly both.

In the light of the analysis of transport and food policies presented here we see that without understanding the global implications and without understanding people's behaviour UK and EU climate change policy runs the risk of being counterproductive.

Waste

The disposal of biodegradable waste to landfill generates methane emissions, a potent greenhouse gas which exacerbates global warming (currently about 3% of UK emissions are from methane) (DEFRA, 2007). Notwithstanding the emissions, waste recycling and energy recovery from it can preserve virgin resources and reduce the use of fossil fuels and related greenhouse gas emissions (DEFRA, 2007). Current UK recycling of paper, glass, plastics, aluminium, and steel is estimated to save more than 18 million tonnes of CO_2 a year through avoided primary material production (Figure 4.1). Figure 4.1 also indicates that municipal waste is about a third of all UK waste including commercial, industrial and municipal. Most municipal waste is landfilled. Most recycling avenues can save carbon emissions (through replacing primary material production with production from recycled goods) whereas landfills create emissions (unless all landfill gasses are caught). Note: home composting and reuse do not appear in DEFRA's analysis of carbon dioxide impacts of waste treatment (DEFRA, 2007).

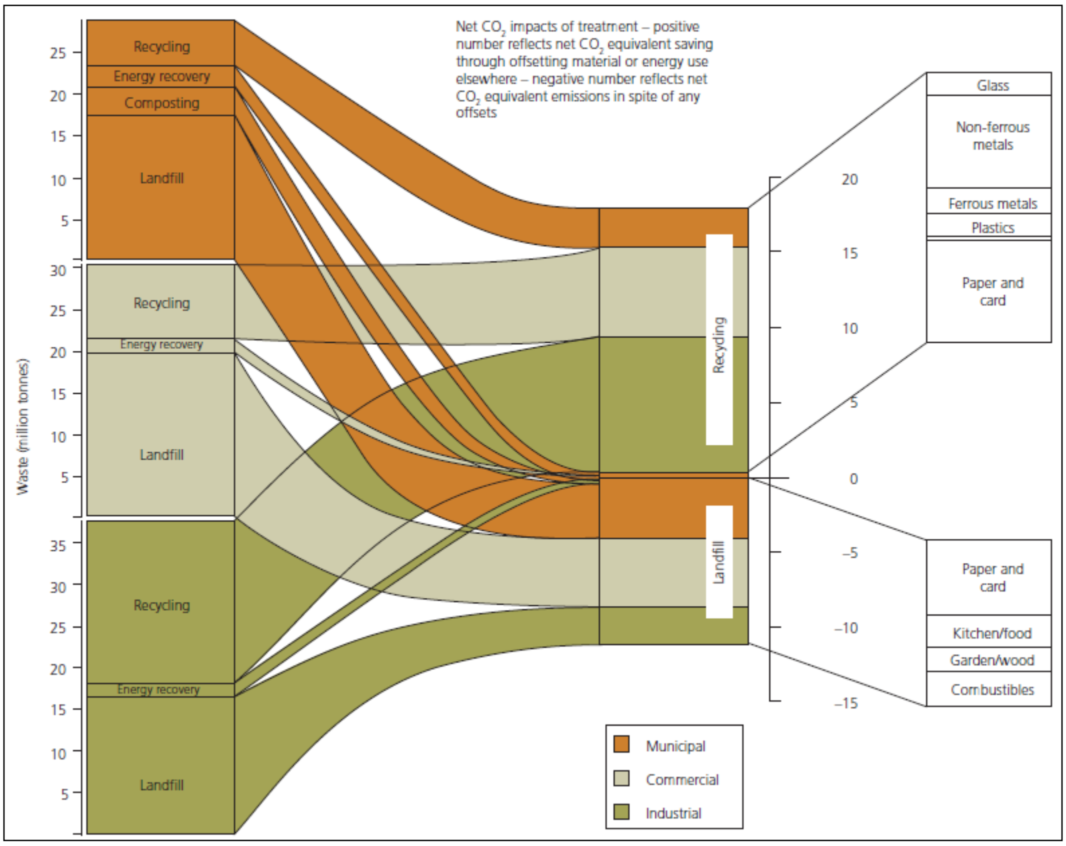


Figure 4.1 Greenhouse gas emissions from main waste sectors (Source: DEFRA, 2007)

The 2007 Energy White Paper (DTI, 2007) neglects to construct a comprehensive plan to reduce emissions from waste, although a number of renewable energy technologies using waste as an energy source will be subsidised through the Renewables Obligation (RO). These include anaerobic digestion, gasification and pyrolysis and energy from waste with combined heat and power (CHP). It is interesting to note that, in contrast to the 2007 Energy White Paper (DTI, 2007), the DEFRA (2007) Waste Strategy includes recycling and the avoidance of waste creation and forecasts carbon emissions from these by 2020. The lack of mention of recycling and waste minimisation 2007 Energy White Paper (*op cit*) allows us to speculate that cross-departmental climate change policy could be better integrated.

The 2007 DEFRA Waste Strategy (*op cit*) provides estimates for CO_2e emissions reductions by 2020 from municipal/household waste. Table 4.3 lists the incremental CO_2e emissions savings resulting from a number of measures. More than half of the forecasted savings of 7.6 to 16.6 $MtCO_2e$/year (minimum and maximum estimates respectively) are to come from a diversion of waste from landfill to recycling. A secondary role is played by the prevention of waste creation and the treatment of biodegradable waste through anaerobic digestion, gasification and pyrolysis. Waste incineration is not mentioned (Table 4.3).

Table 4.3 Carbon emissions reductions from household waste between 2007 and 2020, produced using data from the 2007 Waste Strategy (DEFRA, 2007)

Measure	**Carbon reduction between 2007 and 2020 (Mt CO_2e/year)**	
	Min	Max
Diversion from landfill to recycling	5.0	8.4
Diversion of biodegradable waste from landfill to other treatments (e.g., anaerobic digestion, gasification, pyearolysis)	0.8	3.4
Prevention of waste creation	1.8	4.8
Total	7.6	16.6

The following policies are in place to trigger these emissions reductions:

A. Landfill tax

The Government is using a number of tax measures to support its waste policies. The most important of these is the landfill tax, which increases the price of waste sent to landfill, thereby encouraging diversion of waste from landfills to more sustainable waste management (DEFRA, 2007). The standard rate of landfill tax applying to active wastes (those that emit), currently at £24 per tonne, has been increased by £3 per tonne in each of the past three years leading up to 2007 as part of the Government's 2002 aim, of reaching a rate of £35 per tonne (*op cit*). The landfill tax has been successful to some extent: overall quantities of waste recorded at landfill sites registered for the tax fell from around 96 million tonnes in 1997-98 to around 72 million tonnes in 2005-06, a reduction of around 25%. In the Budget 2007 (OPSI, 2007) it was announced that the standard rate of landfill tax would rise by £8 a tonne each year, from 1st April 2008 until at least 2010/2011 in order to encourage greater diversion of waste from landfill and the use of more sustainable waste management options. Increasing the tax to a higher level makes investments in alternative non-landfill treatments such as recycling and anaerobic digestion more economically viable. Waste producers will have a greater incentive to avoid the burden of increased tax on landfilling through diverting waste from landfill and by using separated waste collection services involving waste auditing and separation of waste at source. These will then become cheaper in comparison, leaving only residual mixed wastes requiring disposal (DEFRA, 2007).

However, while the landfill tax has resulted in a shift in landfilled waste to other forms of waste treatment, the landfill tax has had a relatively low impact on the total production and disposal of waste in the UK (Martin and Scott, 2003). This is particularly the case with municipal waste, which continues to grow at a rate exceeding that of economic growth (*op cit*). The main reason why the tax may have impacted less on the behaviour of domestic waste producers and disposal authorities is probably because the tax on municipal waste is not felt directly by the waste producers, so there is no financial incentive to recycle (Martin and Scott, 2003). Indeed experience from other countries shows that a municipal waste tax relative to a chosen bin size for non-recyclables can be effective in reducing municipal non-recyclable waste generation (Martin and Scott, 2003). In their Waste Strategy (DEFRA, 2007) the Government recognises this shortfall and proposes that Local Authorities incentivise householders to reduce the amounts of waste they do not recycle by following successful schemes from other countries. However, at present this is only a proposition and has not been implemented.

B. <u>The Renewable Obligation (RO)</u>

The Renewables Obligation (RO) is designed to incentivise the generation of electricity from eligible renewable sources in the United Kingdom (Mitchel et al., 2006; Toke, 2006). The RO places an obligation on licensed electricity suppliers in the UK to source an increasing proportion of electricity from renewable sources. The figure was initially set at 3% for the period 2002/03 and reached 6.7% in 2006/07 (Mitchel et al., 2006). Under current political commitments, the percentage will rise to 10.4% by 2011-12 then increases by 1% annually to 2017. Suppliers meet their obligations by presenting RO Certificates (ROCs). Suppliers who do not have sufficient ROCs to cover their obligation must make a payment into the buy-out fund. The buy-out price is a fixed price per MWh shortfall and is adjusted in line with the Retail Price Index each year. The proceeds of the buy-out fund are paid back to suppliers in proportion to the number of ROCs they have presented. Five percent of the total funds have been paid into the buy-out fund by defaulting supply companies (*op cit*). All electricity consumers in effect pay the cost of ROCs since electricity suppliers pass this cost on as a small increase in the tariff for the electricity they sell (Toke, 2006). The RO therefore financially rewards anaerobic digestion, gasification, pyearolysis, and energy from waste, whereas it does not reward recycling, reuse or waste reduction.

<u>Discussion</u>

Despite the fact that the UK and EU waste hierarchies have supported this for decades (Read, 1999), current UK policy structure lacks sufficiently effective mechanisms for arguably the most effective and important ways of reducing carbon emissions from waste: avoidance, reuse and recycling. While the Government is looking into such opportunities, there are currently no significant policy mechanisms in place to support these and the related behaviour change in households. The introduction of such policies is required if the emissions reduction targets proposed by the DEFRA Waste Strategy (2007) are to be achieved.

4.2.4 Potential savings by 2050 and gaps in current policy

In UK energy and climate change policy surprisingly little is stated about the role of behaviour and lifestyle change in reducing emissions. The 2007 White Paper (DTI, 2007) proposes encouraging personal responsibility through information campaigns and advice, but these are not quantified or specifically linked to other policy initiatives. Similarly, the DEFRA Waste Strategy (2007) touches on the opportunity of financially incentivising households to recycle, but there is no policy in place to do so.

Current policies targeting household carbon emissions reductions are therefore largely based on technical solutions. Only a few policies (e.g. energy performance certificates, billing information and real time displays, the road tax banding, fuel taxes) directly target behaviour change or lead to a change in lifestyle. Various research projects (Boardman, 2007; Hickman and Banister, 2007; Tight et al., 2005; Anderson, 2007; Audsley et al, 2009) have investigated how significant greenhouse gas emissions reductions (in the order of 60% to 80%), depending on the specific study, can be achieved by the UK within specific emissions categories such as direct home energy use, transport and food.

Boardman (2007) provides a strategy for reducing direct UK household emissions by 80% by 2050. She concludes that the involvement of the general public is critical to the successful development of a low-carbon strategy.

> *"It is people that buy equipment and switch it on and off, leave windows open and shut doors, and, in a host of other ways, affect the amount of energy used in their homes. Reducing energy demand and carbon emissions cannot be left solely to technology and Government regulations, although both have important roles to play. A complete change of perspective is required by the Government, so that 60 million individuals are seen as a major opportunity, rather than as a part of the problem."* (Boardman, 2007).

Hickman and Banister (2007) develop various policy packages, scenarios and pathways aimed at reducing transport CO_2 emissions. They argue that strategic CO_2 emissions reduction targets are very ambitious relative to current progress, and that more effective policy mechanisms with 'high-intensity applications' will get nearer to achieving these targets. Their paper concludes that a critical issue will be in communicating and gaining greater 'ownership' of future lifestyle choices with stakeholders and the public, and that participation tools could become increasingly important (Hickman and Banister, 2007). Tight et al. (2005) assess the contribution transport can make towards a 60% UK carbon emissions reduction target by 2050. They conclude that the scale of change required suggests that significant behavioural change will be needed to complement gains made through technological improvements and in order to avoid the rebound effect. Bow and Anderson (2007) argue that the high levels of growth of air travel cannot currently be reconciled with the UK Government's then 60% carbon emissions reduction target. Behavioural change towards a reduced use of air travel is essential (Bow and Anderson, 2007), especially when considering that the target has since been raised to 80%.

Audsley et al. (2009) have conducted a detailed review analysing whether and how a 70% emissions reduction from UK food supplies could be achieved. They conclude that both technology and consumption changes are required, including significant changes in what we eat. They also state that such lifestyle alterations can be positive and align with other policies, particularly health.

The aforementioned studies claim that this level of emissions reduction is achievable, but only through noteworthy behavioural changes. Many opportunities identified in these studies focus on or include an element of behaviour change. For example, reducing car travel and changing one's diet involve a direct change in behaviour, whereas recycling more waste or building homes with low carbon building materials are technical solutions which require an amount of behaviour change: i.e. separating waste activity and changing the look and possibly design of the home.

There seems to be an opportunity for reducing carbon emissions through greater focus on behavioural change as an integral part of the overall solution. It is therefore interesting to explore the significance of what can be achieved when behaviour change is included, and whether this can lead to more beneficial solutions for UK individuals and households than the current largely technically-focussed approach of the Government. The "lifestyle approach," which includes both technical and behavioural solutions in an integrated way, aims to identify lifestyles that lead to the greatest carbon emissions reductions with the fewest compromises to UK citizens.

4.3 Opportunities presented by a lifestyle approach

Frequently it is possible to reach an environmental objective, such as reducing household waste, through various actions, which affect people's choices and thereby triggering lifestyle changes (Weber and Perrels, 2000). For example, when individuals respond to encouragement to use mass transit, to insulate their homes, or to install programmable thermostats, carbon dioxide emissions can be reduced. Waste reduction can be promoted through source reduction, reuse, or recycling (McKenzie-Mohr, 2000). In this section the benefits of studying emissions and solutions from such a lifestyle perspective, which by default is fully inclusive of both technological and behaviour changes, are discussed and compared to the Government's sectoral approach. Both approaches are compared and critically evaluated. Specific opportunities in new housing in the UK are also reviewed.

4.3.1 Defining lifestyle

Lifestyle is a term to describe the way a person lives; it was originally coined by Austrian psychologist Alfred Adler in 1929 (Harper, 2010). The current, broader use of the word dates from 1961, and refer to a set of behaviours, and the sense of self and belonging which these behaviours represent (Harper, 2010).

A lifestyle is a characteristic bundle of behaviours that makes sense to both others and oneself in a given time and place, including social relations, consumption, entertainment, and dress (Harper, 2010). The behaviours and practices within lifestyles are a mixture of habits, conventional ways of doing things, and reasoned actions. A lifestyle typically also reflects an individual's attitudes, values or worldview. Not all aspects of a lifestyle are entirely voluntary (*op cit*). Surrounding social and technical systems can influence the lifestyle choices available to the individual and encourage or discourage certain behaviours (Spaararen and VanViliet, 2000). Therefore, a chosen lifestyle results from a mixture of personal choice and environmental parameters. Lifestyle choices are also influenced by the symbols an individual wants to project or the ideals they choose to live by. For example, a "green lifestyle" means holding beliefs and engaging in activities that foster mutually beneficial relationships between humans and the natural world and deriving a sense of self from holding these beliefs and engaging in these activities (Ropke, 1999). This may involve reducing one's carbon footprint by consuming fewer resources and producing less harmful waste for example (Ropke, 1999).

4.3.2 A lifestyle approach as a stepping stone for a low carbon society

Various national and international agreements, legislation, and targets have been put in place to tackle climate change. Whilst climate change scientists generally agree that these may be too small and too late, it is also the case that many countries are not on target to meet them, the UK being one example (de Boer, 2008).

The main barrier towards tackling climate change is not that its science is not well enough understood (Porritt, 2006; Marshall, 2007). Indeed, it is widely accepted that Climate Change poses a serious potential threat to humanity (DEFRA, 2006a; SDC, 2006; WEF, 2006; Marshall, 2007). The approximate emissions threshold beyond which we need to stay to avoid dangerous climate is also well understood. Technical solutions to achieve these reductions are available but the main barriers are psychological, cultural, socio-political and economic (Porritt, 2006). It is about giving up the major subsidy that the use of fossil energy provides for our current activities at the potential cost of our future survival. It is about the will to make major paradigm shifts to achieve the low carbon economy, and about the belief and confidence that this is possible on which basis people may choose to take the next steps (Porritt, 2006; Giddens, 2009; Marshall, 2007).

Once a common vision for a low carbon future becomes stronger than the fear of giving up a carbon intensive lifestyle, a political momentum enabling the required political and structural changes could take place (Porritt, 2006; Giddens, 2009). This is important, because due to the time lag of the ecosystems reacting to anthropogenic emissions (Chapter 2), it is important to set in motion the political momentum before the full consequences of our actions are felt (Giddens, 2009; Leggett, 2000; Lovelock, 2006).

The challenge is therefore to create a positive vision for a low carbon lifestyle. As a basis for creating this vision it is important to understand the full implication of one's decisions upon climate change. Dividing carbon emissions into various components of lifestyles (such as direct home energy use, food, consumables, travel, commuting, etc) rather than into country sectors (domestic, transport, commercial, industrial) may facilitate understanding of how one's choices affect one's carbon footprint. It is a way to communicate that carbon emissions relate to one's daily life and technology choices, rather than it being something outside individuals' control. A lifestyle approach may therefore potentially advance the understanding of a low carbon future among the public, politicians and industry. As a result people, companies and politicians may be able to make choices towards enabling a low carbon future.

4.3.3 Benefits of a lifestyle approach towards tackling climate change

Although it is widely agreed that societal energy consumption and related emissions are not only influenced by technical efficiency but also by lifestyles and socio-cultural factors, to date few attempts have been made to operationalise these insights in simulation models for future energy demand (Webber and Perrels, 2000). None are available for new build housing developments. As a result developers are unable to make informed choices based on the carbon implications of their design decisions (James and Desai, 2003). This lack of focus on lifestyles is reflected in many governmental and international scientific and policy documents: In SAR (Second Assessment Report) of the IPCC (IPCC, 1996) lifestyle changes were not discussed at all, for example. In the UK 2003 and 2007 Energy White Papers (DTI, 2003; DTI, 2007) such awareness raising activity is limited to energy efficiency in buildings, renewable energy, and transport.

This has led to the unsatisfactory situation that in spite of a broad consensus on the importance of lifestyle effects for the development of a low carbon society in general (e.g., Duchin, 1996; Loske et al., 1996) and energy demand in particular (e.g. Schipper et al., 1989; Baranzini and Giovannini, 1997; Williams and Dair, 2007; and Weaver et al., 2008), the extent of these influences is not fully understood (Webber and Perrels, 2000). Several studies in recent years have investigated aspects of the lifestyle-energy interaction by developing comprehensive but basically non-quantitative concepts (e.g., Wilhite and Shove, 1998; Wilk, 1999; Williams and Dair, 2007) or focussed on specific issues like market segmentation (e.g., Prose and Wortmann, 1991; Schoenheit and Niedergesaess, 1995) or appliances (Boardman et al., 1997). Also, the so-called household metabolism concept (Noorman, Schoot and Uiterkamp, 1998; Biesot and Noorman, 1999), despite its comprehensive potential, focuses only on certain aspects of carbon emissions resulting from households. Hence, for UK housing specifically and climate change policy more generally a methodological gap remains between the perceived importance of lifestyle and socio-cultural factors and the quantitative scenario analyses/policy.

An additional benefit of the lifestyle approach is that by considering solutions through a lifestyle perspective (i.e., how will this choice affect livelihoods) it directly incorporates social and economic considerations into the debate, and through this it automatically connects climate change and wellbeing. It enables people to imagine what a low carbon lifestyle could be like, permits one to develop a vision, choose a low carbon future that both improves livelihood and reduces emissions. As such, this approach may allow for more appropriate decisions towards sustainable development than previous approaches. It may also serve as a foundation for a greater acceptance of climate change policy.

The lifestyle approach is potentially easy to understand and relate to by the general public, which means that in a democratic society it has the potential to significantly impact in terms of tackling climate change. In a democratic society the formulation of policies is affected by a general consensus (Porritt, 2006). An educated population is considered to be the basis of an effective democracy (Porritt, 2006). Through accounting for emissions in lifestyle categories, the lifestyle approach eases and enables such education. At the conceptual level both the economic mainstream and modern democracies postulate the citizen/consumer as ultimate sovereign; therefore, a modelling approach that places the citizen/consumer at the centre may give this perspective a legitimate standing in the political process.

4.3.4 Lifestyle approach versus the Government's sectoral analysis

As we have discussed in this chapter, the UK Government accounts for its carbon emissions in four distinct sectors: domestic, commercial, industrial, and transport. Similarly, all climate change policies are subdivided into these sectors. This sector-specific division is limiting and, as exemplified below, can lead to underestimation or a lack of understanding or recognition of the carbon emissions that are the responsibility of UK citizens.

With the sector-based accounting some carbon savings opportunities may slip between the gaps, because the link between consumer and supply chain is not immediately evident. For example, the emissions reduction of manufactured products would fall into the category of industrial emissions, and within these confines the solution is limited to producing the same product in a way that emits less carbon. In contrast, from a consumer perspective (a lifestyle approach) several opportunities would arise, including a more efficient manufacturing process, but also sourcing goods from places where they can be transported with less emissions (e.g., lower distance, lower carbon mode of transport such as by ship), or the use of an alternative good or service (e.g., using alternative materials) which fulfil the same or a similar function. The lifestyle approach can go even further and take a broader, more holistic look and question the function/need and if there is a better approach.

Another major issue is that Government statistics do not consider the carbon impact of consumables imported into the UK (Chapter 3). DEFRA (2005) quotes the per capita CO_2 emission at 9.3 tonnes of CO_2 per person per year, whereas our analysis in Chapter 3 shows that they are significantly greater when including emissions associated with imported goods, but excluding emissions resulting from exported goods. This leads to a misrepresentation of carbon emission statistics, specifically in areas such as food and air travel where most emissions which UK residents are responsible for happen outside the national boundaries. Although DEFRA state that the UK is on course to meet its Kyoto targets, in reality the carbon impact is likely to have been increasing as more and more food and manufacturing products have been imported (Chapter 3). The Government accounting system therefore leaves a large gap for global carbon emissions saving potential, which is directly related and can be influenced through lifestyle choices of UK citizens.

These two factors may pose substantial limits upon the Government's ability to identify and choose the most appropriate carbon emissions reduction opportunities. For example, there is no place where local governments can claim credits for carbon emissions reductions triggered by setting up local farmer's markets despite the high probability that the impact on carbon emissions through a shift from packaged, processed and imported produce to locally-grown fresh produce may be substantial.

Our review of the UK 2003 and 2007 Energy White Papers (DTI, 2007) and the 2006 Energy Review (DTI, 2006) show that the issues identified here are indeed problematic. The aforementioned documents describe the main areas where the UK Government is delivering carbon emission reductions:

1. in domestic and commercial building energy efficiency measures,
2. supply from low carbon or carbon-free generation,
3. from making industry, transport fuels and vehicles more energy efficient,
4. transport modal shifts,
5. and the introduction of a transport emissions trading scheme.

They omit, however, cross-sector and cross-national opportunities, such as:

a) air transport,
b) sustainable and logistically sensible city planning,
c) food miles,
d) embodied energy in material, packaging and recycling.

These cross-sectoral and cross-national opportunities are only addressed through carbon pricing and energy and carbon taxation Through this the UK largely limits its options to the delivery of the same infrastructural service, consumable good or building with less carbon emissions and is currently not opening up to a cross-sectoral view in which structural changes, changes in consumption patterns, logistics operations, or lifestyle choices can also be covered.

If the UK aims, in the words of Tony Blair, “to aspire to global leadership in climate change” (Blair, 2004), a lifestyle approach could demonstrate political integrity as well as allow for further opportunities to be taken to develop a low carbon economy. On this basis it may be possible to make policy more effective and deliver emission reductions in a more cost effective and socially supportive manner.

Whilst accounting for emissions from a sector specific perspective and neglecting emissions outside the national UK boundaries may be simpler to do, this approach does not recognize that climate change is a global problem and that the UK economy and society is an intrinsic part of the world economy. From this perspective we here argue that it is essential to be clear about the direct responsibility of UK residents to climate change, and therefore it is important to quantify their direct impact upon the climate and on this basis be able to identify avenues to reduce this adverse impact.

4.3.5 Design of housing developments and lifestyle

To be sustainable, housing developments need to be technically sustainable (i.e., in terms of materials, construction methods, energy efficiency, renewables, etc.) and to support behavioural sustainability by their residents throughout the building’s lifespan. Houses in the UK have had an average lifespan of about 140 years (Kimata, 1999). Therefore, it is highly important that new housing is able to support the different lifestyles of future residents and encourage all these varied lifestyles to be low carbon. The way housing developments are designed affects lifestyle choices and related emissions in many ways (Desai, 2009); they can make it easier to be green. Some examples are:

a) If a mix of housing, work and amenity spaces are designed into the development, or the location of the development is chosen in proximity to such locations, commuting and recreation travel distances can be shortened (Larus, 2003b). Through this, transport emissions are then reduced.
b) Location of car and bicycle parking and safe cycling and pedestrian access can be designed-in and thus affect the choice of residents for a high emissions (car)

(Larus, 2003b; CLG, 2009) or low or zero emissions (bicycle, bus, walk) mode of transport.

c) A PassivHaus design[4] requires the user to operate their home in an efficient way. In contrast to other energy efficient designs (Krainer, 2008), with PassivHaus it is not possible to keep windows open and turn up the heating. By default, residents may learn to operate their homes efficiently in order to stay warm and comfortable. Preliminary evidence on the performance of PassivHaus from Schneiders and Hermelink (2006) supports this assumption.

d) Easy to use and conveniently located recycling facilities (bin storage inside and outside) and support with recycling can enhance people's willingness to recycle (Williams and Dair, 2007).

e) Provision of low carbon consumables (e.g., a weekly local farmer stall on site, or a shop which sells local fresh food and recycled goods, etc) can make it easier for residents to choose such products (Gill, 2005; Bioregional, 2009). This can be combined with information provision to raise awareness on the health and global benefit of the choice of the sustainable consumable good.

Technical sustainability of housing is widely understood and legislation is in place to ensure minimum levels of energy efficiency (Part L of the Building Regulations), but less is known about the link between design and behavioural sustainability (Williams and Dair, 2007).

Williams and Dair (2007) looked into the opportunities for supporting behavioural sustainability through the design of housing developments. The purpose of their study was to verify the claimed relationship between design features and eight particular behaviours. These behaviours are: use less energy in the home; use less water in the home; recycle waste; maintain and encourage biodiversity and ecologically important habitats; make fewer and shorter journeys by fuel-inefficient modes of transport; make essential journeys by fuel efficient modes of transport; take part in local businesses. They identified both theoretical and empirical evidence in support of the claimed relationship in all the behaviours.

4.4 Overall Discussion and Conclusions

Government policy on climate change in the domestic sector currently focuses largely on new homes. Minimum requirements for energy efficiency (and in many cases, renewables) are in place for new homes and enforced through the planning and building regulation approval process. Further commitment to sustainability and carbon emissions reductions can turn planning officers in favour of granting planning permission. It is more

[4] The term 'PassivHaus' refers to a specific construction standard for buildings, which are highly energy efficient and have excellent comfort conditions in winter and summer. A dwelling which achieves the PassivHaus standard typically includes: very good levels of insulation with minimal thermal bridges, well thought out utilisation of solar and internal gains, airtight, albeit good indoor air quality, provided by a whole house mechanical ventilation system with highly efficient heat recovery (Krainer, 2008).

difficult to regulate for improvements in existing homes, and at present, Government is predominantly only using subsidies and incentives to do so. The 2007 White Paper (DTI, 2007) estimates the carbon emissions reduction potential by 2020 for the four sectors individually, giving a variety of scenario outcomes for the proposed policies. Scenarios and policies are based largely on technological improvements and shy away from targeting any significant behaviour change. Although the 2007 Energy White Paper (*op cit*) does not explicitly mention it, when individually summing the savings, only the most optimistic high impact of the Paper's policies' scenario is forecast to achieve the necessary 26% CO_2 emissions reductions level (on 1990) by 2020, and only when emissions allowances purchased from abroad through carbon trading are included (DTI, 2007). This 26% figure does not account for emissions from aviation and shipping and emissions abroad on behalf of UK residents (DTI, 2007). Importantly, it is clear that the absence of policies intended to trigger lifestyle changes may yet again lead to a future policy framework that fails to reach its 2020 and 2050 CO_2 emissions reductions targets.

Various examples have been listed here where it is unlikely that the specific policy will succeed in meeting the emissions reductions target forecast in the White Paper (DTI, 2007). Incentives to change behaviour and lifestyle are scarcely mentioned in any of the policy incentives listed. The food sector is given scant consideration, even though its emissions footprint is highly significant. Possible explanations for under-emphasis may be:

a) A lack of understanding of the food carbon footprint
b) Much food is imported into the UK and therefore its production and most of its transport emissions are not counted in UK statistics.
c) Methane and nitrous oxide play a significant role in waste production within the agricultural sector. At present the UK climate change target for 2010 refers to CO_2 only.
d) Diet may be seen as a politically controversial issue. Citizens and lobby groups may be opposed to the idea of having to change their diet (for example, eating less meat, or drinking less milk) in order to meet climate change targets (Rifkin, 1992).

The main findings relative to current policy are that:

1. Policy affecting the carbon emission footprint of households is based largely on technical improvements rather than lifestyle changes.
2. It is unlikely to achieve the UK Government's 2020 CO_2 emissions reduction target of 26% over 1990 levels (and the 80% reduction by 2050).
3. For new homes, carbon emissions limits from direct home energy use are legislated for and certain limits must be achieved through design. However,

there is no such (or similar regulation) for existing homes, transport, or carbon embodied in building materials.

4. Whilst there are many opportunities to reduce carbon and carbon equivalent emissions through behaviour change, very few of the current policy mechanisms focus on these.
5. The UK as a significant role in causing emissions directly and indirectly outside of its national boundaries and its Government is currently not accepting full responsibility for addressing these.

The proposed policies in the White Paper are not sufficient to put us on track to meet the 80% reduction by 2050, especially when all emissions that the UK is responsible for are included. It is problematic that we are presently targeting the politically easy wins. Therefore one could argue that emissions reductions should be steep now and level out towards 2050, when the more expensive measures or those more difficult to implement have to be targeted. Instead, the opposite is true: to meet the 2050 target, emissions reduction achievements will have to accelerate from their current trend.

A consumer-based emission accounting methodology could impact on the effect of lifestyle choices in relation to emission changes. It could be used to raise public awareness on climate change solutions and the role that each individual can play in contributing to the solution. In contrast, the sector-based approach used by Government may be one reason for the lack of cross-sector, cross-national and behavioural change policies, which address climate change.

New housing provides opportunities to introduce low carbon technology and also change lifestyles as many decisions, which effect lifestyle are made as the developments are designed. In addition, private sector opportunities may be more likely to arise in new housing as currently in the UK there are a number of regulatory support mechanisms in place to support this change in the new build sector (Section 4.2.2). There is a great need to reduce carbon emissions from existing housing stock and there are significant opportunities to do so, but new housing opens many relatively easy opportunities to change lifestyles that are likely to be more difficult to achieve in existing housing. In new housing it is possible, for example, to design-in ecological habitats, recycling facilities, mixed-use development with work opportunities on-site to reduce transport emissions, and commercial spaces to sell and promote ethical low carbon consumables. These opportunities may be more difficult to implement in an existing community in which design solutions are constrained by existing structures. Junctures of major life changes such as a new job or moving house provide chances for people to break existing patterns of behaviour (Jackson, 2005). Therefore, because individuals who move into new housing developments are, by definition, at a crossroads, an opportunity presents itself to affect the behaviour of a whole community at once. We continue our investigation of the carbon impact of lifestyle solutions in new UK housing in Chapter 6. The next Chapter (Chapter 5) describes the overarching methodology of the thesis.

5. Methodology Overview

5.1 Chapter overview

This chapter gives a brief overview of the methodologies used in the remaining thesis. Precise details and justification of each of the approaches used are given in the appropriate chapters.

5.2 Research objectives and summary of methods

From the literature review it is clear that the contribution of behavioural measures to carbon savings can be significant and need to be exploited for an 80% emission reduction target by 2050 to be achieved (Chapter 4).

New housing is an opportunity to affect behaviours, but no one has looked specifically into the role that new housing can play in changing behaviours and lifestyles and the carbon emissions that can be saved through this. We are here looking at opportunities, which may have market potential, opportunities that could realistically be applied and that house builders may actually be convinced to implement.

Our research has the following objectives:

1. To assess and compare the ability of behavioural and technical measures to save carbon emissions in new housing developments.
2. To identify alternative possibilities to develop housing in the UK, possibilities which may be better at reducing carbon emissions and increase sustainability.
3. To assess the perceived feasibility of eco-self-build housing communities their potential to deliver low carbon lifestyles.

The following research methods were applied in this endeavour:

A. In order to assess and compare the ability of behavioural and technical measures to save carbon emissions, a calculation tool called the Climate Challenge Tool (CCT) is developed. This tool allows us to calculate the life-cycle emission and cost implications of various options available to property developers and community groups building their own homes.

B. Alternative options to the way housing is conventionally developed in the UK for creating low carbon communities through housing development are reviewed and discussed through a focus group.

C. The perceived feasibility of a business opportunity of eco self-build communities is assessed through a stakeholder survey and the potential for eco self-build communities to enable low carbon and sustainable lifestyles is discussed.

These methods are described in more detail in Section 5.3, 5.4 and 5.5.

5.3 Quantifying the contribution that can be made by lifestyle options

A tool was needed which enables the sponsoring company Camco to assess, quantify and compare the carbon and cost implications of technical and behavioural measures which save carbon emissions in new housing developments. Before we developed the tool it was necessary to decide the scope, purpose and required output of the tool. These were decided through a focus group discussion. The focus group members were relevant Camco staff and clients. Emission categories were set by the focus group based on literature findings and the expertise of the focus group members, focussing on categories, which are significant and can be influenced by choices the developer can make. Carbon savings options, which had been applied, to other progressive housing developments, were allocated to each category.

Other tools available in the UK were then reviewed to decide whether a tool already existed that we could use to provide the chosen attributes. As none of the tools considered met the specified criteria it was considered necessary to develop a tool.

An excel spreadsheet tool the Climate Challenge Tool (CCT), was built using empirical and theoretical data from existing databases and literature to assess, quantify and compare cost and carbon implications of the proposed options. To give an idea of the difference the suggested solutions would make to overall household carbon emissions the baseline household carbon emissions of a UK household in an existing and newly build home were also assessed for each category.

To improve accuracy multiple data sources were used to calibrate results. In addition bottom up calculated results were validated by comparing outputs against literature findings and outputs from other tools.

A case study development was used to pioneer the use of the CCT through assessing and comparing two carbon emission reduction scenarios. In order to do this, assumptions about the case study site were made and this data was used as input for the CCT spreadsheet.

The initial result were presented to a second focus group composed of CAMCO staff (Tool Focus Group 2). This focus group discussed and defined the residents' acceptability, social impact and practical implications of each measure, and reviewed how the results should be presented.

These steps are described in further detail in Chapter 6. A summary of the main steps and methods used for each step is provided in Table 5.1.

Table 5.1 Main Steps and Methodologies used to develop the Climate Challenge Tool

Step	Method
1. Define Purpose and Criteria for the Tool	Tool Focus Group 1
2. Check against existing tool	Literature and checklist

3. Design the Tool	Build spreadsheet Tool using literature search and existing databases.
4. Calibrate/Validate the Tool	Check against other tool and literature findings
5. Model case study scenarios	Set assumptions, input data into spreadsheet
6. Review resident's acceptability, social impact and practical implications and presentation of results	Tool Focus Group 2

5.4 Investigating the extent to which different housing development approaches facilitate low carbon lifestyles

A literature review was undertaken to better understand the role the local community can play in driving low carbon lifestyles. The conclusion from this literature review as well as the tool findings (as described in Chapter 7) were presented to a focus group who then set out to brainstorm potential new housing business opportunities for driving low carbon lifestyles and involving the local community and future residents to do so.

5.5 Assessing the perceived feasibility for Eco-self-build communities

The focus group described in Section 5.4 selected Eco-self-build communities as a potential business opportunity, which may drive low carbon lifestyles to be studied in greater detail. Chapter 8 describes this study in detail. Stakeholder interviews and literature were used to develop a business model for Eco-self-build communities and assess the perceived feasibility of this business model. A semi-structured approach and the long interview technique developed by McCracken (1998) and recommended by Mullins (2007) for assessing and developing new innovative business models was used. The interview scripts were analysed using ethnographic content analysis using guidelines by Glaser and Strauss (1967) and Wood (1992). More detail about this methodology is provided in Chapter 8.

5.6 Conclusion

This chapter gave a brief summary of the overarching methodology described in three parts:

1.the development of the Climate Challenge Tool to assess cost, carbon savings and resident implications of technical and behavioural carbon savings options for new UK housing developments,

2. the discussion of alternative business models for new housing which may facilitate low carbon lifestyles.

3. the assessment of the perceived feasibility of eco-self-build communities and its ability to drive low carbon lifestyles.

The next chapter (Chapter 6) will investigate the carbon impact of lifestyle solutions in new UK housing.

6. Assessing the carbon that can be saved in new housing and the associated costs

6.1 Chapter overview

This chapter concerns the reduction of greenhouse gas emissions through the design, organisation and set up of housing developments in the UK. In Chapter 4 it was observed that current policy mechanisms to reduce carbon emissions from households are largely based on technical solutions, specifically, energy efficiency and renewable energy systems; we argued that this approach may not sufficiently contribute to the necessary carbon emission reductions required to meet UK Government targets and thus avoid dangerous climate change. The Climate Challenge Tool (CCT) is developed and applied in this chapter; the tool calculates whole life carbon equivalent emissions and costs of various carbon and energy reduction options that can be incorporated into the design of new developments. The CCT is able to calculate technical and soft (behavioural) measures, covering energy used in the home, energy embodied in the building materials, and emissions generated through transport, food and waste treatment. In this thesis the tool is used to assess the potential and cost-effectiveness of various carbon reduction options for a proposed new housing development in Cambridgeshire. The assessment results show the relative cost effectiveness in achieving carbon emissions reductions when using a lifestyles approach compared to an approach focussed purely on reducing or eliminating the carbon footprint of the direct home energy use. Other wider impact of the lifestyle approach upon residents are also evaluated.

Findings presented in this chapter were published in Broer (2006), Broer and Titheridge (2009) and Broer and Titheridge (2010a).

6.2 Introduction

New homes are a relatively small component of the UK housing stock; by 2050 they are forecast to comprise between one quarter and one third of the housing stock (Boardman, 2007). However, as discussed in the Chapter 4 (Section 4.6), whilst low carbon lifestyle changes can occur across all parts of society, new housing presents a significant opportunity in the UK to impact on lifestyle since many decisions which affect lifestyle (such as transport planning, waste disposal and food provisions) can be made as the housing development is designed. In addition, because the current policy framework (Chapter 4) has a strong focus on reducing emissions and energy consumption in new homes, there may be private sector opportunities for reducing emissions in new housing that are already driven by the current policy framework. On the basis of this new UK housing was selected for detailed analysis of the opportunities for carbon emissions reduction presented by incorporating features that encourage low carbon lifestyle change.

To understand the emissions reduction opportunities, a tool is needed to calculate the overall carbon savings achievable with particular options for new housing communities. The tool needs to be able to apply a lifestyle approach to reducing carbon equivalent emissions in new housing. By lifestyle approach we mean the combination of both technical and behavioural solutions in an integrated approach, including not only energy directly used in the home itself, but also other significant household emissions categories. In other words, the tool must not only be able to calculate emissions from energy used directly in the home (electricity, gas and other fossil fuels) but also include emissions generated from household lifestyle and behavioural choices: from the energy use within the home, to the types of travel residents make, their food purchases, and the amount and means of waste disposal/recycling. On this basis the house builder or property developer can then make an informed decision as to which option has greatest impact upon mitigating climate change at the least cost implication. House builders should then be able to proactively reduce carbon emissions throughout the supply chain in a way that also delivers financial benefits over time. Combining such quantitative analysis with a qualitative analysis of the implication of each option upon the residents can be used as a basis for designing more sustainable low carbon housing communities. To a house builder this is attractive both from a PR perspective, and also it may help them gain planning permission. In addition the tool can support ethically driven house builders to demonstrate and implement their environmental aspirations.

Furthermore, based on the tool outputs policy makers should be better able to formulate sensible policies for new housing, which take account of both the end consumer as well as the overall carbon emissions implications of their policies.

6.3 Purpose of the Tool and necessary Criteria

Hence, a tool is needed which can:

A) assess the relative merit of lifestyle options compared to technical fixes alone, and can evaluate if, and to what extent, a lifestyle approach can achieve greater carbon savings for new housing developments, and
B) be used by the sponsoring company Camco to support its work with house builders advising them on sustainable energy and low carbon solutions.

The tool is aimed at helping Camco to produce sustainability statements for housing developments. These sustainability statements are required by Local Authorities and Camco is regularly is commissioned by house builders to write these for them and with this help house builders to choose and implement sustainability solutions.

A focus group (referred herein as Tool Focus Group 1) was convened within Camco to decide on the tool's necessary attributes. Six members of staff attended, all of whom work as consultants advising housing developers on sustainable energy and sustainability matters. They were chosen for their level of seniority and experience in this role. The focus group method seemed to be a reasonable way to do this, as focus groups are appropriate means for understanding the issues, and achieve consensus through exchanges between relevant experts around the key requirements of a project (Krueger and Casey, 2009).

The following topic guideline was used:

1. Discussion of house builder priorities and their reasons for choosing sustainability measures.
2. Review and analysis of the barriers to greater sustainability action, opportunities to overcome these barriers, and make a significant leap towards greater sustainability performance within the constraints of the current market. The role of Camco and the criteria for a Tool to be used by Camco in its supportive role for house builders during this transition.
3. Agreement on a framework for the tool and the details, which should be included.
4. Discussion and consensus regarding the presentation of the results of the tool.

Following the focus group meeting the minutes and agreed criteria for the tool were emailed to focus group participants. They were asked to confirm if they had been correctly represented and were happy with the proposed criteria for the tool. This resulted in a few refinements being made to these criteria.

When discussing the priorities of house builders and reasons for choosing sustainability measures, it was concluded that developers are under pressure to save money and therefore, in addition to quantifying the carbon emissions, it would be useful to understand the cost implications of the evaluated opportunities. Participants agreed that the second priority of house builders is to obtain planning permission and the main driver for sustainability in new UK housing is the legal framework and the need for the developer to prove to the local authority that sustainability is being addressed in order to gain planning permission.

The discussion led to new opportunities, which are not normally included in the sustainability or low carbon strategy Camco produces for housing developments. It was noted that particularly for behaviour change measures, carbon emissions implications are less well understood, but some of these may be relatively easy and may cost little to implement. It was decided that it would be useful if the tool could include both technical and behaviour options which have a technical and behavioural element. Participants mentioned that developers need to prove to local authorities that they are taking sustainability and climate change seriously, and that they deliver on requirements and other desirable criteria listed in the Local Plans and policy literature. To gain planning permission, it also helps them to show that they have followed a rigorous methodology upon which their sustainability and low carbons strategy is based. Therefore the tool quantifying costs and carbon needs to be able to demonstrate rigour. Moreover, the social impact on the residents should be included in the assessment for further coverage of some of the wider sustainability aspects. Using the carbon and cost evaluation of each measure should enable the comparison between the options on the grounds of environmental cost effectiveness. This will allow developers to prioritise the most cost-effective measures, thereby saving money whilst promoting low carbon living, and pleasing the local authority.

The level of detail, which the tool should provide, was also discussed. The Focus Group members agreed that, in order to be able to roll out sustainable energy strategies costs effectively focus had to be on the most relevant information. This would also have the advantage that the strategy would quick to read and easy to understand by both the developer and the local authority. Therefore, the tool inputs and outputs should focus on the main issues: carbon, costs and residents' impact. Other sustainability considerations can be included where these are significant. The group considered that many practical implications of the tool are site-specific and should be part of individual projects rather than outputs of the tool.

Another major component of the discussion was to decide which emissions categories should be included. Desai's (2005) lifestyle categories and proportional split of the typical UK resident's carbon footprint together with its analysis in Chapter 4 (Section 4.2.3) was used to identify areas where significant emissions reductions could be realised through sustainable housing developments: direct home energy use, building materials, personal transport, household waste, and food. Water was also considered for inclusion as a separate category but was later ruled out as literature search proved it to be insignificant.[5] However, because there are significant emissions from heating water, these were included in the direct home energy category under energy efficiency. It was agreed that the main transport category that a developer could influence is commuting transport, through providing or supporting means of sustainable transport, and through building homes close to workspaces. In contrast a developer has little means of effecting business and leisure travel. Therefore transport from commuting was selected to be included. For food and waste it was decided to draw the boundary to only include household waste and food consumed within the home itself.

The last part of the discussion focussed on the presentation of the results of the tool; it was decided to compare the achievements of the low carbon housing development with the carbon footprint of a typical UK household. In addition, the environmental cost-effectiveness £/CO_2e saved would be shown on a bar chart for each option, visually displaying the basis for selection. The description of the measure and qualitative social impact assessment would be brief, easy to understand, and provide visual information to attract the reader.

[5] Treating, storing and transporting tap water including fresh and waste water treatment only contributes about 0.5% to the total greenhouse gas emission footprint of the UK (Hickman, 2007; Camco, 2009c).

The final main attributes for the Climate Challenge Tool are to:

1. provide a ratio of £ invested per tonnes of CO_2e saved for each option,
2. cover technological and behavioural options,
3. compare the carbon savings to those of a typical UK household,
4. include major carbon emissions categories for housing developments: direct home energy, building materials, transport from commuting, food consumed in households, and household waste,
5. carry out a qualitative assessment of the impact on the residents.

At this stage it was decided that once a tool was developed a second focus group (Tool Focus Group 2, described in Section 6.5) comprising of Camco consultants and property developers would be convened in order to review residents' acceptability, social impacts and practical implications of each measure.

6.4 Carbon Emissions Assessment Tools

Before deciding to develop a tool, a review was conducted of tools currently available to practitioners for calculating energy or carbon emissions. Tools were reviewed on the basis of how well they met the attributes chosen in Section 6.3, in order to understand whether a tool already existed that could be used for or to support our purpose.

1. Does the tool calculate the life cycle CO_2e emissions and life cycle costs of different measures and options available to house builders? This information then enables proposed options to be ranked according to the amount of CO_2e saved per £ invested.
2. Does the tool allow a wide variety of measures to be considered, including measures, which promote behavioural change, such as car sharing?
3. Does the tool allow the user to compare the carbon footprint of the dwelling (or development) being assessed with that of a typical UK household?
4. The scope of the tool, specifically: does it include all direct energy used in the home, energy embodied in the building envelope, energy used in the production of the food and other goods and services used by the household, energy used for transport of the residents, and for household waste disposal?
5. Does the tool account for the wider impacts of any measures on future residents of the buildings and the acceptability of these measures to potential residents?

The list of tools reviewed here is by no means exhaustive. However, it includes the main tools used at present and readily available in the UK to assess the sustainability of housing developments and communities. These are reviewed here and can be grouped into three main categories:

1. Tools for general sustainability assessments such as life cycle analysis (LCA) and life cycle costing (LCC), ecological footprinting.

2. Tools that assess the sustainability of homes themselves, such as the Code for Sustainable Homes, EcoHomes, Envest, SAP, and Energy Certificates.
3. City-wide energy and emissions assessment tools such as TEMIS, Dream-City, Tranus, EEP.

Life cycle analysis (LCA) encompasses all the environmental impacts through the life cycle of a product, but does not include cost impacts, whereas *life cycle costing* (LCC) investigates the cost implications throughout the whole life cycle. LCAs sometimes include emissions inventories that can account for carbon emissions. However, as LCA and LCC are separate assessments, it is not possible to study the cost-versus-carbon implications of a particular option in one study. LCAs are complex and costly; therefore, they are mostly used to support business strategy (18%) and R&D (18%), as an input to product or process design (15%), in education (13%), and for labelling or product declarations (11%) (Cooper and Fava, 2006). They are generally not applied to housing developments (Cooper and Fava, 2006), where the developer sells the home and further costs are borne by the future owner rather than the developer (Aplin, 2007).

The *ecological footprint* is a measure of human demand on the Earth's ecosystems, which compares human demand with Earth's ecological capacity to regenerate. It aims to represent the amount of biologically productive land and sea area needed to regenerate the resources a human population consumes and to absorb and render harmless the corresponding waste. Using this assessment, an estimate is made of how much of the Earth (or how many planet Earths) would be required to support humanity if everyone lived a particular lifestyle (Wackernagel and Rees, 1996; Wackernagel and Silverstein, 2000). Ecological footprinting has been used to understand the environmental impact of whole cities and regions, but it has also been applied to measure the impact of a housing development in the Thames Gateway in London (James and Desai, 2003) and to Bedzed (Bioregional, 2009). Life cycle carbon emissions are included in the assessment but costs are not considered (Wackernagel and Rees, 1996; Wackernagel and Silverstein, 2000). Furthermore, as Ayeares (2000) asserts, the current calculation methodologies provide no meaningful rank ordering, and are not up to the task of evaluating solutions. This view is shared by Moffatt (2000) who remarks: “it (the ecological footprinting) offers no policy suggestions apart from either including more land, reducing population, or reducing consumption per head”.

The *Code for Sustainable Homes* (CSH) (already mentioned in Chapter 4) has been developed to enable a step change in sustainable building practice for new homes in the UK (CLG, 2006). It has been prepared by the Government in close working consultation with the Building Research Establishment (BRE) and Construction Industry Research and Information Association (CIRIA), and through consultation with a Senior Steering Group consisting of Government, industry and NGO representatives (CLG, 2009). The Code is intended as a single national standard to guide industry in the design and construction of sustainable homes. It is a means of driving continuous improvement, greater innovation and exemplary achievement in sustainable home building (*op cit*). EcoHomes is its predecessor and the main difference between the two is that the Code for Sustainable Homes is more stringent and challenging; it introduces minimum requirements on energy and water, a post construction review process, and generally more challenging criteria (BRE, 2006; CLG, 2009). The design categories in the Code are energy/CO_2, water, materials, surface water run-off, waste, pollution, health and well-being, management and ecology. The CSH measures the sustainability of a home against these design categories, rating the ‘whole home’ as a complete package. It uses a sustainability rating system indicated by ‘stars’ to communicate the home’s overall sustainability performance. Sustainability ratings rank from one (⋆) to six (⋆⋆⋆⋆⋆⋆) stars, depending on the extent to which it has achieved Code standards. One star (⋆) is the entry level – above the level of the Building Regulations; and six stars (⋆⋆⋆⋆⋆⋆) is the highest level – reflecting exemplary development in sustainability terms (CLG, 2009). However, a drawback of the CSH is that it only quantifies carbon emissions from direct home energy and does not include, or quantify, costs for any of its categories. As shown in section 4.2.3 the weighting for these other categories also is not representative for the actual carbon emission reductions delivered through each category.

Envest is a software tool developed by the BRE to calculate life cycle carbon emissions from both the use of buildings and that, which is embodied in the building materials (BRE, 2008a). This Tool nearly achieves our aim. However, it covers only the direct home energy and building material categories, not transport, consumables, waste, and behavioural choices. Furthermore, it has a limited number of inputs from which to choose.

SAP is the standard assessment procedure to calculate the likely carbon emissions resulting from energy used in the home (ODPM, 2006). Minimum ratings are required for all new buildings. The SAP rating leads directly to an *energy performance certificate*, which now has to be displayed at point of sale or rent for all homes in the UK (Boardman, 2007). SAP estimates energy costs and carbon emissions, but does not calculate capital expenditure. Moreover, it is limited to the energy used in the home and ignores embodied energy in the home and other consumption categories. *Envest* and the *CSH* use SAP to calculate the carbon emissions from direct home energy use (CLG, 2009; BRE, 2008a).

Other tools exist to assess energy and other environmental impacts in housing as part of a city or region-wide assessment. These include *TEMIS* (Heseltine and Nelson, 1996), developed for assessing energy policy at a national scale, but has since been adapted to the city level; the *EEP* (Energy and Environment Prediction) model (University of Wales at Cardiff, 2004); *DREAM-city* (Dynamic Regional Energy and Emissions Assessment Model) (Titheridge et al., 1996; Titheridge, 2004); *TRANUS* (Rickaby et al., 1992); *LEAP*

(Long-range Energy Alternative Planning System) (Commend, 2010); and the *Quantifiable City Model* (May et al., 1997). In a similar manner in which the Government accounts for its emissions, in these models CO_2 emissions are mostly considered on a sector-by-sector basis, covering the domestic, commercial, industrial, and transport sectors. Little or no emphasis is placed on the relationships between these sectors and how those emissions translate into the carbon impacts of products and services delivered to UK households. These models and tools tend to focus on assessing the overall carbon footprint and trends rather than model specific measures to reduce it. For these reasons, none of these citywide assessment tools were suitable for our purposes.

Table 6.1 compares the general sustainability assessment tools and tools to assess the sustainability of homes against the criteria chosen by the focus group. As can be seen from Table 6.1, none of the reviewed tools meets all of the set criteria; as already mentioned, they tend to cover only home energy use (space heating, water heating, lighting, and some appliances), with a few including the energy embodied in the building envelope. Very few of the tools include costs as well as carbon emissions as outputs; and almost none of the tools allow for a direct comparison with a typical UK household., even though this could be achieved in some of the tools by entering data on, for example, the features of a typical UK home to provide a baseline comparison.

Table 6.1 The scope of the main tools currently available to house builders for assessing the carbon emissions of their developments

Tool and Source	1. Outputs include Cost (£)/tonne of CO_2e saved?	2. Technical and behavioural options included?	3. Compares savings to the carbon footprint of a typical UK household?	4. Includes direct home energy use, materials, food, waste and transport?	5. Impact upon residents assessed?
Life Cycle Assessment (LCA) (Cooper and Fava, 2006)	No. life cycle carbon emissions are sometimes included but costs are not.	Both may be included, depending on individual assessment.	No	Yes, can do, depending on boundaries.	Yes
Life Cycle Costing (LCC) (OGC, 2010)	Costs are calculated but not life cycle carbon.	Behaviour normally not included.	No	Yes, can do depending on boundaries.	No
Ecological footprint (Global Footprint Network, 2008)	Costs are not included. Life cycle carbon emissions are included but are not usually listed separately.	Yes.	For the ecological footprint yes, but not for the carbon footprint.	Yes, but based on national averages.	No
EcoHomes (BRE, 2006)	Costs not included. CO_2 footprint only for direct home energy .	Technological measures are included. Behavioural measures are touched upon.	No	Food not included.	
The Code for Sustainable Homes (CLG, 2009)	Costs not included. CO_2 footprint only for direct home energy .	Technological measures are included. Behavioural measures are touched upon.	No	Food not included. Transport issues limited to Home Office and cycle parking provision.	Health and wellbeing covered but only at an aggregate level.
Envest (BRE, 2008a)	Cost and life cycle carbon.	Behaviour not included. Limited design choices available.	No	Food, waste and transport not included.	No.
SAP and Energy Certificate (ODPM, 2006)	No. CO_2 emissions for regulated emissions from direct energy used in home only, estimate of cost implications of energy bills.	Behaviour not included.	No, but this could be possible.	Only energy use of building is included.	No.

As shown in Table 6.1 and the discussion above, we can conclude that none of the tools reviewed meets the criteria set by the Tool Focus Group 1. Therefore, it was considered necessary to develop a tool to meet the specified criteria. It was also decided that for greater accuracy primary carbon and cost data sources would be used for developing the Climate Challenge Tool (CCT). However for those tools, which were freely available, where data sources were listed in the above tools these were sought and use for the CCT.

6.5 The Climate Challenge Tool

The Climate Challenge Tool (CCT) was developed in response to the inability for current emission calculations tools to meet the criteria set by the Tool Focus Group 1. The CCT includes emissions generated as a result of a households' lifestyle and behavioural choices – from energy use in the home, to travel, food purchases, and amount and means of disposing of waste. Emissions are split into five categories chosen by the Camco focus group because they reflect areas, which are significant in emissions and can, to some extent, be controlled by the house builder. These categories as selected and described by the Tool Focus Group 1 and supported by the literature search presented in Section 4.2.3, are:

1. **Direct home energy**: the carbon emitted by a home through consumption of energy (for example electricity and fossil fuels, such as gas). A house builder can influence these emissions through energy efficient design and by building integrated renewable and low carbon energy generating sources. Unregulated emissions (i.e. emissions from sources not covered in Part L) such as those from appliances used within the home are included.
2. **Building materials**: the carbon generated in the production and transport of building materials, construction on site, and disposal at the end of the life of the building. A developer can influence this by choosing locally produced materials using building materials that require little energy to manufacture (e.g., timber, reclaimed building materials) and by recycling construction waste or avoiding it altogether.
3. **Transport from commuting**: the carbon emitted from cars and public transport. A house builder can affect this by choosing a site where residents can work nearby and by providing low carbon transport solutions (car sharing, public transport), carbon-free transport provision (attractive cycling paths and walkways), and by creating jobs locally, for example, through building offices and mixed-use spaces.
4. **Food consumed in households**: the embodied carbon in food from fertilizers, livestock emissions, agricultural machinery, transport, packaging material, storage, distribution and sale can be influenced by the developer by providing allotments to grow food and market stalls for selling local produce; they can promote low carbon/ethical food by creating local amenities which offer local, low carbon and ethical produce.
5. **Household waste**: providing recycling and composting facilities reduces waste sent to landfill sites where it emits methane, a very strong greenhouse gas. In addition, replacing virgin products with recycled products often means a lower carbon footprint in the manufacture of the product. A house builder can influence recycling rates by including good recycling provision and by raising awareness.

In addition to quantifying carbon equivalent emissions and monetary costs over the lifetime of the home, social acceptability and impacts on residents of the housing development are incorporated qualitatively.

The Climate Challenge Tool was developed in Microsoft Excel and uses a database of carbon emissions reduction measures, their potential for carbon savings and their cost in order to calculate the total amount of carbon equivalent emissions avoided (tones) per £ invested per measure for the development under consideration.

The development could be a single dwelling or larger, with multiple housing types or mixed use. The tool ranks the measures being considered on the basis of cost effectiveness, defined as £ per tonne of CO_2e saved. The cost effectiveness of each measure is compared using charts as per Figures 6.3, 6.4, 6.5, and 6.6 (in Section 6.7). Information on social impacts is displayed in tables as per Tables 6.2, 6.3 and 6.5. (in Section 6.7). Using the combined graphical and tabular outputs, the user can draw conclusions about which measures may be most appropriate. In the cases discussed within this thesis, a five-point scale is used to indicate which measures are considered to be most appropriate, where 1 is inappropriate and 5 is highly recommended. On this basis, developers can make informed choices on how to deliver carbon emissions reductions and other sustainability measures. The tables are to be used as part of an overall sustainability and sustainable energy strategy to be produced by Camco for the developer and local authority.

Within the CCT, capital costs are offset against any monetary savings. These saving were discounted over the lifetime of the home using net present value (NPV) calculations. In addition to capital costs, energy savings and maintenance costs, replacement costs were also taken into account. The NPV was calculated using a 3% discount rate. This discount rate is the mid point of the proposed upper and lower bounds of a reasonable and defensible social discount rate for the UK of 2% and 4%, as argued by Pearce and Ulph (1999). This is also the standard rate used by CAMCO.

The database contains secondary data on potential emissions savings, costs and lifetime of a wide variety of behavioural and technical measures. Multiple data sources were used to increase the reliability of the estimates. Where values from the few initial sources differed markedly, efforts were made to find additional sources. The data has come from a variety of source such as IPCC (IPCC, 2006a), academic literature (Audsley et al, 2009; Jones et al, 2005), research institutes' publications (Danish Technology Institute, 2006; Entec, 2004; BRE, 2008b; Anderson and Shiers, 2002) Government's statistics and publications (EPA, 2007; ONS, 2008b; DEFRA, 1999; DEFRA, 2007d; DEFRA, 2008d; DfT 2005; DfT, 2007d; ODPM 2006), publications by industry experts (Langdon, 2008; WRAP, 2007; Cyril Sweet, 2007; City Car Club, 2006; Fitch, 2006; James and Desai, 2003; Bioregional, 2009), and from Camco internal databases and calculators (Camco 2009a; Camco 2009b; Camco 2009c). These have been collected over the past five years, and include data on costs and carbon emissions collected from quotations from suppliers, academic literature, imperial measurements, government statistics, and research organisations.

The Camco databases and calculators include benchmark emissions for a range of buildings (with different years of building regulation compliance), and the savings potential from energy efficiency and renewable energy measures, data on carbon emissions from building materials per volume or weight and typical quantities for various construction methods, carbon emissions per mode of transport per distance travelled, and methane emissions from household waste per unit waste land-filled. In addition to the secondary data, a range of relevant stakeholders, such as a house builder (Aplin, 2007), a building material embodied carbon specialist (Edwards, 2007), a recycling specialist (Head, 2007) and a behaviour specialists (Head, 2007; Riddleton 2007) were consulted in order to gain insights into what emissions reduction is likely to be reached for different measures that may lead to behaviour changes, and to validate assumptions based on literature review. Where reliable data was not available best estimates were used.

The residents' acceptability, practical implications and other social impacts of the measures were determined based on the findings of a consumer preference survey by Ipsos MORI (2006) and a second focus group workshop (Tool Focus Group 2) conducted with four sustainable-buildings-consultants from Camco and two staff from property developer Crest Nicolson. In Tool Focus Group 2 each measure was discussed until consensus was reached on the social impact and resident's acceptability. Based on the minutes from Focus Group 2, Tables (6.2, 6.3 and 6.5) were produced and approved by each Tool Focus Group 2 member.

A more detailed description of the CCT is provided in Appendix A.

6.6 Application of the tool

To illustrate the potential of the CCT and investigate emissions reductions achievable through a lifestyle approach, two baseline cases and two scenarios (future developments) were explored:

<u>Baselines:</u>

1. a typical UK dwelling
2. a new home (built to Part L 2002)

To act as a baseline for comparison, household carbon emissions from 1 and 2 were evaluated.

Future Developments/Scenarios:

1. A development comprising average UK households occupying a case study site designed to meet the zero carbon homes standard (as defined by Government; a home that is a net zero producer of carbon in direct home energy use)
2. A development comprising average UK households occupying the same case study site designed with the lifestyle approach incorporating both technical and behavioural solutions.

For the future development analysis, first carbon reduction options, which go beyond current regulations, were assessed. On the basis of this analysis a number of measures were selected for each of the future developments/scenarios.

The selected case study was a proposed development on the edge of Cambridge with approximately 2000 houses containing a mixture of houses and flats. The developer had employed Camco to develop their sustainability strategy for the site. Whilst the findings are specific for this site, similar outcomes are expected for other developments in the UK (as discussed in Section 6.7). Changes would result for example from changes in household sizes and composition, environmental resource parameters, local transport networks, local amenities, and overall size of the development.

For ease of comparison, the household composition and size of home were kept the same for presenting the resulting emissions of a typical household under different scenarios (Figures 6.1, 6.2, 6.7 and 6.8) and is based on average UK data on household size and occupancy. Baselines and future development scenarios is described in more detail in the following two sections 6.6.1 and 6.6.2. The results of the baselines and scenarios are presented in section 6.7.

6.6.1 Baselines

A typical UK Household

Initially, the baseline of the emissions in the aforementioned categories has been calculated, based on characteristics of a typical UK household. Including the five categories from Section 6.5, the emissions footprint of the typical UK household can then be calculated.

Data is calculated using Transport Statistics of Great Britain 2005, DfT,; DETR 1999 indicators for sustainable development for the UK; Audsley et al. (2009) for food emissions, conversation with Jane Edwards, BRE (Edwards, 2007); Green Guide to Housing Specifications, BRE (Anderson and Shiers, 2002); EPA data on waste (EPA, 2007); Camco carbon calculator for building materials (Camco, 2009a) and Camco carbon calculator for waste (Camco, 2009b). The Camco building materials calculator (Camco, 2009a) includes carbon emissions from a wide range of building materials and typical quantities used in different construction methods. The Camco waste calculator (Camco, 2009b) measures methane emissions from landfilled waste and includes UK typical waste treatment streams; this procedure was supplemented with the WARM (Waste Reduction Model) calculator (EPA, 2007).

An average sized UK household is a 2 or 3 bed home (Camco, 2009a). The average occupancy per household is 2.36 occupants (derived from UK population from ONS, 2008b and number of households from National Statistics Online, 2001). Most existing homes are built using bricks and blocks (Camco, 2009a).

CO_2e emissions from direct home energy have been estimated by multiplying total UK domestic sector consumption of fossil fuels and electricity (DETR, 1999) with the CO_2e emissions factors per unit of energy for each fuel (DEFRA, 2008d for electricity and IPCC, 2006a for fossil fuels). The total sum was divided by the number of households in the UK (from National Statistics Online, 2001).

Emissions from building materials were provided by Entec (Entec, 2004), who estimates the typical footprint of UK home. This was verified using the Camco internal building materials carbon calculator (Camco, 2009a) to check the range of typical UK construction materials and housing designs. Findings were largely coherent. A midpoint average was used in the final figure.

Emissions from commuting were estimated by multiplying the total UK working population (from National Statistics Online, 2001), by the proportion for each mode of transport used for commuting (DfT, 2005), by the average commuting distance travelled by each mode per year (DfT, 2007b), and finally by the CO_2e emissions per distance travelled (DEFRA, 2008d and Camco, 2009c). The sum of the emissions from each mode then gives the total emissions of UK commuters, which is divided by the number of UK households in order to obtain the average emissions footprint from commuting per household.

Emissions from food in UK households cover those resulting from food consumed or prepared in the home itself. Eating out is not included. Data from Audsley et al.(2009) provide the emissions footprint from processing, distribution and UK retail, agriculture and land use change including emissions abroad on from food consumed in the UK. Audsley et al. (2009), also provided the proportional contribution from food consumed in households themselves.

The waste carbon footprint was calculated using average UK household waste consumption data and waste treatment methods (from Jones et al., 2005; and DEFRA, 2007d) and calculating the carbon footprint using the Camco waste carbon calculator (Camco, 2009b) as well as the WARM (Waste Reduction Model) (EPA, 2007) calculator, which measured upstream and downstream emissions from waste for a chosen waste treatment scenario. Therefore, the waste emissions calculated here is the net emissions impact after waste has been disposed. Some waste treatment such as recycling can cause a net negative emissions footprint because the emissions from the virgin material are replaced by the less energy-intensive production of the replacement recycled material.

New Home (Part L 2002)

Under current UK legislation, the only category for which CO_2 emissions are significantly affected is the direct home energy category.

Under Part L of the building regulations (ODPM, 2006), every new home is required to achieve a certain energy efficiency standard under the Standard Assessment Procedure SAP (ODPM, 2006) (Chapter 4). SAP forecasts the theoretical carbon footprint of the regulated energy used by the home, based on standard home usage profiles. Regulated emissions include most emissions from direct energy use, with a few exceptions, such as appliances, which are not regarded as an integral part of the home itself. These are called unregulated emissions. Therefore, in this scenario the unregulated emissions from typical appliances for a new home in the UK taken from Camco (2009c) were added to the total SAP emissions footprint.

In 2002 there was a step change in the energy efficiency standard required under Part L. Therefore to calculate the direct energy use for the baseline new home, emissions were calculated using a range of energy efficiency options typically recommended by Camco for achieving Part L 2002 in a cost-effective way (Camco, 2008).

6.6.2 Future Developments/Scenarios

After calculating baseline emissions for a typical UK household in an existing home and for a typical UK household in a new home, opportunities to exceed building regulations in new housing developments have been explored. Two scenarios were studied in detail and their results are presented here: a case study housing development designed using the lifestyle approach and the same development designed to meet the Zero Carbon Homes standard. At the time this research was conducted the Government had not provided a final definition of the zero carbon homes standard, and therefore the proposed definition of all net emissions from direct home energy use to be zero was used for the purpose of this research.

Zero Carbon Home

In addition to the assumptions made for the new home build to comply with part L of the 2002 building regulations (DCLG, 2007b), this scenario included the total offset of direct energy used in the home through on-site renewable energy generation and energy efficiency measures. The net carbon emissions from direct home energy are therefore set to zero. This describes a home, which would meet the Government's planned building regulation standard from 2016 onwards (DCLG, 2007a).

Several different possible combinations of measures, particularly renewable energy sources, were assessed to give a range of costs. The combinations include the optimum configuration of measures as well as 2nd and 3rd choices, considering that not all renewable energy options are possible at all locations. The Camco internal carbon database and calculator (Camco, 2009c) and Cyril Sweet (2007) provided data on costs and carbon implications for energy efficiency and renewable energy measures.

Lifestyle approach

The aim here was to achieve the same savings as a zero carbon homes development but using a wider range of measures, specifically including behavioural (or soft measures) in addition to technical measures, and by looking beyond energy used directly within the dwelling and included measures from all five household energy categories.

The reader is here reminded with the proposed lifestyle approach we do not exclude technical solutions, however we include behavioural measures alongside and thereby widen the options for reducing emissions to include the conventional opportunities for reducing the direct home energy use (energy efficiency measures and renewables) alongside other behaviour and technical measures in the other four categories: building materials, transport, food and waste.

All energy efficiency opportunities typically considered for housing by Camco were assessed and compared for the case study development.

A similar analysis was conducted for renewable energy solutions. The assessment was based on a target of reducing household carbon emissions by 10% through renewable energy sources. The 10% reduction target was a requirement for the site (Cambridge City Council, 2006) under the Merton Rule (Merton Council, 2010). Cost and carbon data for the energy efficiency and renewable energy calculations was take from Camco (2009c) and Cyril Sweet (2007).

Even though there are many possible combinations, such as going beyond 10% renewable energy contribution or mixing different technologies, the initial analysis was conducted by comparing each available renewable energy source and its environmental cost effectiveness for meeting a 10% requirement. This allows us to make a direct comparison between the different renewable energy technologies.

A choice of options to reduce the carbon emissions embodied in the building materials has been assessed and compared. These include the replacement of a building element material with a material with lower embodied carbon (e.g., concrete with wood) and minimising the use of building materials through responsible waste management. Various sources were used for the calculation: the Camco internal building materials carbon calculator (Camco, 2009a) and Danish Technology Institute (2006) (for CO_2e); the BRE Green Guide to Specification (for costs and CO_2e) (Anderson and Shiers, 2002); Spons (for costs); (Langdon, 2008); and WRAP data for cost implications for waste management options (WRAP, 2007).

Waste composition was based on UK typical household waste composition (Jones et al, 2004; DEFRA, 2007d) and quantified according to the number of households in the proposed development. Note that the waste scenario presented here was selected from a number of scenarios for the greatest CO_2e reduction achievement, and that to maximise carbon savings, the best disposal method may be different for different categories of waste. The recycling, composting and incineration rates assumed reflect rates deemed achievable with good recycling provision and awareness-raising activity, and have been achieved elsewhere (based on DEFRA, 2009; Livingstone, 2003; and Head 2007).[6] Costs for waste separation and compost bins were taken from Cyril Sweet (2007).

In Cambridge there is a large share of people who cycle 24%, compared to the 3% national average (ONS, 2008b). Many people commute into Cambridge to work (ONS, 2008b). There is at present an insufficient number of homes to provide accommodation for the working population; building more homes in Cambridge therefore means reducing commuting distance and emissions. The site-specific base line carbon footprint from commuting was calculated using Census data for travel modes and distances (ONS, 2008b) and carbon emissions from the Camco database (Camco, 2009c). The effects of a car share scheme and a subsidised bus route were also modelled. The City Car Club (City Car Club, 2006) provided estimates of the changes in car travel patterns and ownership caused by setting up a car club; and these were verified using empirical data from Bioregional (2009). The impact of the subsidised bus route on travel patterns and costs of setting up a bus route were estimated by Colin Buchanan, the transport consultant for the scheme (Fitch, 2006).

For food emissions, the promotion of an organic veggie box scheme as well as a café and shop offering these products was planned. The carbon emissions reductions, which may be achieved from the triggered changes in consumption patterns were estimated based on Audsley et al. (2009) for emissions implications and James and Desai (2003), Riddleton (2007) and Bioregional (2009) for likely effect of these measures on food consumption choices of the residents. .

In addition, it was assumed that a sustainable living officer (SLO) would be employed for the first 18 months on site with the main responsibility to raise awareness and ensure the smooth operation of the low carbon provisions. For costs, salary and overhead costs of the SLO at BEDzed were used. Based on personally conversations with Sue Riddleton (BEDzed resident and Director of Bioregional) and her view of what impact the SLO had at BEDzed and to what extend this could be replicated, it was assumed that the SLO achieves a 10% uplift in recycling rates, sustainable food uptake, uptake of sustainable transport options, and home energy management (Riddleton, 2007). Further evidence to support this assumption was not available.

[6] Note that reuse was not an option considered here.

6.7 Results and Discussion

6.7.1 Baseline: A typical UK Household

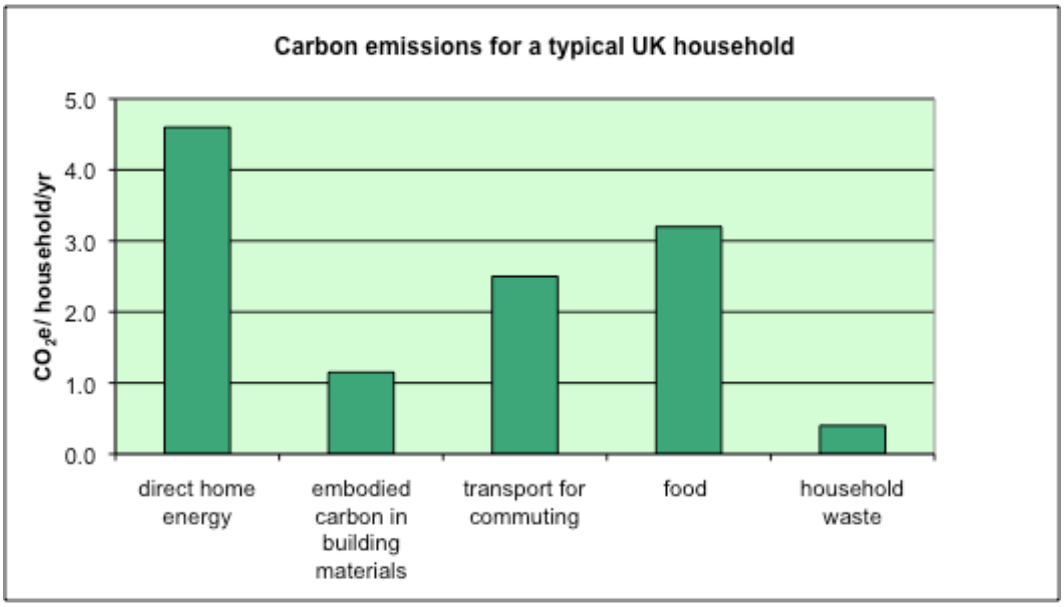


Figure 6.1 Carbon Emissions for a typical UK household (tCO_2e/household/year)

Figure 6.1 displays the carbon footprint of a typical UK household. The total household emissions, i.e. the sum of the five categories, amounts to 11.9 tonnes of CO_2e. We can observe that, with 4.6 tonnes of CO_2e the largest emissions contributor category is direct home energy contributing 39% to the overall household carbon footprint. Therefore, arguably, the Government may have been right in focussing on reducing emissions of this category through its regulation in Part L. However, as its contribution is smaller than 50%, this suggests that whilst it is an important category only targeting this category is insufficient.

6.7.2 Baseline: New Home (Part L 2002)

The Climate Challenge Tool was then used to model the carbon footprint of a home built to 2002 Part L of the Building regulations (ODPM, 2006). As discussed in Chapter 4, there is no maximum limit to be met by new UK housing developments in categories other than direct home energy use. Whilst some local authorities may have policies which may positively or negatively effect emission reductions in the other categories (building materials, transport, food and household waste), these are unlikely to be significant (see Chapter 4); and no national legislation is currently enforced to ensure that all new homes are covered. We therefore assume that emissions from other categories are the same as in the typical UK household (in an existing home).

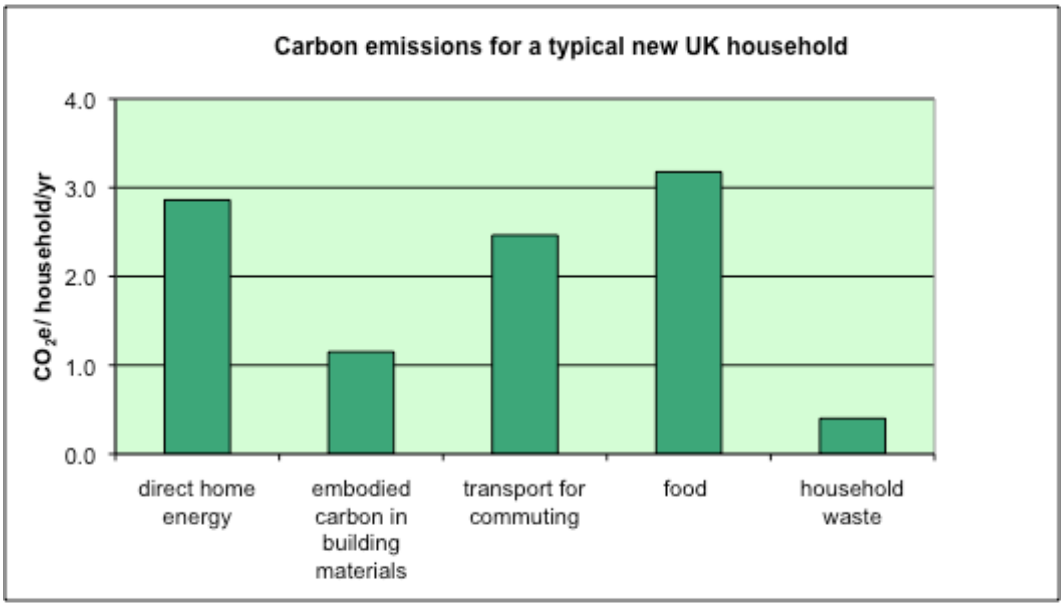


Figure 6.2 Carbon Emissions for a typical new UK household

It was shown that energy consumption in a home built after 2002 in the UK would be approximately 40% lower than the typical UK home, at 2.9 tonnes of CO_2e/household/year (Figure 6.2). In this case, for a new home the carbon footprint of transport from commuting and of food is of similar importance to that of the energy used in the home itself, and thus the total household carbon footprint is only reduced by 15% to 10.1 tCO_2e. It is interesting to note that changes to regulations since 2002 and the plan to make all homes zero carbon by 2016 (DCLG, 2007a) focus only on reducing the direct home energy category even further – despite the fact that other categories (food and transport) have a similar carbon footprint for households in new housing.

6.7.3 Future Developments/Scenarios further description

For the case study site: the proposed development on the edge of Cambridge of approximately 2000 dwellings, emissions reduction opportunities that exceed current regulations are evaluated, and the cost effectiveness and the impact of residents on emissions reduction opportunities is assessed. Before examining the two case study developments/scenarios, a range of measures, which go beyond building regulations, needed to be explored. Rules were developed to determine which measures would apply to which case developments. For the zero carbon homes development, the most cost effective solutions for achieving the zero carbon homes standard were selected as they were deemed achievable on site and were likely to gain planning permission. For the lifestyle approach, a list of preferred options was made by the developer choosing measures that reduce emissions in all five categories rather than just the direct home energy use (which is the focus of the zero carbon home scenario). From these, those measures were selected which would achieve (at least) the same level of carbon emissions reduction as the zero carbon standard, in the most cost-effective way. A 10%

renewable energy contribution to direct home energy was included, even though other cost effective solutions were available; the developer wanted renewable energy to be included and he felt that the local authority would view this favourably.

The following results in section 6.7.4 describe the assessment of options in each of the five categories. This is followed by a description of the outcome of the two scenarios (zero carbon home and lifestyle approach) in section 6.7.5 and 6.7.6. For each of the two scenarios the most suitable measures for meeting the scenario aims were selected.

6.7.4 Assessment of household emission reduction measures

The assessment of household emission reduction measures was grouped into the following categories:

1. Direct home energy: energy efficiency
2. Direct home energy: renewables
3. Building materials
4. Promoting sustainable lifestyles: transport, food and waste.

The zero carbon home scenario as previously explained uses a mix of options from the first two categories in order to achieve a zero carbon footprint from direct home energy use. The lifestyle approach on the other hand draws on all 4 categories in order to achieve a similar overall reductions in household carbon emissions.

Direct home energy: Energy efficiency

Figure 6.3 orders the energy efficiency measures investigated according to their net present value over tones of CO_2e saved ratio. It can be observed, that the seven measures on the left side of the graph save carbon and have a negative net present value (NPV) because the value of energy savings is greater than the initial capital outlay, even after discounting. They make the most sense in terms of both reducing emissions and saving costs. Other measures save carbon at widely varying costs. Recommendations were made both based on these cost-effectiveness criteria and on the qualitative assessment of the measure (Table 6.2). For example, whilst showers with a flow rate of 6 l/s or less save money and carbon, they were not recommended as they are seen as having significant comfort reduction for the residents. Note that not all these measures are included in the UK building regulation's SAP assessment (ODPM, 2006). For example, the water reduction measures and A rated appliances are not included in SAP (ODPM, 2006) (Figure 6.3). The energy efficiency measures which save both energy and money over their lifetime were calculated to be water saving measures: low flow taps and showers, low water use bath, good air tightness and insulation[7], and improved hot water storage insulation. They cost little and save comparatively a lot of

[7] *See table 5.2 for explanation of the measures.*

carbon over their product lifetime. A number of other measures save nearly as much as they cost in terms of investment, such as a greater proportion of low energy lighting than building regulations require, A-rated fridge-freezer, good glazing, and best insulation standard. Some energy efficiency options have significant costs compared to their savings. For example, Micro-CHP, A-rated washer dryer or mechanical ventilation with heat recovery cost more than £300 per tonne of CO_2e saved. Note that for existing homes the cost effectiveness coefficient for many of these measures may be much more favourable. This is because they are here an improvement to an already significant energy efficiency standard for new housing that has to be met through the building regulations. For existing homes the replacement of old, inefficient equipment or un-insulated homes can be very cost effective (Boardman, 2007).

Figure 6.3 and Table 6.2 represent the costs and implications of the measures at the case study site and are representative for both the zero carbon scenario and the lifestyle approach scenario. The difference between the two scenarios is that for the zero carbon home scenario more of the measures were selected including some more expensive ones. The chosen measures for each of the two scenarios are listed in Section 6.7.5 and 6.7.6.

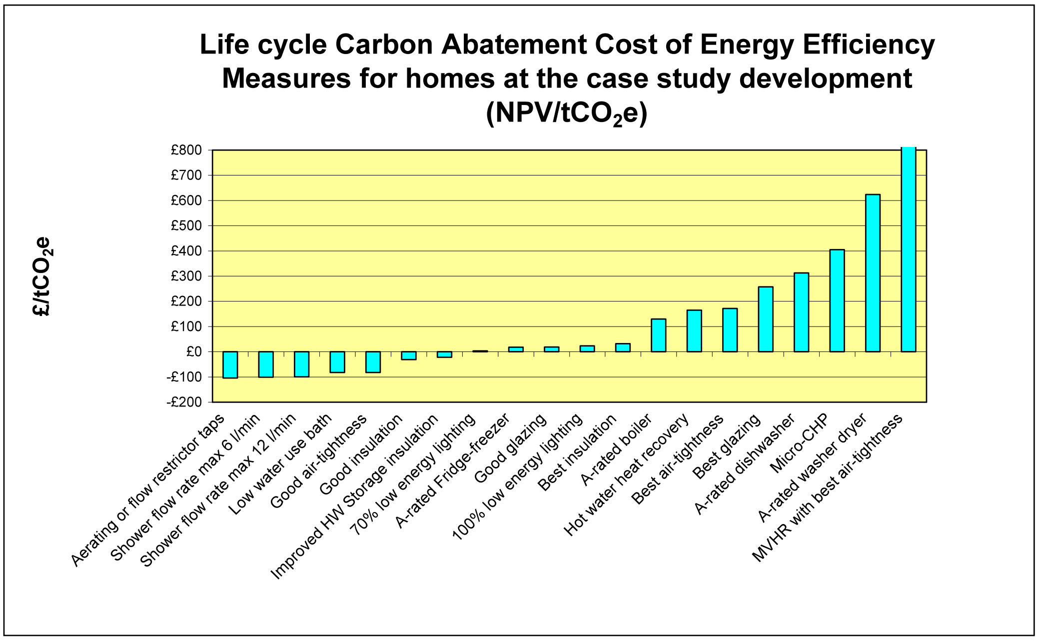


Figure 6.3 Life cycle carbon abatement costs of energy efficiency measures for homes within the case study development in terms of £ (at NPV) per tonneCO_2e saved

Table 6.2 Energy Efficiency recommendations for the case study development
The scoring system used in the table below indicates a judgment of appropriateness.

This is based on a sliding scale ranging from * indicating unsuitable to ***** indicating highly appropriate.

Area	Measure	Descriptions, practical implications, acceptability and residents' impact[8]	Additional capital costs estimate per dwelling	Recommendation
Hot water saving measures	Aerating flow restrictor tabs	Modern mixer tap reduces hot water consumption and makes it easier to wash hands.	Plus £0 to £20 compared to equivalent mono-taps	***** highly recommended
	6 l/min flow restrictors for showers	Reduce water flow rate to 6 l/min. This is a compromise in comfort, the flow is too low.	£5- £10	* not recommended.
	12 l/min flow restrictors for showers	Reduced flow rate to 12 l/min. Flow rates at 10 l/min or above meet comfort levels.	£5- £10	***** highly recommended
	Low water use bath	Either use small bath, or for taller people use a larger size bath with lowered overflow.	Smaller baths cost less. The Ideal Standard Alto bath can be fitted with low overflow at no extra cost.	**** recommended
	Hot water heat recovery	Recovery of heat from shower water via heat exchange coil around drainage pipe. 25% of heat lost in use and 60% of remaining heat recovered as hot water pre-heat.	Approx. £350	**** recommended
Appliances	A-rated dishwasher	Low energy appliance saving 300kWh/year.	Approx. £ 75 above typical dishwasher	*** not recommended

[8] *Practical implications, acceptability and residents' impact are only listed where it was judged not to be negligible.*

	A-rated washer dryer	Low energy appliance saving 170kWh/year assuming 3 uses per week.	Approx. £500 above typical washer dryer	* not recommended
	A-rated fridge freezer	Low energy appliance saving 350 kWh/year assuming 1 use per day.	Approx. £250 above typical fridge freezer	**** recommended
Mechanical and electrical services	Improved boiler efficiency	SEDBUK (Seasonal Efficiency of Domestic Boilers in the UK) A-rated condensing boiler (92% efficient).	Approx. £200/dwelling	**** recommended
	Improved hot water storage insulation	Increased Hot Water Storage insulation thickness (160mm factory applied).	Approx. £100/dwelling	***** highly recommended
	Micro-CHP	1kWe / 6kWth Micro-CHP unit operating in response to dwelling heat demand in place of boiler.	Approx. £1500/dwelling	* not recommended, not cost effective.
	MVHR with 'Best' air-tightness	Whole dwelling Mechanical Ventilation with Heat Recovery system and best air-tightness (3m3/m2/hr) supplying 0.5 air changes per hour (ach) with 66% heat exchange efficiency.	Approx. £1600/dwelling	* not recommended, not cost effective.
	'Good' low energy lighting	70% fixed low energy light fittings.	Approx. £150/dwelling	**** recommended
	'Best' low energy lighting	100% fixed low energy light fittings.	Approx. £300/dwelling	**** recommended
Mechanical and electrical services	Improved boiler efficiency	SEDBUK (Seasonal Efficiency of Domestic Boilers in the UK) A-rated condensing boiler (92% efficient).	Approx. £200/dwelling	**** recommended

	Improved hot water storage insulation	Increased Hot Water Storage insulation thickness (160mm factory applied).	Approx. £100/dwelling	***** highly recommended
	Micro-CHP	1kWe / 6kWth Micro-CHP unit operating in response to dwelling heat demand in place of boiler.	Approx. £500/dwelling	* not recommended, not cost effective.
	MVHR with 'Best' air-tightness	Whole dwelling Mechanical Ventilation with Heat Recovery system and best air-tightness ($3m^3/m^2/hr$) supplying 0.5 air changes per hour with 66% heat exchange efficiency.	Approx. £1600/dwelling	* Not recommended, not cost effective.
	'Good' low energy lighting	70% fixed low energy light fittings.	Approx. £150/dwelling	**** recommended
	'Best' low energy lighting	100% fixed low energy light fittings.	Approx. £300/dwelling	***** highly recommended
Building Fabric	'Good' insulation levels	~20% improvement on Part L 2006 standard with wall U-value of $0.2W/m^2K$, roof U-value of $0.11W/m^2K$.	Highly dependant on construction detail, typically £30 to £150/dwelling.	**** recommended
	"Best" insulation levels	40% improvement on Part L 2006 standard with wall U-Value of 0.2 W/m^2K, roof values of 0.11 W/m^2K.	Highly dependant on construction detail, typically £100 to £400/dwelling.	**** recommended
	"good" glazing	Double glazed argon filled, overall U-Value of 1.5 W/m^2K.	Approx. £150/dwelling	**** recommended
	"best" glazing	Triple glazed argon filled, overall U-Value of 1.1 W/m^2K	Approx. £400/dwelling	* not recommended, not cost effective.

	“Good” air tightness	5 $m^3/m^2/hr$ at 50 Pa achieved through good detailing and workmanship,	Normally no extra costs, but subcontractor needs to be made responsible.	***** highly recommended
	“Best” air tightness	3 $m^3/m^2/hr$ at 50 Pa achieved through good detailing and workmanship, and additional draft specifications.	£200/dwelling.	**** recommended

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Direct home energy : Renewables

Figure 6.4 shows an example of the Climate Challenge Tool renewable energy output here displaying the results for a 10% direct home energy carbon emission reduction scenario. For the exemplary site the only cost-effective renewable energy source is a medium or large-scale wind turbine. Other renewable energy sources never pay for themselves; their costs can range from approximately £200 to £700 for each tonne of CO_2e saved, varying with the different renewable energy technologies.[9] Like the energy efficiency analysis, recommendations to the developer can be made, both on the £/tCO_2e ratio and on the basis of other practical considerations and additional benefits to residents. Key recommendations would be to employ cost-effective energy efficiency measures before renewables, and for this particular site to investigate the potential for developing a wind park and hot water contribution from solar thermal energy.

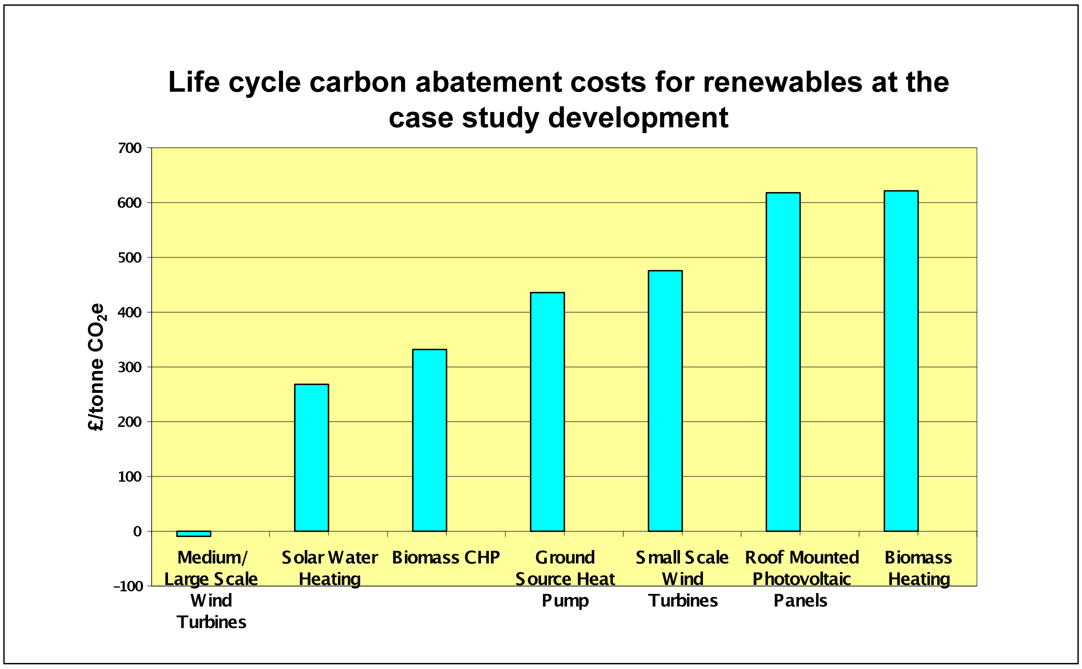


Figure 6.4 *Life cycle carbon abatement costs for renewables options that could be installed at the case study development based on meeting a 10% direct energy use reduction requirement*

Similar to the energy efficiency analysis, we have constructed a table of the Tool output, comparing and contrasting the advantages and disadvantages of each technology and listing recommendations as to which technology is the most cost-effective towards achieving the target, and most beneficial for the site. Table 6.3 represents the output for the case study site and assesses options for a 10% emissions reduction from direct home energy through renewables produced for the exemplary site. Table 6.3 and Figure 6.4 indicate that a medium or large wind turbine would be the most cost-effective and simplest way to generate renewable energy for the site. However, gaining planning

[9] *Please note that these calculations were performed prior to the introduction of feed-in tariffs, which have therefore not been considered.*

permission may be difficult and cannot be guaranteed, and the developer decided not to consider this as an option as the planning authorities response to this suggestion was not encouraging and because the planning application for the wind turbine could delay the overall timescales of the development. The simplest and most cost-effective alternative to wind for achieving a 10% renewable energy contribution is solar hot water. If, however, a greater contribution from renewables were to be sought, another energy source would be needed, as solar hot water can contribute only a maximum of 50 or 60% to hot water consumption (Schuco, 2007),[10] which for an energy efficient home would amount to about 10% direct home energy carbon emission reduction.

When considering a 100% renewable energy contribution under the zero carbon scenario only medium to large scale wind or biomass CHP could achieve this on their own. Otherwise a combination of renewable energy technologies would need to be used. Due to great resource constraints and load management challenges, costs per tonne of carbon saved for each technology may increase by about 5% to 20%, depending on technology mix and site parameter. In addition overall costs per tonne of carbon saved from renewables may further increase because to meet the 100% requirement some of the more expensive renewable energy sources may need to be used. Because the developer had stated that he did not want to consider wind energy as an option the technology options for meeting the 100% renewable energy requirement considered here were: biomass CHP, biomass heating with PV and solar hot water, and ground source heat pumps with PV.

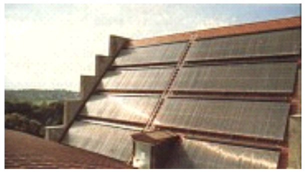
Even though the case study site was chosen as a development which is largely representative for most new housing in the UK (in terms of housing mix, density, mixed use, household sizes), it is noteworthy that the environmental cost-effectiveness coefficient (£/tCO_2e) of some of the renewable energy sources could differ at another location. For example, for wind energy the coefficient is largely influenced by local wind speed and topography. The case study site is located next to fields with good wind speeds which is a positive coincidence and unlikely to occur for most UK housing developments (Aplin, 2007). In contrast, most of the energy efficiency measures would score similarly or even identically in other developments.

[10] 50 to 60% is the average for the year, the contribution is greater in summer and smaller in winter.

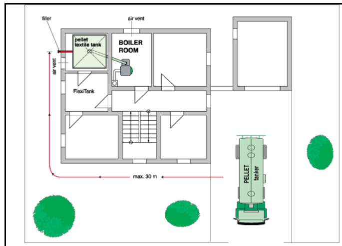
Table 6.3 Qualitative Renewable Energy Assessment

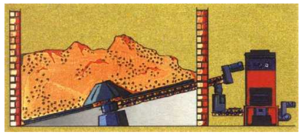
The scoring system used in the table indicates our judgement of appropriateness, which we base on a sliding scale ranging from * indicating unsuitable to ***** indicating highly appropriate.

Costs should be read as generic guidance only and will fluctuate according to specific setup and the detailed design of the case study site

Renewable Energy Source	Description, practical implications and residents' impact	Additional Capital Costs[11]	Recommendation
Wind Turbine 	One medium to large scale wind turbine (100kW to 2 MW) could be located either on the edge of the site or in South Cambridgeshire district council. This is the most economic form of renewable energy in the UK where high wind speeds are prevailing. Gaining planning permission is the greatest obstacle for this form of renewable energy. If planning permission is plausible we would most recommend this renewable source of energy. However, based on discussions with Cambridgshire District Council planning permission is likely to be a major obstacle at this site and the developer decided not to consider this as an option.	£160 per dwelling	* not recommended as planning permission would be difficult and could delay the whole construction timescales.
Solar Water Heating 	Solar hot water panels will provide a visual statement. They are positioned on the sunny side of the roofs. They are normally sized to provide 50% of annual hot water demand and therefore would not on their own meet the 10% renewable energy target. This is, however, a simple and low cost technology, with minimal maintenance requirements. The cost calculation assumes that all homes will have individual solar hot water panels. Communal systems could be installed with lower capital costs but may necessitate higher maintenance costs resulting from O&M, metering and billing.	£1,860 per dwelling	***** highly recommended
Biomass CHP	Biomass CHP is the second most viable form of renewable energy for the NIAB site. Economies of scale for this type of communal heating and electricity system are high for a large and dense new development such as our case study. It requires the set up of an energy service company to be in charge of operating the plant, metering, and billing	£2583 per dwelling	** recommended if

[11] *Please note that these are additional costs per dwelling and not the costs of the appliances. Costs of replaced goods are deducted, for example where boilers are replaced by biomass heating or CHP or GSHP. Please also note that where not all houses need to be fitted with the renewable energy technologies to meet the overall 10% emission reduction target, the costs are listed as the additional costs for all homes and not just the homes where the technologies are installed. This means that the table allows comparing the overall capital costs implications of each technology option with eachother.*

	users. Biomass CHP technology is still in its infancy with only a few pilot schemes in the UK. This option is recommended if tight warranty contracts with a reliable supplier are set up. Access would have to be provided for a lorry to deliver wood chips or pellets. On average, to meet the 10% renewable energy requirement, the site would consume 54 m^3 of wood chips. Storage would have to be provided for this. Make costing on the assumption that, to meet the 10% carbon reduction target, the primary school and 500 flats would be supplied by the district heating network.		warranties are tight
Ground Source Heat Pump 	Ground source heat pumps (GSHPs) are electrically powered systems that tap into the stored energy of the earth. Prerequisite to the installation of GSHPs is a geological survey. If the project is agreed, a length of pipe is buried into the ground, either in a borehole or a horizontal trench. If sufficient land is available the cheaper option of laying horizontal trenches is possible. We assume that boreholes will need to be drilled. Costs may be reduced if either land in South Cambridgeshire can be used or the installation size is reduced significantly and it becomes an additional technology. The heat pump itself acts as a reverse fridge and uses the heat from the ground to produce hot water for heating and in some cases hot water consumption. Heatpumps are a relatively new renewable energy technology in the UK. Ground source heat pumps work best in new houses which are designed with their installation in mind, including a low temperature heating system using under-floor heating or oversized radiators, a building with high thermal mass, and large hot water storage facilities. Heating and hot water control systems need to be set up to maximise the use of cheap nighttime electricity, and users need to be made aware of this. This type of integrated design can lead to a very high level of thermal comfort. To meet the 10% target heat pumps would need to be installed in approximately a third of all dwellings on site.	£3,900 per dwelling	*** partially recommended
Small Scale Wind Turbines	Building-integrated Wind Turbines are still considered innovative, despite the already widespread use of larger scale wind turbines in wind farms. The integration of wind turbines in building projects requires a very early commitment to deal with architectural and structural integration. There is significant risk when dealing with wind speed estimates	£1,990 per dwelling (or £5,910 per	** not recommended on a large scale

	in a turbulent environment. A total of about 600 small (1kW) turbines would be required to meet the 10% CO_2 reduction target. As with larger wind turbines, obtaining planning permission may be a problem.	turbine)	A small number of turbines would be good for publicity
Roof Mounted Photovoltaic Panels 	Photovoltaic cells (PVs) produce electricity directly from sunlight. PV is an established straightforward renewable technology in the UK, appropriate for most homes in the UK, as long as largely un-shaded roof space facing largely south can be found. PV technology can demonstrate a visual statement of the development's commitment to sustainable energy solutions. However, the capital cost associated with PV technology is high compared to its contribution in CO_2 emissions reduction. To save costs on components such as inverters, it is most cost-effective to not connect each dwelling to PV cells but rather to have larger installations on two-thirds or one-half of the dwellings (detailed decisions will also depend on available roof space and orientation).	£3,190 per dwelling	** only recommended if other renewable energy options prove too difficult.
Biomass Heating 	Biomass Heating is a capitally low cost renewable energy technology for large scale dense developments. Biomass supply contracts, system management and ownership issues need to be decided beforehand to ensure the smooth running of such a system. This type of communal heating system works best with a low temperature heating system such as under-floor heating or oversized radiators. Its advantage over biomass CHP is that it is a tried and tested technology. Access would have to be provided for a lorry to deliver wood chips or pellets. On average to meet the 10% renewable energy requirement, the site would consume 66 m^3 of wood chips. Storage space would need to be provided.	£1,300 per dwelling	** only recommended if other renewable energy options prove to be difficult

Building materials

Figure 6.5 displays the CO_2e abatement costs for a number of options to reduce the carbon footprint of building materials. The results suggest that it is important to understand carbon and cost implications and that significant carbon and financial savings can be made when sustainable materials choices are made based on this assessment rather than on an ad hoc basis. Using construction waste seems to be the best option. Using recycled cellulose insulation instead of rock wool is not cost-effective. Natural carpet is also a far more expensive choice than wooden or tiled floors, but residents may have other reasons for choosing them.

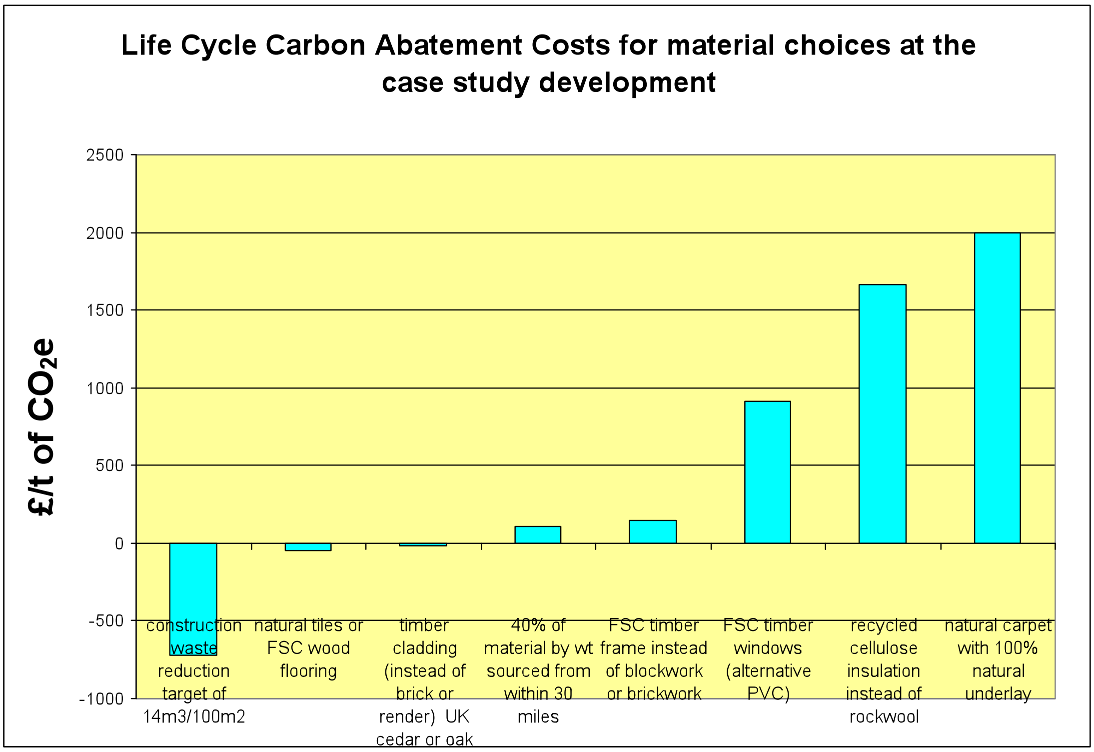


Figure 6.5 *Life cycle carbon abatement costs for building material choices at the case study development*

Specific opportunities for reducing carbon emissions through building material choice and handling lie both in reducing construction waste and in replacing the use of energy-intensive building materials (concrete, brick, carpet) and building material having a low embodied CO_2e (timber). With less than £100/tCO_2e, these options are more cost-effective at reducing carbon emissions than nearly all renewable energy options for the site (except medium or large scale wind). Reducing construction waste through intelligent management has been shown to not only reduce carbon emissions but also overall construction costs, as extra management costs can be more than offset by reducing the amount of building materials which need to be purchased (WRAP, 2007). The durability of natural tiles or timber flooring may also save money and over the long-term, as opposed to carpets, they need not be replaced regularly and are less energy intensive to produce, if grown in responsibly managed forests as timber absorbs carbon when grown.

Conversely, recycled cellulose insulation and natural carpets are expensive and make little difference to the overall CO_2e footprint. Moreover, not all timber replacement solutions are cost-effective alternatives to the use of materials with greater embodied energy. For example, if FSC timber windows are chosen rather than PVC ones, this costs £800/tCO_2e saved, which is more than most renewable energy solutions for the site – and more than nearly all energy efficiency opportunities investigated.

The Tool Focus Group 2 (discussed in Section 6.5) has deemed the social impact and resident acceptability of material choices as generally having little impact. The emphasis seemed to be mostly a concern for aesthetics. In the case of social housing provision and private housing sold for the rent sector, maintenance such as the need to paint timber windows is a maintenance issue. Generally, it was thought that the use of timber flooring and tiles is in fashion and may make homes easier to sell or rent. The focus group judged that the social acceptability of material choices required further investigation before detailed tables could be produced; and therefore decided that this should be considered during the second stage of the development of the Tool, or judged by a site architect. Instead, it was decided that a table describing the residents' impact of sustainable material choices compared with the four categories (direct home energy, transport, food and waste) should be produced (Table 6.5).

Promoting Sustainable Lifestyles: Transport, Food and Waste

The costs and carbon savings involved in making sustainable living easy were investigated; they include a mixture of measures in the areas of transport, food and waste.

Provision of amenity and workspaces in close proximity not only reduces carbon emissions through cutting transport emissions, they can also improve residents' livelihoods, as less time is spent in traffic and community cohesion may be facilitated. Other transport options assessed were a car share scheme and a subsidised bus route. With nearly £600 per tonne of carbon saved the bus route may be a good idea in terms of improving access and social mobility, but it is not a cost-effective solution for cutting carbon emissions. A car share scheme at the case study site costs about £100 per tonne of CO_2e saved, but is still much cheaper than most renewable energy options and some energy efficiency options (Figure 6.6).

Progress may be made through employing a sustainable living officer to organise events, volunteer opportunities, generally raise awareness and provide a platform for people to meet and thereby foster community spirit. Organising a weekly farmer's stall may encourage low carbon food consumption; such opportunities save carbon at a lower cost than most renewable energy options (Figure 6.6), and with potentially significant benefits to local residents (Table 6.5).

The waste scenario displayed in Table 6.4 is the chosen waste scenario for the lifestyle approach scenario at the case study development. This scenario is based on the Major of London Waste Strategy's (Livingston, 2003), DEFRA (2009) and Head (2007) suggestions of realistically achievable collection rates for waste separated by households, which suggests that a 60 to 65% collection rate is a realistic target. The exception to this is food scraps for which the suggested achievable target is 40%. The Waste Reduction Model (EPA, 2007) was used to test which waste treatment method (recycling, composing, or combustion) would deliver the greatest carbon savings for each waste material category. On this basis those treatment methods, which delivered the greatest carbon emission reductions for each particular material category, were selected. The chosen waste scenario for our case study development is shown in Table 6.4. These results illustrate that CO_2e emissions reduction from intelligent waste treatment can be greater than the direct emissions from waste disposal, i.e., the methane emissions from waste if sent to landfill can be more than compensated for if waste is recycled, thereby offsetting emissions that would have been caused by the use of replaced virgin material.

Costs for excellent internal and external recycling bins and composting facilities, which would enable this shift, were taken from Cyril Sweett (2007).

Table 6.4 Waste scenario for case study site

Material	Tonnes of waste produced	Total CO_2 if sent to landfill (tCO_2 e)	Assumed recycling rate	Assumed compost-ing rates	Assumed combust-ion rate	Total CO_2 if sorted (tCO_2e)	Waste not sent to landfill (tones)
Aluminium Cans	16.66	0.64	60%			-149	10
Steel Cans	37.49	1.44	60%			-40	22
Glass	197.15	7.58	60%			-30	118
Cardboard and Paper Packaging	111.07	164.86			60%	22	67
Food Scraps	340.16	485.02		40%		264	136
Garden Waste	191.60	-5.58		60%		-25	115
Mixed Paper	242.97	298.67	60%			-343	146
Mixed Metals	6.94	0.27	60%			-30	4
Mixed Plastics	112.46	4.32	60%			-100	67
Other MSW	134.67	213.85				214	0
Total	*1391.18*	*1171.07*				*-217*	*686*
Reduction						*119%*	*51%*

We can notice that Figure 6.6 displays a number of low cost options to reduce carbon emissions at the exemplary development. Below £100 per tonne of CO_2e are:

1. choice of the right location or mix of uses of the development, such as locating homes near jobs or jobs near homes
2. improved access to sustainable local food through creating allocated commercial space on site or nearby
3. raising awareness on sustainable living (such as home operation, access to sustainable consumables, recycling, sustainable transport options) by employing a sustainable living officer on site.

If we compare Figure 6.6 to Figures 6.3, 6.4 and 6.5, it becomes clear that there are a number of cost-effective carbon reduction solutions in the area of energy efficiency and building materials choice. The majority of carbon emissions reduction measures do, however, involve additional costs, and the difference in costs per unit of CO_2e saved vary significantly.

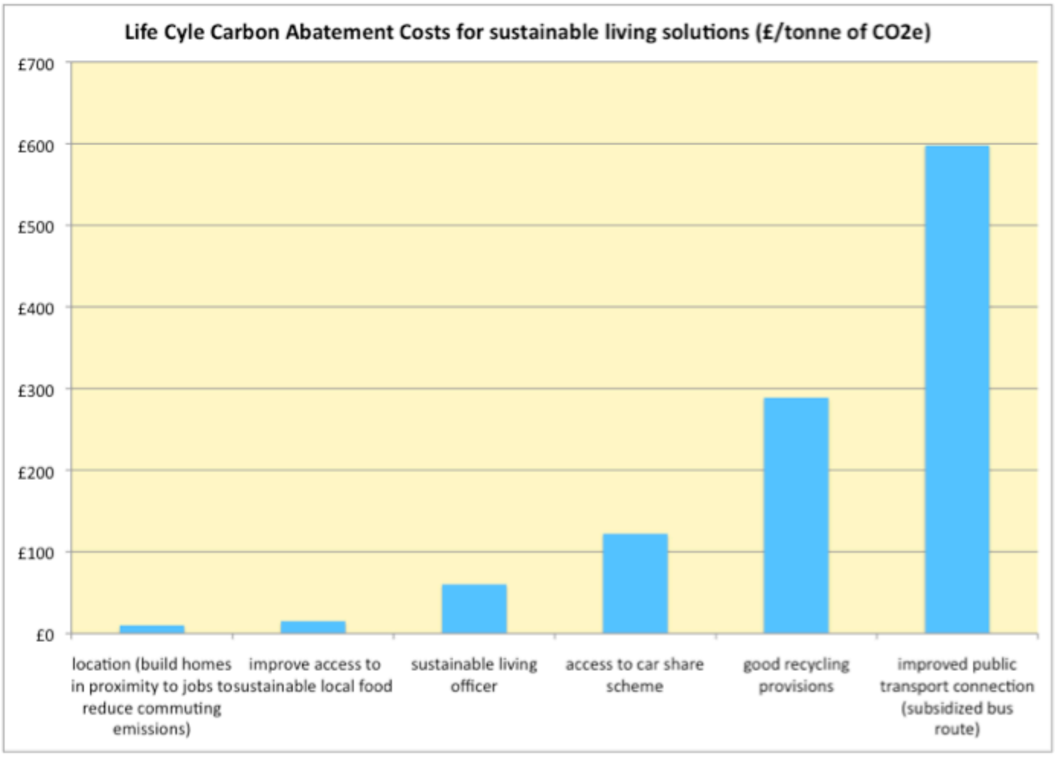


Figure 6.6 *Life cycle abatement costs for sustainable living solutions at the case study development*

Here again the Tool Focus Group 2 decided to set aside the detailed residential impact assessment of each category for a second stage upgrade of the Tool, which could take place after the Tool had been applied to a number of sites and responses and secondary data had been gathered. Instead, a general assessment, including a discussion of the categories was conducted (described below) and is summarised in Table 6.5.

Overall social assessment: lifestyle approach versus current policy

The social assessment addressed customer acceptability and the social impact upon the residents, comparing the selected household carbon emission categories. Judgements presented in Table 6.5 below arose from consensus among Tool Focus Group 2 members.

On this basis Table 6.5 presents a summary of the analysis that was carried out, with various measures bundled into themes. From the analysis it became clear that many of the measures that are outside the normal set considered by developers (especially those relating to transport and food), can significantly add to the wellbeing of residents. This is normally something, which many of the traditional low carbon solutions, which focus on reducing direct home energy consumption cannot achieve.

Table 6.5 Summary of the impacts of various measures upon residents

Theme	Residents impact	Judgement
Energy efficiency measures (draft proofing, insulation, solar orientation, low e lighting, low e appliance)	Improve thermal comfort and day lighting	Positive
Renewable energy generation	Some renewables have little or no impact upon the residents (e.g., solar hot water, heat pumps, solar electricity); others have negative impacts (e.g., biomass reduces air quality and can be less reliable, wind has visual impact)	neutral or negative
Building materials (e.g., use of wool, recycled cellulose insulation, reduced use of concrete)	Impact can be positive or negative, depending on taste and choice of materials. Use of timber (e.g., hardwood flooring) is becoming increasingly popular. Timber framed houses can be noisier, but allow for more interesting designs such as split level flooring.	Neutral
Transport (car-share schemes, pedestrian friendly streets, mixed use developments, cycle friendly measures, access to amenities and jobs nearby)	Building mixed use developments and matching the job and amenity specifications to needs and wishes of future residents can hugely improve the livelihoods of the residents. Cutting out commuting time by car frees up time for other activities.	highly positive
Waste (good recycling provision, awareness raising to reduce waste generation and increase recycling rates)	Residents need extra space for recycling bins in their homes and need additional time to separate the waste. A space where residents can leave useable items they no longer want, for others to take, will benefit those on low income.	Neutral
Food (e.g., weekly market stall, promoting veg. box scheme, local shop or cafe dedicated to selling ethical low carbon local produce)	Making ethical health food easily accessible can improve the health of residents and support local farmers	highly positive

6.7.5 Future Development/Scenario: Zero Carbon Home

In most locations the UK Government's proposed carbon emissions reductions for 2010, 2013 and 2016 (25%, 44% and 100% reduction of the direct energy used in the homes, respectively) (DCLG, 2007c) will largely require the use of higher-end energy efficiency and renewable energy measures. A few exceptions would be locations near suitable sites for wind energy (i.e., near a field with medium to high wind speeds). After wind, the most cost-effective means of achieving carbon neutrality is through biomass CHP. The costs of the majority of measures employed may lie in the range of £100 and £500 per tonne of CO_2e saved. Indeed, for a so-called carbon neutral home (as per the Government's 2016 target), the additional capital costs for renewables and energy efficiency measures compared to a home that meets building regulations are calculated here to lie in the order of £20k to £36k, unless medium or large scale wind is feasible at the site and permission is grated. This assumes that direct home energy consumption is reduced by the following energy efficiency measures: best air tightness, hot water heat recovery, best insulation, 100% low energy lighting, A-rated fridge-freezer, improved hot water storage insulation, good air-tightness, low water use bath, showers with a maximum flow rate of 9 l/min, aerating or flow restrictor taps (see Table 6.2 for a detailed description of each of these). The remaining net energy use is to be generated by renewable sources, which could be biomass CHP, biomass heating with PV and solar hot water, or ground source heat pumps with PV.

Since the analysis was conducted, feed-in tariffs have been introduced in the UK, which would have reduced the lifetime costs of the renewables to the user. However, feed-in tariffs are a subsidy and are paid indirectly by all electricity users. Therefore, the true costs of on-site renewable energy generation to society are still reflected in Figure 6.4.

Figure 6.7 shows the household carbon emissions for a typical UK household living in a zero carbon home. Whilst carbon emissions from direct home energy use are at zero, without further measures all other categories remain unaffected.

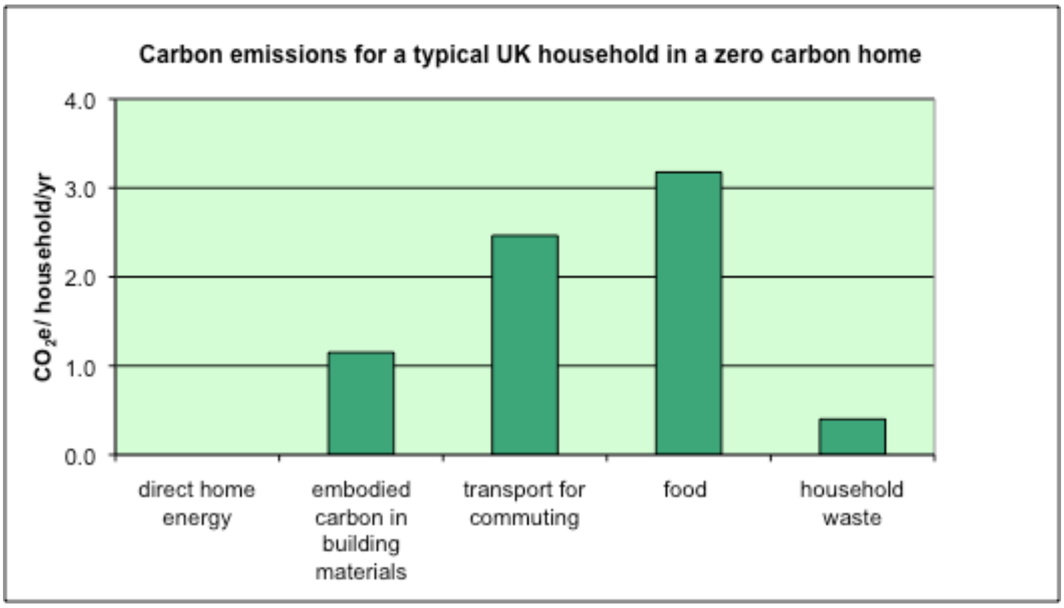


Figure 6.7 Carbon Emissions for a typical UK household under a Zero Carbon Scenario

Figure 6.7 indicates that the total carbon footprint is reduced by 2.9 tCO_2e over that of home, which meets 2002 building regulations. This is a total reduction of 29% over the base case scenario of building a new home, or an overall household carbon footprint of 7.2 tCO_2e.

6.7.6 Future Development/Scenario: Lifestyle Approach

Table 6.6 displays the chosen carbon emission reduction measures chosen by the developer of the case study site. His choice was based both on the carbon emission reduction cost effectiveness coefficient, and on residential impact, practical considerations and personal preference. The analysis shows that the extra costs of achieving a similar level of CO_2e emissions reduction (2.9 tonnes of CO_2 per household per year, based on our baseline analysis) using the lifestyle approach at the exemplary site would amount to approximately £4,000 per home. Sensitivity analysis reveals that costs would be similar for other housing developments of similar scale and may range between £3,000 per home and £10,000 per home. This is a fraction of the extra costs to achieve the same emission reduction using the zero carbon homes route (net zero emission from direct energy use), which would cost about £20,000 to £36,000 per home (Section 6.7.7). Table 6.6 shows the chosen scenario for the exemplary development and the emissions savings, which were calculated to be achieved in each category.

Table 6.6 Estimated CO_2e savings per household at the case study development under lifestyle approach scenario for chosen measures that go beyond current building regulations

Measures	**Annual CO_2e reduction (tCO2e/household/year)**
Low cost energy efficiency measures (air tightness, low e lighting, low flow tabs and showers)	0.3
Solar hot water	0.3
20% increase in waste reduction and recycling through good provision and awareness-raising	0.5
15% carbon emissions reduction of food carbon footprint through awareness-raising and advice on organic veggie box schemes, a low carbon themed café and shop at the site selling local and low carbon and ethical food and products	0.5
25% reduction in commuting transport emissions through choosing a location with jobs close to homes, increased cycling, car share scheme and public transport	0.6
Low cost building materials with low embodied carbon is chosen (timber frame, timber and tile flooring, timber cladding, site construction waste reduction, minimising use of concrete and lead)	0.3
Sustainable living officer achieves 10% uplift in recycling rates, sustainable food uptake, uptake of sustainable transport options, and home energy management	0.3
Total	2.9

Figure 6.8 shows the resultant change in household carbon footprint at the proposed development.

We can observe in Figure 6.8 that household waste now contributes to savings rather than causing emissions to rise. The percentage reductions achieved in each category compared to a new house which meets 2002 building regulations are: direct home energy - 21%, building materials – 38%, transport – 25%, food – 15%, and waste – 130%. Note that the chosen waste scenario now results in net negative carbon emissions, i.e., due to the high recycling rates, emissions from the production of virgin products are avoided through recycling, and new products are made in a more carbon-efficient way.

The selected measures represent a relatively small sample of all the investigated measures, which allow us to achieve savings. Other opportunities include for example reducing the internal temperatures, more targeted ventilation, car-co-ownership, opportunities to grow food locally, and offering to build and sell or rent customized workspaces and commercial spaces to new residents who want to setup businesses locally. Therefore, if one developer does not like specific opportunities, or if on another development some opportunities are not appropriate, other measures may be employed. As a result, we can conclude that it is very likely that similar savings and beyond can be achieved in most developments using the lifestyle approach.

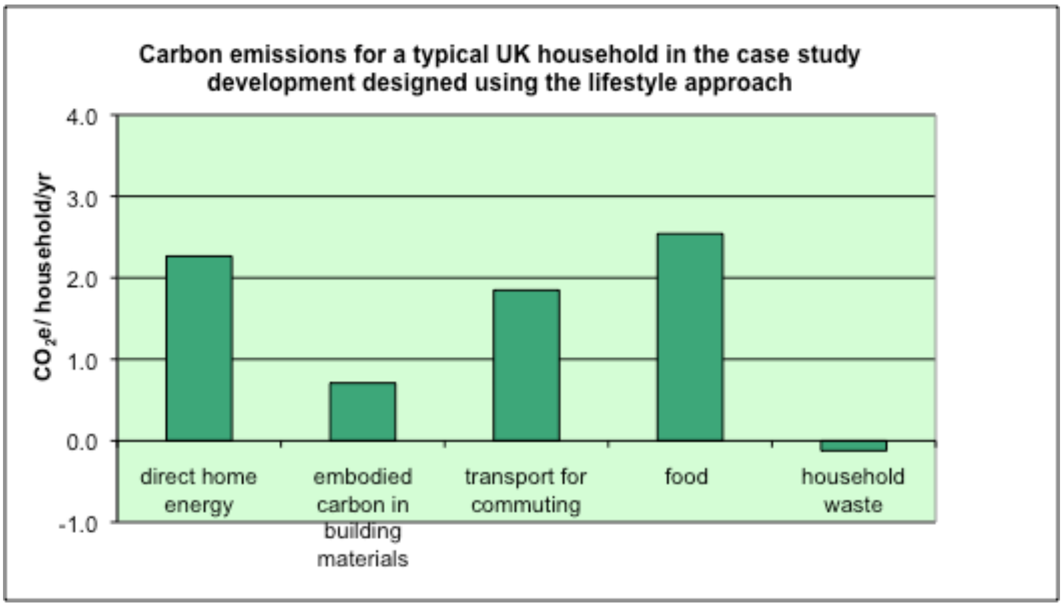


Figure 6.8 *Carbon Emissions for a typical household in case study development designed using the lifestyle approach*

Whilst the above analysis shows how emissions can be reduced for less money by including other emissions categories, not just the direct home energy category, this does not mean that we should not build homes which have net zero emissions from direct home energy. Rather we conclude that to achieve the challenging 80% emission reduction target (Chapter 2 and 3) it makes sense to include all solutions available and do as much as possible wherever we can. In addition in order to minimize the adverse impact upon society, it makes sense to prioritise on implementing those solutions, which have the least negative impacts upon society and economy. The lifestyle approach tested here shows that for new housing a different focus including all available opportunities may be a way to achieve greater emission reductions and perhaps do so at lower costs and negative societal impact.

6.8 Further Discussion and Overall Conclusions

We have shown that carbon emissions reductions in new housing can be achieved at much lower cost through an approach that enables sustainable lifestyles, rather than focusing purely on reducing the emissions of the building in its use. In addition, many of the low carbon lifestyle solutions have greater additional benefits to residents than just energy efficiency and renewable energy measures. Good low carbon transport provision (walking, cycling, public transport, car-share schemes), local access to jobs, amenities and low carbon consumables, convenient recycling facilities, and a sustainability officer who supports implementation and community cohesion, may be more valuable to local residents and the wider local economy than renewable energy and energy efficiency measures only.

To achieve its challenging climate change targets, the Government needs to complement its low carbon/carbon neutral homes aspiration with policy that makes low carbon living easy and attractive. Transport, waste and local amenity policies could have a greater emphasis on reducing CO_2e emissions. The successful emissions reduction achieved through building regulations, which regulate the maximum likely CO_2 emissions of a building in use could be replicated in other categories, such as building materials, emissions from commuting, emissions from waste, and consumption. This may be a more sensible and cost-effective way forward than stipulating that energy used in new homes has to be brought down to zero by 2016, or in the light of the challenging overall carbon emission reduction target the 2016 carbon neutral homes target could be complemented by other policies which reduce and/or limit emissions in the other four household carbon emission categories and which enable more sustainable lifestyles.

Both policy makers and developers can use the Climate Challenge Tool in support of the design of sustainable low carbon communities. When designing new housing developments it is important to understand the full carbon emissions implications of residents. This assessment should not be limited to the direct energy use of the buildings only, but should include a better understanding of the carbon emissions resulting from transport, consumption patterns, waste disposal, and building material choices, as well as efforts to raise climate change awareness on site. Only with such a holistic understanding will it be possible to achieve the UK Government targets for carbon emissions reductions.

Our findings have shown that many carbon reduction measures, such as building integrated renewable energy, currently required by many local planning authorities, cost far more per tonne of carbon saved than other, as yet, unregulated solutions. Many of the lifestyle options have additional benefits to the residents and may even without additional policy incentives be a viable option for progressive house builders. The Climate Challenge Tool with its outputs on carbon and financial implications may help design more sustainable and climate friendly yet profitable developments.

Combining lifestyle and technical options is the way forward, and in new housing developments can contribute significantly towards reducing greenhouse gas emissions without provoking an overall negative impact on residents. But how can we be certain that developers will implement all the lifestyle measures, particularly when there are already signs that certain technical measures are not implemented? (See section 4.4.2: Building Regulations: Part L and Merton Rule). What happens when a number of the lifestyle measures require action by the developer *after* planning permission has been granted? Perhaps a whole new approach to housing development is needed. A significant success factor for low carbon lifestyles is the willingness of future residents/communities to take advantage of viable opportunities presented, and that they want to change their lifestyles in order to live in an eco-friendly way. Lifestyle changes may be supported or triggered by active communities; therefore in Chapter 7 we investigate the role of local communities to enable low carbon lifestyles.

7. Sustainable Communities

7.1 Chapter overview

In Chapter 4 we demonstrated that Government policy based largely on technological change is not sufficient to deliver an 80% carbon emissions reduction target by 2050, or the intermediate target of 26% by 2020. Chapter 6 discussed how new housing development options enable low carbon lifestyles to be part of a possible solution, and contribute significantly to carbon emission reductions. In this chapter we argue that lifestyle changes in new housing developments may be facilitated through fostering communities.

We have highlighted in the literature two potential approaches for achieving long lasting lifestyle changes: the first one is set up and economic incentives and the second one a change in social norms. We argue that the combination of both will achieve the largest carbon savings. Set up and economic incentives are already being applied to new housing, whereas social norms are difficult to legislate for and to introduce within the present UK housing framework. However, social norms can be created through communities, and on this basis we investigate how community values can be changed, and how such value-driven communities can be cultivated to create low carbon new housing developments.

A focus group discussion was conducted to explore how communities can create low carbon neighbourhoods and whether there are ways to develop new housing to enable such utilisation. We found that carbon savings may be enhanced through a wider sustainable community approach and that this could also have other sustainability benefits. Our review of the literature supports this outcome. We identify an opportunity for community engagement in new housing: eco-self-build communities. This was selected for further investigation in Chapter 8.

7.2 Changing lifestyles in housing developments

7.2.1 Approaches to fostering low carbon lifestyles

In recent years there have been three major UK Government reviews aimed at bringing about behaviour change. These are:

1. Collins et al. (2003) is a Government review for DEFRA regarding how to influence public behaviour towards environmental goals.
2. Professor Tim Jackson (2005) conducted a Government review for the Sustainable Behaviour Unit of DEFRA with the aim to identify effective methods for triggering pro-environmental behaviour. He collected evidence from the academic literature to understand what has worked in the past and what has not,

and on this basis made recommendations for future governmental decisions for changing behaviour.

3. Futerra (2006) – "New Rules of the Game – Communication Tactics on Climate Change" is a Government review by Futerra published by DEFRA. The document was created as part of the UK Climate Change Communications Strategy for changing climate behaviours. Futerra based their review on evidence from extensive literature about what works in relation to changing behaviour and attitude (Futerra, 2006).

A common thread among the reviews (Futerra, 2006; Jackson, 2005; and Collins et al., 2003) is that they advocate a combination of set up and economic incentives and social norm change. Examples of possible interventions by housing developers in these categories may include:

1. **Set-up and economic incentives**: Designing the development so that the sustainable choice becomes the obvious, automatic choice or the route with the most benefit to the person making the choice. An example would be to locate work spaces near living spaces and to combine this with good pedestrian, cycling and or public transport access and reduced or charged car parking spaces. This would make the sustainable transport choice the easiest and perhaps cheapest way to get to work for the resident. The set-up and economic incentive category includes technological options (e.g., energy efficient housing, integration of renewable energy) and through a set up that facilitates sustainable living (e.g., lack of car parking spaces, good cycling and public transport provisions, easy access to sustainable products such as local food, etc). BedZED (BRECSU, 2002), One Brighton and Masdar City (Desai, 2009) are developments where these technological options and facilities for sustainable living, which are here, listed as examples have been employed.
2. **Social norms**: Encouraging responsible behaviour, thereby increasing the possibility of reducing emissions further and creating more vibrant communities through a change in conduct and through altruistic involvement of residents. The BedZED (BRECSU, 2009) is an example where in addition to set up and economic incentives responsible behaviour and the use of the sustainability facilities was encouraged through awareness raising activity through employing a sustainable living officer (SLC), and handing out information leaflets. This can encourage the uptake of the sustainable behaviour as sometimes people stick to their old habit even though through the new set up and economic incentive this behaviour is no longer their best choice (Jackson, 2005). Using social norms can in this case encourage them to try new ways and possibly also to go further and

do something purely because is it a more ethical choice rather than just providing personal benefits (*op cit*).

Both economic incentives and social norms can contribute differently to reduce the carbon footprint and contribution to their communities. When aiming to create socially sustainable communities with minimal adverse impact on the planet it is important to focus on both aspects, as they work in mutual support of each other and synergies can then be achieved (Jackson, 2005; Futerra, 2006). Jackson (2005) found that pro-environmental behaviour change requires a concerted study that integrated economic incentives with social norm change, which in their combination make it easy to behave more sustainably. This should be achieved through incentive structure and institutional rules which favour sustainable behaviour, combined with enabling access to the pro-environmental choice through making people aware of it and removing any remaining barriers, and through engaging people in initiatives to help themselves and doing things differently. Jackson (2005) also stresses the importance of role the change agent (for example the Government or housebuilder) has as a role model the desired change within its own policy and practice.

These findings are similar to those of Collins et al. (2003) who show that information alone is not enough and that only a minority of people will change their behaviour if they have to make personal sacrifices for doing so. Therefore, for significant change to occur, awareness-raising campaigns need to go hand-in-hand with structural, technical and/or policy changes in order to make the sustainable choice either positive or neutral to the person who makes the choice.

7.2.2 The UK Ecotown Initiative and low carbon lifestyles

Before exploring new ways of fostering sustainable lifestyles in new housing communities it is worthwhile to review how sustainable lifestyles will be or could be encouraged under the Ecotown Initiative (CLG, 2007b) (Chapter 4, Section 4.2.2), whether there are lessons to be learned, and whether and to what extend the current governmental flagship projects could enable low carbon lifestyles.

Whilst as already mentioned it is planned that the Ecotowns have a zero carbon footprint for the direct energy used in their homes, in the Ecotown Prospectus (CLG, 2007b) the Government says little about changing social norms and awareness-raising activities, which are linked to the design, technology and architectural solutions (Warren, 2007; TPCA and Lock, 2007). Specifically whilst the Ecotown Prospectus (CLG, 2007b) states that “community participation and involvement” is to be encouraged, no mention is made of awareness-raising activity and neither does it go into detail as to how community participation and involvement is to be encouraged.

As we have detailed in Section 4.6 when breaking down the emissions footprint of a typical UK resident living in a home built to 2002 building regulations, the overall CO_2 footprint resulting from all direct energy used in the home only amounts to 11% of the total emissions footprint of their residents (Desai, 2005). Our analysis in Chapter 6 shows that direct energy use amounts to only 28% of the household carbon footprint calculated including the chosen five emission categories which could be influenced by they way new housing is designed and managed. Thus we question whether the phrase *zero carbon development* is appropriate if it applies only to the direct energy used in homes themselves would account only for about 11% of the resident's carbon footprint and 28% of their household carbon emissions.

Despite the fact that certain elements of the carbon footprint of future Ecotown residents are beyond the control of developers, and that elements in Ecotown design encourage carbon emissions reductions in the area of building materials (low environmental impact and responsibly sourced building materials) personal transport (e.g., local job provision, cycling, walking, and public transport provision) and waste, (recycling and composting provisions), these areas are unlikely to contribute significantly to carbon emission reductions. This is because the CSH is used to enforce progress in these categories, and our analysis in Chapter 4 has shown that this only tackles a very small percentage of the overall carbon footprint of the household. We therefore ask what else Government can or should do to change social norms and behaviour in the Ecotowns and new housing in general.

Government could require developers to raise awareness, for example, through information provision, campaigns, and events or through employing a sustainable living officer; however, these are difficult to enforce after planning permission has been granted, and at this juncture Government has little authority to incentivise house builders to deliver a quality awareness campaign. In addition, changes in lifestyle may not continue after the campaign or lifestyle officer employment finishes. We argue that, in order to succeed at changing social norms, the approach to housing development cannot be led by housing developers who seek primarily to maximise profit margins. As in there seems to be little opportunity to change lifestyles within the current way most housing is developed (including the Ecotowns), in order to change lifestyles new approaches to housing development may be required. The remaining sections of Chapter 6 set out to explore how community may be utilised to enable lifestyle changes in new UK housing developments.

7.2.3 Changing social norms and behaviour through fostering communities

Social norms consist of rules of conduct and models of behaviour prescribed by a society of which communities are a part; norms of behaviour are rooted in customs, traditions and value systems that develop over time (Cite de Sciences, 2010). Communities and particularly close-knit local communities are part of the society people belong to (Riger and Lavrakas, 1981). Therefore social norms of individuals are influenced by the communities they belong to (Taylor and Moghaddam, 1994; McKenzie-Mohr, 2000). Social norms can be affected and changed through awareness raising on issues, changing attitudes and through promotion of behaviour change activity, and through convergence of understanding within the community (Taylor and Moghaddam, 1994; McKenzie-Mohr, 2000; Barton, 2000).

We will next define the term: community and explore how social norms can be influenced by, and within, communities. We follow on with an exploration of alternative approaches to new housing development that utilise and work with the community to shift social norms in order to create low carbon communities.

Barton (2000) defines community as "*a network of people with common interests and the expectation of mutual recognition, support and friendship*." Gilchrist (2000) describes the relationships between the people and the benefits of a strong community stating that community refers to that layer of society in which interaction takes place between people who are neither close family and friends, nor yet total strangers. The term, he continues, embraces a quality of life that seems universally valued: a sense of belonging, which absorbs some of the stresses and strains of an increasingly fragmented existence (*op cit*). Through this, in Gilchrist's view community *"shapes our social identity and helps people to make sense of a complex and dynamic world*." (*op cit*) Community can be associated with a particular place or it can be applied to a network or group of people with a shared interest. For the purpose of the thesis, we use the definition of Riger and Lavrakas (1981) of community as a place with increased neighbourhood attachment that can be measured through social bonding and deep-rooted behaviour.

From social and behavioural sciences literature, there are a number of behaviour theories that have been identified that support the claim that community influences social norms. Four key theories are described below:

1. <u>Adjusted expectancy value theories</u>

   Adjusted expectancy value theories state that choices are based on expected outcomes and the values attached to those outcomes, and through this go beyond pure rational choice (Fishbein and Ajzen, 1975). An individual's values can be influenced by the values that their community adopts (Fishbein and Ajzen, 1975).

   In recent years attempts have been made to incorporate moral beliefs and social norms into these theories, for example, in the Value Believe Norm Theory (Stern et al., 1999). This has in some cases improved accuracy in prediction behaviours, and has shown that behaviour change can to some extent be triggered through changing social norms, which again can be influenced by their community (Stern et al., 1999; Jackson, 2005).

2. <u>Habitual Behaviour Theory</u>

This theory states that behaviour is often habituated and that individuals often do not change as a matter of routine but may conscientiously decide to change for logical or other reasons (Jackson, 2005). Behaviour change strategy therefore needs to aim towards long-term habit changes, rather than a temporary or one-off change, so that chosen changes can be carried into the future. In a local ethically-guided community, peer identity and pressure may help to establish long-term change in habit patterns rather than one-off attempts (Jackson, 2005).

3. <u>Social Identity Theory</u>

Social Identity Theory states that our actions are largely driven through the attempt to preserve our identity in society and in our communities (Taifel and Turner, 1979). Therefore if a sustainable behaviour is cultivated and praised in any given community each member becomes more likely to adopt sustainable behaviours in their desire to have a respected identity (Taifel and Turner, 1979).

The Habitual Behaviour Theory and Social Identity theory may help to explain some behaviour. However, as people's behaviour is not only influenced by habit and social identity, but also by practical and moral considerations, these can only ever shed light on certain elements of pro-environmental behaviour change (or reluctance to change) and how they relate to the social norms and values of the community to which a person belongs (Taylor and Moghaddam, 1994).

4. <u>Integrative theories on consumer behaviour</u>

Integrative theories include both internal dimensions (values, attitude, intention) and external factors (incentives, norms, institutional constraints) (Turner, 2002a; Turner 2002b; Burt, 1983). Integrative theories attempt to incorporate all aspects of other theories and not only show how the individual is influenced by one's community social norms, but also how they can play an active role in shaping the norms of the community and its other members (Turner, 2002a).

Because social norms can be influenced by communities – and residents of a new housing development are likely to become members of their local community – there may be a way to influence social norms through affecting the local community set-up, community cohesion, culture, its understanding of sustainability issues, and how it operates.

Community-based promotion of sustainable behaviour may be an attractive option for speeding up the transition to a low carbon, more sustainable future (McKenzie-Mohr, 2000). Using psychological knowledge of behaviour change, promoters identify the activity to be promoted and the barriers to this activity, and then either design a strategy to overcome these barriers or design solutions into the structural set-up of the housing development, to achieve the same purpose. Unlike many information-intensive campaigns, which were shown to have less impact, community-based social promotion that focuses on changing social norms has been shown to strongly promote sustainable behaviour (McKenzie-Mohr, 2000). Below are a number of examples in which community focus delivered a change in social norms and pro-environmental behaviour.

The Waste Reduction in the Community Project (WRCP), initiated by the Recycling Consortium, funded a dedicated full-time development employee in April 1995 to work with five local communities in Bristol and South Gloucester (Rowe and Robbins, 2002). Each of the five communities also has a Waste Action Group composed of volunteers. Rowe and Robbins (2002) found that the two most effective communities in terms of an increase in local recycling activity and change in social norms had the strongest sense of community: local identity, shared values and existing capacity, indicating that a strong sense of community can promulgate pro-environmental behaviours and social norms. Therefore, if a strong sense of community can be cultivated within new housing community set-up and development, pro-environmental behaviour may be enhanced and extend through the entire community.

McKenzie-Mohr (2000) piloted community-based social promotion or marketing as a means for triggering behaviour change and to test its effectiveness compared to non-community based approaches. He applied this community based approach with the aim to get people in a given neighbourhood to save water and use it more responsibly during periods of drought (McKenzie-Mohr, 2000). He used a variety of mechanisms, described in more detail below. He found that, in contrast to many governmental awareness campaigns, a community-based social promotion approach can be supported by a number of factors deemed critical by psychologists for triggering significant behaviour change. These include awareness that a change is required, commitment to change, alignment with social norms, and a mechanism that reminds individuals to execute the new behaviour. The resulting elements he suggested be incorporated into a community-based social promotion approach are described and analysed below in relation to new housing developments and how this knowledge could be linked to design decisions for housing developments.

1. <u>Gaining a commitment from an individual to change specific behaviour</u>

   When an individual agrees to an initial small request, the likelihood that he or she will subsequently engage in a more substantial activity increases dramatically - the so-called "foot-in-the-door effect." (McKenzie-Mohr, 2000). Commitment techniques have been used successfully to foster a variety of activities that favour the environment (Katzev and Wang, 1994). For example, bus ridership has been increased using commitment (Bachman and Katzev, 1982), as has direct home energy efficiency (Pallak, Cook, and Sullivan, 1980). In a newly forming community of a new housing development, it is possible to obtain collective and individual commitment to certain low carbon living choices from group members. As each group member shares their commitment with the group, it grows stronger, as it is no longer just a one-to-one commitment, but has spread to neighbours and the local community (McKenzie-Mohr, 2000).

2. Prompts

A variety of activities that promote sustainability are often neglected, simply because people forget to engage in them (McKenzie-Mohr, 2000). For example, repetitive actions such as closing blinds on warm days, turning down a thermostat, checking tyre pressure, and turning off an idling engine are all activities that many individuals are willing to do if they simply remember to do so (McKenzie-Mohr, 2000). In such cases prompts can be an effective tool for encouraging action. A prompt is a visual or auditory aid used to remind people to carry out an activity that they might otherwise forget (McKenzie-Mohr and Smith, 1999). Prompts are designed not to increase motivation or change attitudes but rather simply to remind one to engage in an action that he or she is already receptive to. Prompts have been used extensively in the area of waste reduction and have frequently been demonstrated to be very effective (McKenzie-Mohr, 2000). For example, the introduction of a prompt reminding people about what types of paper can be recycled was shown to increase recycling capture rates by up to 54% (Austin, Hatfield, Grindle, and Bailey, 1993). In a new housing community prompts can be used, for example, by a sustainable living officer, in order to reinforce commitments community members have already made. Community members may also prompt each other.

3. Developing community norms that support eco-friendly or low carbon behaviour

Community and cultural norms can work both in favour and against sustainable behaviour. For example, backyard composting could be perceived as respected responsible behaviour demonstrating the person's commitment to the environment – or alternatively, as irresponsible behaviour of someone who is attracting rats and flies to the area (Stern, 2000). Community norms may need to be realigned to support sustainable behaviours. Awareness-raising in the community, such as on the planetary benefits of composting and how best to do it, can change perceptions from negative to positive and thereby change the social norm of the activity among local community members (McKenzie-Mohr, 2000). Community members can then encourage each other to take up the responsible behaviour.

4. <u>Direct personal contact</u>

A direct personal contact has been shown to increase the effectiveness of number 1 to 3 above (Burn and Oskamp, 1986; McKenzie-Mohr and Smith, 1999). In a new housing community direct personal contact can be established with the person who raises awareness in the community such as a sustainable living officer or possibly community members who chose to take on this responsibility themselves. The personal contact can be with someone who is known by all community members, which is potentially more effective (McKenzie-Mohr, 2000). In addition, as the culture shifts, community members will encourage responsible behaviour and direct personal contact on a recurrent basis (McKenzie-Mohr, 2000).

5. <u>Tie awareness campaign into convenient behaviour by changing the infrastructure</u>

The aforementioned methods (1 to 4) deal with barriers within an individual or local community. As effective as these methods may be, if significant external barriers exist, a programme will fail (Jackson, 2008; Collins et al., 2003; Stern et al., 1999). As both Stern et al. (1999) and Jackson (2008) have pointed out, crucial structural barriers to behaviour change are often present. For example, if a convenient mass transit system does not exist, commitment strategies will be ineffective in convincing people to ride the bus. Because external barriers are likely to vary widely among communities, programme designers attempting to create successful strategies will need to determine the external, non-psychological barriers in each community and implement an appropriate programme to remove these barriers (Jackson, 2008; Collins et al., 2003; Stern et al., 1999). Within the design of new housing communities there may be opportunities to make design decisions, which remove structural and/or technical barriers, for example, providing convenient and user-friendly recycling provision and designing in workspaces to reduce car journeys, as discussed in Chapter 6. Likewise, structural and technical low carbon options can be supported by awareness-raising activity in the local community. Jackson (2008) and Collins et al. (2003) have pointed out that a concerted strategy which includes both technical and structural changes and the promotion of sustainable lifestyles is much more effective than the sum of its parts when these activities are not joined up. With a combined situation of new housing and its scope of structural and technical solutions, and the opportunity to influence people behaviour with a community-based approach, low carbon lifestyles can potentially become fully realised.

Whilst this method of community-based promotion has been tested only on one environmental problem in one location, the literature here reviewed (particularly Jackson, 2005; Collins et al, 2003; Futerra, 2006; McKenzie Mohr, 2000; Jackson, 2008; Burn and Oskamp, 1986) suggests that these approaches work more generally. However, it is likely that outcomes and effectiveness would differ in different situations.

7.2.4 Conclusions

Both set up and economic incentives (making it easy to live with a low carbon footprint) and a change in social norms and behaviour are required as pillars of a low carbon society. There is an opportunity in new housing developments to provide both. A greater change in behaviours and social norms can be achieved with a community approach. The current conventional way in which new housing developments are conducted are not normally supportive of such a community approach. In Section (6.4) we will explore the question of how we can we utilise community in order to create low carbon new housing developments. However, in order to understand how this can happen we will first (in Section 7.3) review literature, which explores the links between people, the build environment and the natural environment.

7.3 The Need for Wider Sustainability Considerations

According to Barton (2000), for a community to take positive action towards an issue such as reducing carbon emissions, they need to be motivated by a wider cause for which they feel ownership. Concerns about the future of their community and their personal well-being may provide a stronger motivation for change. Therefore based on Barton (2000) we here assume that sustainable communities, including social, economic and environmental considerations, may be a more attractive proposition than low carbon communities.

In this section we define sustainable communities, assess linkages between socio-economic and environmental sustainability, and analyse the effectiveness of a wider sustainability approach for delivering low carbon communities.

7.3.1 Defining sustainable communities

The term "*sustainable community*" is often used to describe environmental sustainability features of a housing development but without including social factors (Smith, 2001). For our purposes we need a definition that encompasses the social aspects of community. In order to derive a better definition it is worth first examining what is mean by the two parts of the term.

The terms *sustainability* and *community* are both used differently in political discourse; the meaning of the term community was discussed in section 7.2.3 and the definition by Riger and Lavrakas (1981) with community being a place with increased neighbourhood attachment that can be measured through social bonding and behavioural rootedness was adopted for the purpose of this thesis. Before we can build on this to define what we mean by sustainable communities, it is worth briefly exploring what is meant by "sustainability".

As with community, 'sustainability' has no single or agreed meaning, but rather it takes on meaning within different political ideologies and programmes underpinned by different kinds of knowledge, values and philosophy (Huckle, 1996). A 'weak' view of sustainable development looks to continuing economic growth in terms that favour existing financial and economic practice (Smith, 2008). A "*strong view represents a revised form of self-reliant community development, which sustains people's livelihoods using appropriate technology*" (Huckle, 1996). The former fits in with what we might refer to as mainstream politics in many western countries; the latter represents a green and holistic vision. It echoes the concerns of E. F. Schumacher (1973) who argued for appropriate scale, wholeness and connectedness (Smith, 2008). We adopt for our purpose here the sustainability definition of Huckle (1996). This definition is particularly pertinent as it draws on the concept of community. Thus by sustainable community we mean a place which is as self-reliant as possible, which sustains people's livelihoods and wellbeing using appropriate technology and one where the people living their have a strong attachment to the place and strong social bonds with and live in mutual support of each other.

Now we have described what we mean by sustainable communities we want to better understand how both people and the build environment contribute to sustainable communities and how people and the built environment can work in mutual support of each other.

7.3.2 People centred initiatives - strengthening social and human capital

Sustainable development should be more than merely "protecting" the environment (Seong-Kyu, 2007). Instead it requires economic and social change in order to improve human wellbeing while reducing the need for environmental protection (*op cit*). Social sustainability is another way to discuss social capital. Socially sustainable community members are able to provide adequate and appropriate shelter for themselves; enjoy a sense of belonging; be assured of mutual social support from their community; enjoy freedom from fear, and security of person; and participate actively in civic affairs (Seong-Kyu, 2007).

In most studies on sustainability, locality is important and local problems require locally-generated, particular solutions (Choguill, 1996). The new, emerging role of Government is seen as facilitator rather than mere provider (Choguill, 1996).

Choguill (1996) theorised that

"In this manner, through the use of locally-generated solutions, the active involvement of residents in their own affairs and a facilitating government, it would be expected that a basis would be laid for the successful carrying out of local community improvements".

In order to use locally generated solutions, community capital, and particularly social capital, is the foundation for sustainable community development (Roseland, 2005). The community capital approach to sustainable community development requires new thinking about broad questions of community sustainability and self-reliance. Mobilising residents and Governments to strengthen all forms of community capital is required, because only then can community capital be used to serve a larger purpose, for example, in the case of a global issue such as climate change (Roseland, 2005; Seong-Kyu, 2007).

As we have discussed in Chapter 6, in the absence of lifestyle changes, the challenging targets required for avoiding dangerous climate change is highly unlikely to be achieved. Community mobilisation is necessary to coordinate, balance and catalyse community capital (Seong-Kyu, 2007). Such community capital in turn may serve as a way to trigger such lifestyle changes.

Community capital can be used as a driver for carbon emissions reductions through changing behaviour of its residents, and also as a way to raise awareness and change behaviour among networks (friends, family and colleagues) who may be keen to form strong communities (Seong-Kyu, 2007). Volunteer activity, information events to raise awareness on global issues such as climate change, and what the community and its members can do about it, as well as events to celebrate success can create a general feeling of bonhomie towards a meaningful cause, by increasingly encouraging community members to take part (Seong-Kyu, 2007).

As a result social sustainability may have the potential not only to deliver social welfare but also to significantly contribute towards a low carbon and environmentally-sound society. As explained in Chapter 4, lifestyle changes can have very significant impacts in terms of carbon emission reductions. Indeed, without them dangerous climate change could not be avoided. Chapter 6 has shown that for new UK housing development, lifestyle solutions are promising. It would therefore seem beneficial for a low carbon lifestyle strategy to incorporate social development.

7.3.3 Community, wellbeing and the built environment

In Section 7.4.2 we have seen that by strengthening the social and community capital in housing community both greater social and environmental sustainability may be enabled. Here we will examine how social networks can deliver wellbeing and also how the design of the built environment can be used to foster social networks.

A growing body of evidence suggests that there are advantages to being well connected in strong social networks; membership in social networks promotes physical and mental health (Pilisuk and Parks, 1986; Argyle, 1996; Kearns, 2008).

The design of the built environment can influence the strength of the local community: the diversity and intensity of connections formed between residents is enhanced through opportunities for conversation and casual interchange (Gilchrist, 2000). Examples include a communal garden on a pedestrian-friendly street where neighbours can socialise and children can play safely, or at junctures where people meet each other as they return to or leave home. Kearns (2008) found a direct link between the physical environment, such as housing type, and mental wellbeing. However, his research also found that feeling empowered to contribute to the community and to a global cause such as climate change was more important for mental wellbeing than the physical environment itself.

7.3.4 Conclusion

The above analysis shows that the physical design, community cohesion, the wellbeing of the community members and their ability and willingness to do something about a global problem such as climate change are intrinsically linked and can work in mutual support of each other. This supports the hypothesis that a community approach towards delivering low carbon lifestyles in new housing is most effective if an overall sustainability approach including social, economic and environmental sustainability is taken.

A sustainable community is not only sustainable in itself but takes an active role in changing people's attitude and behaviour within its own community and outside. This could be through leading by example, being a positive example of sustainable living, and through direct provision of information. In order to do this the community needs to resemble a way of life, which others aspire too and seek. This stresses the importance of finding solutions, which meet environmental as well as socioeconomic aspirations, rather than sacrificing one for the other.

7.4 Exploring approaches for utilising community

In order to understand how sustainable low carbon housing communities can be enabled in the UK, it is important to first review the conventional way housing development takes place in the UK, and to compare this business model with alternative models.

To date, innovation in UK housing has been downplayed as a competitive strategy for the British speculative house building industry. Firms traditionally have focused on optimising their land holdings and timing the sale of dwellings to benefit from house price inflation (Ball, 1983; Bramley et al., 1995). Land acquisition and marketing skills have therefore been regarded as paramount (Ball, 1996; Bramley et al., 1995). New housing remains an essentially mass-designed and mass-produced product in the UK (Ball, 1996; Clarke and

Wall, 1996). Many have argued that this approach has been detrimental to innovation in the industry and resulted in a low wage, unskilled workforce (Ball, 1996; Clarke and Wall, 1996). Such an industry already lame in technical innovation will also find it problematical to direct innovation towards facilitating sustainable behaviours. It is therefore important to understand if and how sustainable behaviours can be enabled within the current industry, and whether alternative business models can do the job.

7.4.1 Aim

The aim of the research presented in this section is to review business models relative for developing housing in the UK, which incorporate community into developments such that future residents will adopt low carbon lifestyles.

7.4.2 Methodology

A focus group brainstorming session, with six relevant staff members at the sponsoring company Camco, set to work to identify, to compare and to evaluate alternative business models for delivering sustainable communities in the UK. This method was chosen as an effective method as the participants and group composition (staff from Camco) available for this research matched the required expertise, and the discussion between participants was seen as a way to understand major barriers and opportunities of any possible business model. This is backed by Krueger and Casey (2009) who recommend focus groups as appropriate means for understanding the issues and achieve consensus through exchanges between relevant experts around the key issues of a project or venture opportunity.

The literature suggests that the main stages of organising focus groups involve planning, recruiting, moderating, analysing, and reporting (Berg, 1998). Each stage was fine-tuned to take into consideration the specific demands of our research aims. We departed from the standard focus group format, where discussion is documented and later analysed through systematic coding via content analysis or ethnographic summary (Catteral and Maclaren, 1997; Kueger, 1997b; Morgan, 1988). Instead, we used a highly skilled group of participants who, with the support of the moderator as part of the focus group workshop, conducted the analysis directly within the focus group itself, and were thus able to bring in the expertise of all participants into the analysis and conclusions.

Choosing participants

Staff at Camco were selected based on their relevant expertise, degree of experience, and seniority in the company. Expert areas covered by the participants include:

- Sustainable energy engineering solutions applied to UK housing development
- Advice and management of implementation of sustainability and sustainable energy solutions in housing developments in the UK

- Behaviour change expertise with experience in application to sustainability solutions in housing developments.
- Entrepreneurial expertise, including social/ethical entrepreneurship.
- Experience in work with and within communities on sustainability projects.
- Expertise in running focus groups and workshops to support productive and focussed discussion.

The range of staff who participated and their experience meant that we covered direct work experience and academic background in all of the above areas. To avoid local bias expert participants were brought in from all four UK Camco Offices: Rural Wiltshire, London, Edinburgh, and Sheffield. Choice of location was based on the notion that there would be different experience according to distinctive local environments and for providing a range of socio-economic contexts. Whilst we accept that a focus group of six cannot be truly representative, it was nevertheless important to ensure that we capture the widest views possible on the issues.

We also acknowledge that certain bias may be introduced, as all participants work for the same company. However, this route was chosen because it was the only way to bring together such a high level expertise around the table at no cost (as it was in the sponsoring company).[12] Another significant advantage in choosing a group of people who are already familiar with each other is that prior to the focus group, participants had already built rapport and trust with each other and the researcher (myself). In advocating this method, Kaden (1977) has suggested that the initial group discussion be limited if the participants know each other well.

Topic Agenda and Approach to Idea Generation

Merton et al. (1956) outlined four broad criteria for an effective focus group: There is need for range, detail, depth, and understanding of the personal context of the participants. Range refers to the breadth of relevant observations that participants produce. Although the topic area agenda was followed, subsequent discussion was allowed to take different directions to identify new approaches, facts and business models. Asking participants specific questions about the reasoning and underlying experience that had led to their judgement on the topics provided detail and depth. Participants were asked about their personal context and unique world perspective, with the aim to better understand the attitudes and norms underlying their particular view. By so doing it was possible to analyse the validity of their comments on the basis of observation or personal judgement. Here the dynamics of a focus group were used to provide an immediate, direct juxtaposition of views through peer group discussion.

The moderator set out the development of the topic agenda (Table 7.1), followed by the research goal and discussion structure. After initial introduction to the background of the

[12] *The budget of the Engineering Doctorate would not have allowed for this sort of research.*

topic by the moderator, current UK housing was discussed, along with the challenges faced by participants acting as sustainability and sustainable energy advisors in promoting and delivering low carbon living solutions. This was followed by an opportunity for the participants to explain their own business context and direct experience.

Table 7.1 The Topic Agenda

Identifying promising business models which enable low carbon living in new UK housing developments **Focus Group Topic Agenda**		
Topic		Planned Outcome
Introduction	Introduce the topic and aim Explanation of format of the discussion and conventions (confidentiality, all views important, open debate, report on proceedings) Presentation of research findings form the Climate Challenge Tool, and the potential opportunity for delivering low carbon living through a community approach.	Moderator: i.e., EngD researcher (myself) sets the stage, rules of engagement and vision
Discussion Topics	Step 1: Current new UK housing climate and its ability/inability to deliver low carbon lifestyles.	Understanding the relevant issues.
	Step 2: Participant's views on the main challenges and opportunities.	Definition of critical success factors along the supply chain.
	Step 3: Opportunity wheel assessment.	Market opportunities.
	Step 4: Business opportunities, theme analysis.	Select top promising opportunity theme (if there is one) for feasibility analysis.
Conclusions	Summing up. Next steps.	

Participants' views of the main challenges and opportunities were explored as a second step. First, the main pillars for enabling low carbon living in new housing development were discussed, with the outcome of an agreed list of critical success factors along the supply chain of new housing development in the UK.

The critical success factors along the supply chain were used for further analysis in Step 3,as there are a number of steps, or links, in the translation of a low carbon resource, or asset, into a low carbon outcome in the market. Intermediate links could be the physical collection or agreement to utilise the resource; its conversion into a useful form; the transport or distribution of low carbon energy to the market; and the successful uptake of low carbon energy in the market through uptake of new technology and behaviour change, local community influence on various parts of the supply chain, and role of the developer to influence the community. By systematically interrogating the supply chain and residents' behaviour responses to change in this way, enabled areas of supply failure to be identified, thus generating a broad list of specific business opportunities aimed at addressing these failures.

A diagram was produced, showing the area of market opportunity: low carbon housing developments in the centre of Figure 7.1. For each stage of the critical success factors identified in the supply chain (shown in each segment of the target diagram), we asked the question "Why isn't this happening?" For example, for the critical success factor of creating community cohesion, we asked "Why isn't more done to develop community spirit in new housing development?" and noted the responses to this – say, "lack of regulation and financial incentive for house builders"- in the 'Why isn't" area of the chart. The next question asked - "why not?" - and noted the responses in the next box which, for our example, might be "Mainstream house builders are largely driven by profit targets only." Then the question "what if?" - "what if houses were developed by an entity with social and environmental objectives as well as financial ones?" and put this scenario in the outer area of the chart. The group then assessed if there was sufficient basis for a business opportunity to intervene in order to address the "what if?", noting this opportunity outside the circle.

The Opportunity Generation Wheel we used was drawn onto a poster-sized piece of paper, which filled the whole table. Post-it notes were used for comments and attached to the wheel in the relevant places.

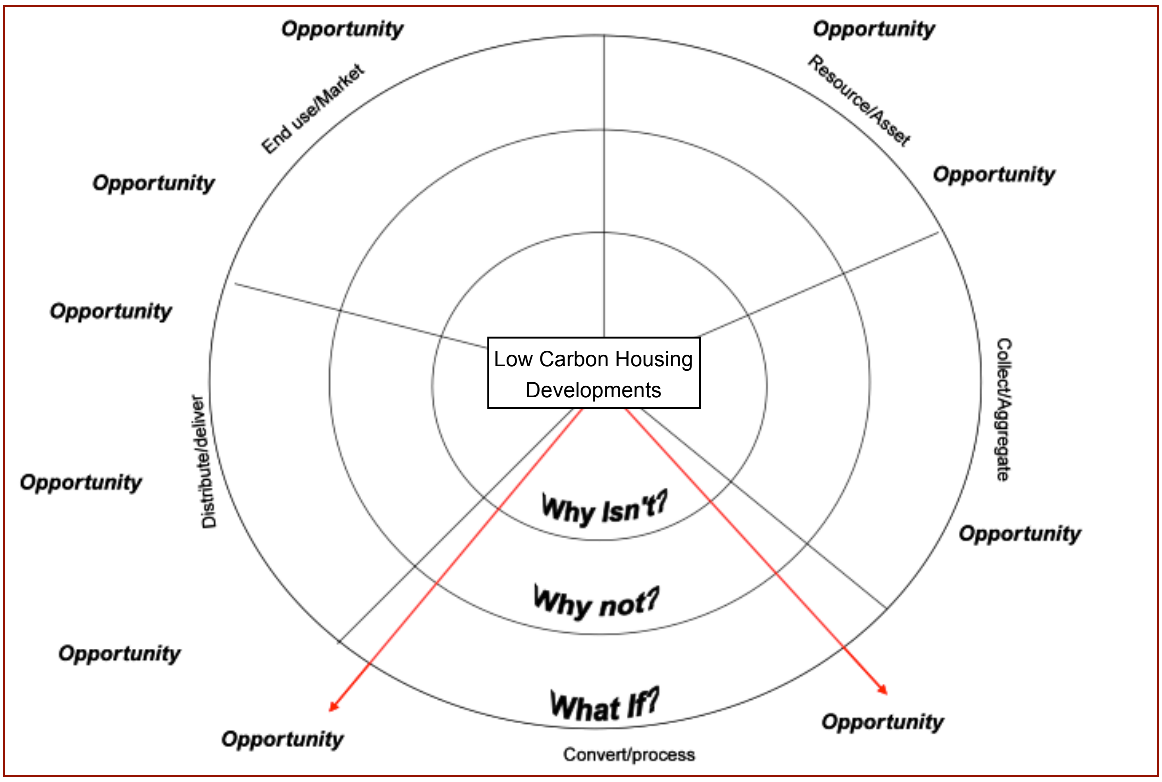


Figure 7.1 Opportunity Generation Wheel

By working around the diagram the group generated opportunities from across the breadth of the supply chain. The combined outcome is a list of business ideas: where a specific intervention in a particular market segment could lead to a new venture, and could also suggest the form of commercial approach that could be taken.

The opportunities resulting from Step 3 were organised into four "themes" which, altogether, defined the low carbon investment space. In the discussion it became clear that in order to incorporate community into developments so that future residents will choose low carbon lifestyles, a wider sustainability approach would have to be adopted.[13] This approach would also have other benefits. A discussion then took place rating the ability of each of the opportunities for market attractiveness: ability to become a profitable business, ability to significantly reduce carbon emissions, and ability to deliver on other social, environmental and economic sustainability aspects.

7.4.3 Results and Discussion

The four themes identified in the focus session are summarised in Table 7.2. The table also summarises our discussion on environmental (including carbon), social and economic sustainability benefits. Whilst these overlap, dividing sustainability into the three categories seemed to the group to be the most sensible way to structure the

[13] *This assumption was backed by the literature: Schumacher (1973), Smith (2008), Seong-Kyu (2007), Chogull (1996) and Kearns (2008), Section 7.3.*

discussion. Because the task was about identifying potential business models to enable sustainable communities, it was also decided that the discussion should start with the sustainability parameters and then as a second step cover the financial feasibility side (specifically on carbon savings that could be enabled). Ideas and concepts arose on a general basis; these were then discussed in specific detail.

Table 7.2 Business models identified and their ability to deliver sustainable communities

Business model	Social sustainability	Economic sustainability	Environmental sustainability
Conventional UK housing with added sustainability features (e.g., high code for sustainable homes rating).	• Little community empowerment. • Common sustainability theme may bring community together.	• Carbon emission reductions are achieved at high cost to the economy.	• Carbon footprint of the home itself would be reduced up to zero. • Difficult to change lifestyles.
Co-housing with environmental features (private homes with shared communal facilities and activities, e.g., shared kitchen and dining area and communal dinners three times a week).	• Social sustainability and empowerment enabled through providing many opportunities for community members to interact and contribute to their community, for example, through cooking a meal.	• Shared facilities can be more cost effective use of services and buildings. • Community interaction fuelled through the co-housing approach supports exchanges of skills and services and use of local reliable workforce and services.	• Shared facilities are also less resource-intensive. Shared means make it easier and cheaper to purchase ethical produce in bulk. • Co-housing communities can be themed around sustainability and this can be easily cultivated through the many community features of the scheme.

Eco-self-build individual homes (Privately owned homes that are designed and built by their future owners).	• Individual self-build homes help empower the individual to take action to improve their livelihood. • They do, however, have little effect on the surrounding community.	• Self-builders are likely to employ individual and small enterprises rather than big companies, thereby supporting SMEs and the local economy and often achieving lower costs on the build. • The profit from the home stays with the individual rather than a large property company, facilitating further spending on sustainability measures.	• Environmentally minded self-builders are able to choose novel eco-friendly building materials and technology. This choice is not normally available when purchasing a home outright where house builders tend to choose technology largely driven by cost only. • Self-builders directly profit from energy efficiency measures because their bills are reduced. Therefore, they are likely to be more willing to pay the extra capital costs.
Eco-self-build communities (groups of self-builders who come together to each build their own homes and their community together).	• Eco-self-build communities can empower people not only to build their own homes, but to build their own communities. • Social interaction is enhanced by group activity, and inviting people to choose community features they would incorporate into the community design.	• In addition to the advantages of individual self-builds, costs are further reduced through bulk purchase, sharing management responsibility (e.g., price negotiation and researching building materials), and recommending contractors to each other. • The scale of the scheme allows for training site staff in eco-construction thereby creating employment and building up a new qualified workforce in the field of sustainable construction.	• Eco-self-builders can share each other's tools and building materials. One self-builder may use the off-cuts of another one, thereby minimising waste. • By allowing everyone to feed into the design from the start, opportunities open up to customise mixed-use development (work, community and living space on the same site), thereby reducing emissions from commuting, and maximising uptake of benefits.

Based on Table 7.2 and further discourse, the group exchanged views on the financial viability, carbon savings potential, and wider sustainability potential; and, on joint consensus, evaluated each category. The overall judgements are presented in Table 7.3 and the outcome of the discussion is described in detail below.

The dialogue revolved around the possibility of adding sustainability features (e.g., community features, low carbon technology, awareness-raising activity) to conventional housing developments. Group members had significant experience in this area and aimed to do so with progressive and less progressive developers. It was thought among participants that, while there was room for improvement of conventional developments and a proportion of house builders would be willing to go beyond legal requirements, really significant shifts in UK house building had never occurred. Developers would commit to extra sustainability activity on the assumption that this would improve their planning negotiations with local authorities. Therefore, behaviour shift activity towards sustainable developments after gaining planning permission would be less likely. The group saw a small window of opportunity for smaller commercial house builders and social housing providers that do not put profit targets foremost. However, small house builder and social housing providers' activity is limited because they need to obtain bank loans. Although their focus on profits may be a lower priority, they are duty-bound to loan repayments and financing restrictions. But this option was regarded by the majority of participants as a realistic opportunity to improve on housing development.

A second opportunity was seen in Co-housing. Often described as "the old-fashioned community of the future," co-housing aims to provide residents with a balance between personal privacy and living amidst people who know and care about each other. This small-scale, mainstream, neighbourhood design overcomes the alienation of modern housing complexes where knowing one's neighbours is rare and there is little sense of community. Co-housing is characterised by private home ownership plus shared communal facilities. Private dwellings cluster around a "Common House" which may include a dining room, play rooms, workshops, sitting areas, or library. Residents of co-housing communities often have several optional community-wide meals in the Common House each week prepared on a volunteer basis by the residents themselves.

Co-housing neighbourhoods range in size from as few as eight households to as many as 50. Co-housing communities follow no ideology. Indeed, attracting a wide range of people of different ages and professions is the co-housing developments' modus operandi (The Ecohousing Corporation, 2009).

The group judged that co-housing provides a very good opportunity to involve the community, as people who join co-housing schemes already seek community. Co-housing features may also provide reduced resource and energy consumption through sharing facilities. However, the panel was uncertain about the popularity of co-housing and regard it as a small niche market. One member had specifically investigated co-housing and remarked that it was not currently something many people were actively looking for.

The group then proceeded to deliberate the opportunity for self-build. Self-build is the practice of creating an individual home for oneself through a variety of methods. People build individual homes mainly because: they want to create something tailored to their family's unique requirements; or something architecturally appealing in all manner of styles; or because they want to live in a home they might not be able to afford on the open market. Very few self-builders in the UK actually build their homes entirely by themselves. The majority employ an architect to sketch the design and then contract a builder to construct it; others use so-called 'package' companies to provide a one-stop solution. Many others manage building sites and deal directly with planners, trades people and materials suppliers. There are also so-called “semi-self-builders” who purchase homes that are completed on the outside, but they complete the inside: electrics, plumbing, internal walls, and layouts, painting and decorating themselves based on their personal preferences (NaSBA, 2008).

Judging from the popular literature about it and from personal experience of one participant, in the UK there is a high demand for self-build homes and a significant share of self-builders are interested in sustainable and eco-friendly homes. Currently, the UK self-build market is composed of individuals who build their homes on a plot they have purchased. The group only knew of one example of a group who had collectively undertaken an eco-self-build community scheme. Thus it was decided to assess the opportunity for two separate self-build categories: individual eco self-build homes and eco self-build communities.

In contrast to property developers, self-builders make decisions regarding their homes based on personal preferences and values. They neither need to report to a company nor are they under pressure to meet profit targets. If they have adequate finances, they can make pro-environmental choices based on personal belief. Decisions made when building a house can also pay-off over the long-term, for example, energy efficiency or water saving measures. A self-build house builder is more likely to include and pay for such measures as the person who will benefits from them is both the resident and the house builder.

The group conferred about how self-builders can design their houses to their exact specifications to meet their personal needs and use resources more effectively. In a community scheme, where the whole community infrastructure and set-up could be designed to meet the needs of a group and adhere to community formation and behaviour change, this idea could advance further than for individual self-builds. By default, the self-build process and need for communal decision-making would support the formation of a close-knit community even before people moved into their homes. Sustainable and low carbon lifestyle values could become integral to the community where members take pride in what they have created and established for the wider benefit of the community and the planet as a whole. The social capital of future residents could be harnessed through their involvement in the design and construction of their homes and community, and if desirable places could be created this way, they may promote sustainable behaviour and shift social norms in the wider world as a spill-over effect. Participants mentioned terms such as – “create beautiful communities where it is cool to be green”, “places which communicate that being green can be fun” - thereby changing awareness and behaviour not only within the community itself, but which support a shift in social norms in the wider society.

The group saw great potential in this approach, but wondered why even though there was high demand for self-build in the UK, they were only aware of one community scheme: The Ashley Vale Site in Bristol. They speculated on the barriers, but the group decided that they knew too little about these aspects to give a valid judgement. The group concluded that the eco self-build community may be a promising route for enabling low carbon lifestyles and wider sustainability and community benefits and thus warrants further investigation. This seemed to be the only (and most promising) outcome with the potential to significantly reduce carbon emissions in new housing developments.

Table 7.3 Overall rating of the business models on carbon, financial viability potential and other sustainability benefits

Business model	Likely ability to be financially viable	Carbon savings potential	Wider sustainability benefits
Conventional UK housing with added sustainability features	Currentl very few developers go further, although no change in business model is required. Only one development Bedzed has demonstrated significant progress. Bedzed was not financially viable. Judgement: **LOW**	Within the financial viability range carbon savings are limited. Judgement: **LOW**	No significant change foreseeable from current status quo. Value-driven property developers may be able to make a difference. Judgement: **LOW to MEDIUM**
Co-housing with environmental features	Uncertainty about demand for co-housing in the UK. Could be a very small niche market. Judgement: **LOW**	Carbon savings through shared resources and community activity. Judgement: **MEDIUM to HIGH**	Significant social benefit: Judgement: **HIGH**
Eco-self-build individual homes	High demand for self-build in the UK. Judgement: **HIGH**	Savings as people build want the want/need, and can make choices they directly benefit from themselves (e.g., energy efficiency measures) Judgement: **MEDIUM**	May support local economy and environment. Judgement: **MEDIUM**
Eco-self-build communities	High demand and willingness to pay. However uncertainty about how easy it is to implement because there is currently only one scheme, hence no existing industry. Judgement: **UNCERTAIN** to **HIGH.** Worth further investigation to identify current barriers and potential solutions.	Both savings from meeting the exact needs and being able to innovate, and from shared resources and community activity. Community spirit can enhance a shared vision and activities related to creating low carbon futures together. Judgement: **HIGH**	Significant social benefits may support local economy and wider environmental issues. Judgement: **HIGH**

7.4.4 Discussion and conclusion of business model investigation

The co-housing and eco-self-build community proposition shows significant opportunities for delivering social, economic and environmental sustainability, over and above what a conventional development with sustainability features may achieve. The eco-self-build community proposition could incorporate community and co-housing features. It is highlighted as a possible business opportunity due to the increasing and unmet demand for self-build opportunities. Therefore, it is selected for further analysis in Chapter 8.

7.5 Overall Conclusions

There are two approaches for achieving long lasting life-style changes: firstly set up and economic incentives and secondly a change in social norms. The combination of both is required for achieving significant carbon savings. One way of delivering lifestyle changes in new housing developments may be through a community approach. In order for the community-based approach that delivers low carbon new housing communities to succeed, a wider sustainability approach should be chosen. This approach also has other social and environmental benefits. A particular opportunity is identified which warrants further investigation: eco self-build communities. Chapter 8 will scrutinise the feasibility of delivering a sustainable community and low carbon lifestyles through the route of the eco-self-build community.

8. Feasibility Study for Eco-Self Build Communities

8.1 Chapter overview

Conventional business models for new housing development, operating under current Government regulations, policies and targets have failed to develop housing which encourages the adoption of sustainable lifestyles taking whole life consumption into account. An alternative business model of eco-self-build communities has been proposed in Chapter 6 as a way to foster desired behaviour change. The perceived feasibility of eco-self-build communities and their scope for supporting low carbon sustainable lifestyles is assessed through stakeholder interviews, and through quantitative assessment of costs, carbon emission reduction potential, and other sustainability impacts of technical and lifestyle options. Eco self-build communities are also compared with conventional approaches to building new housing in terms of their ability to deliver wider social, environmental as well as economic sustainability objectives.

Findings presented in this chapter have been published in Broer (2010) and Broer and Titheridge (2010b).

8.2 Introduction and Background

Chapter 6 showed that soft measures not usually required by the development control authorities or as part of the building regulations, could be more effective at reduction carbon emissions than the zero carbon homes approach and would cost less. In addition, a number of wider sustainability benefits were identified. Using the social capital of future residents through involvement in the design and construction of new housing has been identified as a possible opportunity to create such momentum in Chapter 6. This may help create more sustainable developments - places where it is "cool to be green", places which communicate that being green can be fun - thereby changing awareness and behaviour not only within the community itself, but which support a shift in social norms in the wider society.

Self-build is one mechanism by which residents can become more involved in the design and construction process. Self-build is the practice of creating an individual home for oneself through a variety of different methods ranging from designing and building the whole house oneself, to simply managing the construction process or employing an architect to design and manage the construction of a personalised design. In the UK the demand for self-build homes exceeds its supply (NaSBA, 2008). In addition, there is increasing demand for sustainable homes and communities (Ipsos MORI, 2006; Knight and Frank, 2007; Cabe, Halifax and WWF, 2004) and innovative and sustainable technology, for example, high levels of insulation, timber frame, solar energy, under-floor heating, and ventilation systems are particularly favoured amongst many self-builders (NaSBA, 2008; Lovel, 2005; Barlow et al., 2000; Building Link, 2000). Furthermore, building homes as part of a community can have advantages and additional opportunities such as communal infrastructure and renewable energy systems, communal recycling facilities, shared garden, bulk purchase, and sharing skills and advice among themselves during construction. This chapter assesses the potential of using the self-build model for creating sustainable and low carbon communities in the UK.

8.3 Literature Review

Literature was reviewed to understand the demand for both self-build and for sustainable homes and self-build communities, as well as industry, market and customer preferences relating to new homes.

8.3.1 Demand for sustainable homes

There is increasing demand for sustainable homes. Recent market research, undertaken by Ipsos MORI (2006) to understand the demand for sustainable homes in the UK, showed that 92% of consumers surveyed want sustainability features to be offered as optional on new homes, 64% would like them to be compulsory. The results were obtained from a questionnaire-based telephone survey of 501 homeowners across the UK in 2006. Four focus groups were also held in London in 2006 to provide depth to the survey results. Survey quotas were set on gender, age, ethnicity, social grade, and location to obtain a representative sample of homeowners aged 18 to 55. The research also found that sustainable homes are considered to be "modern", "attractive", "high tech", "fashionable", and "good value". Consumers want access to clear information on the environmental standards of homes for sale. The majority of consumers surveyed (52%) responded that they are willing to pay more when they purchase a sustainable home (Figure 8.1). Thirty-eight percent would not pay more, and 10% abstained. Nearly 40% of homeowners were willing to pay over £2000 more, and 21% would pay over £5000 more. Respondents also claimed they would pay a monthly charge for sustainability services such as convenient recycling facilities, a green caretaker and car sharing (Ipsos MORI, 2006). Whilst it cannot be taken for granted that willingness to pay as stated in an interview translates into actual willingness to pay, limited empirical data confirms the trend: for example, two EcoHomes Excellent projects developed by Cornhill Estates at Poundbury and Northampton sold at premium and off-plan (Ruyssevelt, 2007) and the carbon-neutral homes built by Lowry Renaissance at Titanic Mill near Huddersfield also sold off-plan prior to completion (Ruyssevelt, 2007).

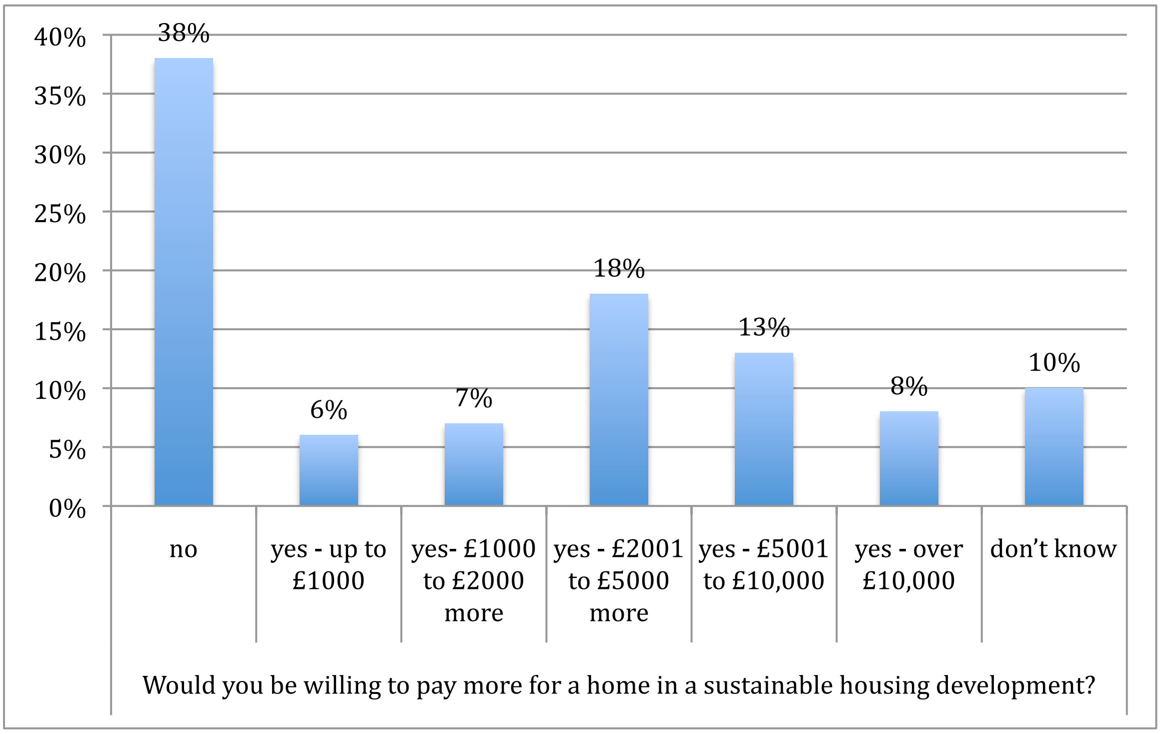


Figure 8.1 Willingness to pay more for a home in a sustainable housing development – responses from UK residents (Source: Ipsos MORI, 2006)

8.3.2 Demand for self-build

In the UK around 12% of all new homes currently belong to the self-build sector (NaSBA, 2008). The market has grown steadily from 2,000 homes in 1978 to 15,000 homes (8%) in 1999, to 20,000 homes in 2007 (12%) (NaSBA, 2008). However, two-thirds of UK residents state that they are interested in building their own home (NPBS, 2004). Demand is likely to be driven by the mainstream media, the specialist press, and regular exhibitions (NaSBA, 2008; Barlow et al, 2000). In many European countries self-build represents more than 50% of all new homes built. Canada, the US, Australia and New Zealand had more than double the number of self-build housing compared to the UK (NaSBA, 2008; Barlow et al., 2000) (see Figure 8.2).

The main reason for the lower rates of self-build in the UK is the lack of suitable land available (NaSBA, 2008). At present, there are many more people seeking suitable sites than there are plots available. At any one time there are around 6,000 plots listed in the UK; yet there are tens of thousands of people searching for a plot to purchase (NaSBA, 2008). Whereas many European countries local authorities have regulations in place to govern the sale of single plots for self-build and are accustomed to dealing with planning permission requests from single plot holders, this is not the case in Great Britain. In Northern Ireland, for example, which has proportionately a far larger self-build sector than England and Scotland, planning consent on greenbelt land is granted on the basis of need and policies are in place to regulate the design of self-build homes (Barlow et al., 2000). Barlow et al. (2000) suggest that in England, Scotland and Wales planning authorities are more “dictatorial” over design issues in the case of self-build proposals compared to proposals from speculative developers who may be building similar sized multiple housing in the same area (Barlow et al., 2000). It is interesting to note that during the recession of the early 1990s when house prices dropped by more than 10%, the self-build rate rose (NaSBA, 2008); this may be due to increased land availability as a result of reduced competition from property developers.

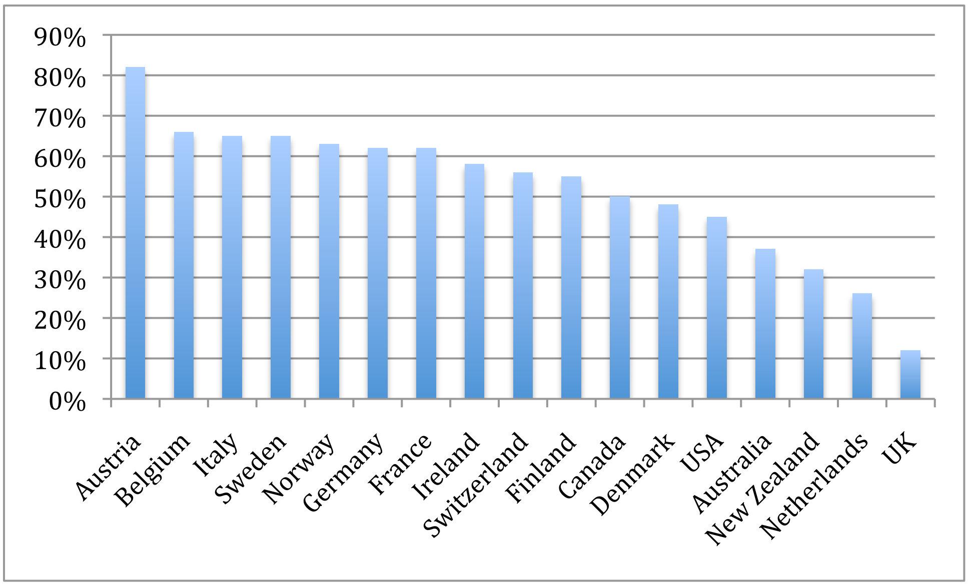


Figure 8.2 Percentage of new dwellings which are self-build homes in different countries (Source: NaSBA, 2008)

8.3.3 Demand for community self-builds

No literature was found to indicate the demand for community self-build housing. However, community self-builds can have a number of advantages over individual self-builds (Community Self Build Agency, 1996). There is the opportunity of growing a strong community through building homes together. Self-builders are able to take part in the decision not only of the design of their home but also their community. For example, they can incorporate communal garden, community room, shared utilities (e.g., washing machines) and/or pedestrian friendly streets. They can support and advise each other in the process of building their own home. They may save money through bulk purchases of building materials and through recommending reliable contractors to each other. Whilst these are significant advantages, community self-builds do not come without challenges (Community Self Build Agency, 1996). The communal decision-making process would require a platform to handle disputes and conflicts (Community Self Build Agency, 1996). Any Eco-self-build housing venture would hence need to address potential conflict in order to ensure success.

8.3.4 The market for self-build and sustainable homes

The market consists of a high number of homebuyers interested in living in a sustainable housing development, and in particular, a proportion of these want to be involved in design and/or construction themselves. Eighty-three percent of the interviewees in the Ipsos MORI study (2006) want to live in a sustainable housing development, and 18% of these are interested in a community feel. Just over 60% of UK residents are interested in building their own home and eco-friendly designs are popular amongst self-builders (NaSBA, 2008).

Of all the people who would both like to self-build and live in a sustainable housing community, only a small proportion is likely to be ready, willing, and able when confronted with the opportunity. To estimate the addressable market (effective demand), we have made the following assumptions: Ipsos MORI (2006) found that 83% of respondents want to live in a sustainable housing community, and out of those 18% are interested in a close-knit community. On this basis we assume that 15% of UK residents would like to live in a close-knit sustainable housing community. Applying the NaSBA (2008) figure of 60% of UK residents who would like to self-build, this would result in a split of 9% of UK residents who would like to self-build in a sustainable community, and 6% who would like to purchase a completed home. In the absence of available reliable data, we have assumed that out of the willing self-build group only half would build their own home when confronted with the opportunity to do so.

The home purchaser group would be smaller still, as only 39% would be willing to pay more than £2000 extra for a sustainable home (Ipsos MORI, 2006). However, it was assumed that this would not apply to self-build, as savings from building one's own home may outweigh the extra cost for sustainability gadgets[14]. Based on these assumptions, we estimate that the addressable UK market may be in the order of £7.2 billion per year for completed sustainable homes, and £5.5 billion per year for plots, equivalent to 33,000 homes and 64,000 plots per year. This is equivalent to 2.3% and 4.5% of all homes sold in the UK respectively, or 20% and 38% of all new homes built. Whilst these figures seem to provide a reasonable view of the overall market for sustainable and self-build housing, given the percentage of new homes that are self-build in other European countries (NaSBA, 2008), and the lack of existing sustainable housing communities which people could buy into, this amounts to a significant proportion of all new UK housing.

[14] *Self-builders typically save in the region of 30% on the total costs of a home when compared to purchasing a similar home built by a developer (NaSBA, 2008). The average price of a home in the UK in January 2007 was £260,000. Therefore, even if over £10,000 is spent on sustainability measures, the overall savings would be far greater.*

8.3.5 Industry and competition

The self-build industry currently largely consists of individual self-builders who purchase available single plots, typically infill in urban area or small brownfield sites. The supply for self-build plots is at present limited to single plots, as multiple plot sites tend to be sold to house builders specialising in building and selling homes. Community self-build projects look to purchase larger sites (Barlow et al., 2000) suitable for multiple plots and therefore compete against conventional housing developers for land.

There are two main groups of house-builders serving the UK housing market for multiple plot sites, differentiated by size:

1. Volume house-builders tend to build large developments of hundreds or thousands of homes, but sometimes also build smaller developments.

2. Small developers, including a builder with his team, are likely to build and sell small groups of properties at a time (Barlow, 1999).

In addition, there are pioneering small developers who build medium-sized developments, of which some are innovative sustainable homes. Most large-scale developers and small-scale builders are concerned primarily with reducing costs: they tend to avoid using innovative construction techniques and materials; and they aim to meet the minimum requirements of the building regulations. In a web-search, only one company is currently coordinating the construction of private individual self-build homes: the Tutti Frutti Development in New Islington in Manchester. However, this development does not have sustainability or community features exceeding legal requirements (Urbansplash, 2009).

No company was found that is, at present, coordinating the construction of private individual self-build homes in conjunction with a thoroughly developed concept that delivers sustainability and low carbon living in addition to self-build. The Ashley Vale Action Group in Bristol (see Box 8.1) mentioned by the focus group in Chapter 6 comes closest to our concept. The National Self-build Association (NaSBA, 2008) identifies one other eco-self-build community of six houses in Hockerton. Apart from this example, NaSBA (2008) refers to international case studies in order to exemplify what is possible.

The supply of sustainable and self-build community homes may be constrained by the lack of companies offering such frameworks, and also by the type and availability of land in locations where demand exists, and where planners would be amenable to this sort of development. For example, some development opportunities are in inner cities, where local planning authorities would expect to be developed to very high densities. Blocks of high-rise apartments may not lend themselves easily to self-build and community projects.

Box 8.1 Eco Self-Build Community in Ashley Vale, Bristol

Ashley Vale eco-self-build community is the only one of its kind in the UK. The Development was set up by Ashley Vale Action Group - a community group based in inner city Bristol, set up the development. The group formed a not-for-profit company to take control of the re-development of a brown-field site in their neighbourhood. They believed that building developments should be community-based, environmentally-sensitive initiatives (Ashley Vale Action Group, 2006). In May 2001 they succeeded in buying a 2.2 acre development site at the market rate in order to create innovative and sustainable self-build housing and office, workshop and community space. Once the site had been acquired, the initial group members advertised for others to join them in this eco-self-build-community venture through local leafleting and word-of-mouth. Those who responded to the recruitment campaign were interviewed. Selection to participate in the project was made on the basis of shared ideals with the founding members, financial ability to resource a self-build dwelling, and the skills that each person could contribute (Ashley Vale Action Group, 2009).

The land was split into 20 building plots, with space allocated for a communal garden and for an access road (Ashley Vale Action Group, 2009). It was decided to refurbish the derelict office block of about 400 m^2 floor-space on the site. The sale of the building plots at £35k each was sufficient to pay for the whole site (£600k), legal fees, services to each plot, and construction of the road. Six of the 20 self-builders chose to form terraced or semi-detached town houses as a way to have bigger houses or gardens. At a second stage further income was generated through the sale of part of the office block to a further six self-build parties who converted offices to apartments. Part of this income paid for a biomass boiler for the entire office block, a large community room, and three workshop spaces which have since been rented to local businesses (Ashley Vale Action Group, 2009).

8.3.6 Homebuyer priorities

Table 8.1 displays the reasons people listed for an interest in living in a sustainable housing development as part of Ipsos MORI's survey (2006) to identify homebuyer preferences. Here it is interesting to note that many people are not only attracted to reducing their environmental impact (which was listed by over half of the respondents as a reason to live in a sustainable housing development) but also to community features, such as "a better quality of life", "cleaner and fresher", "better for children", "safer", and "a close-knit community feel".

Table 8.1 What attracts people to sustainable housing developments (Source: Ipsos MORI, 2006)

Why (if at all) would you be interested in living in a sustainable housing development?	**Percentage of people answering yes in Ipsos MORI study**
It would help me do my bit to save the planet	54%
It would reduce the amount I pay on bills	35%
It would increase the quality of life for me and my family	25%
It would be cleaner and "fresher" to live in	24%
It would be a better place for bringing up children	20%
It would have a close-knit community feel	18%
It would be safer than other places to live	16%
It would have cutting edge design and technology	16%

Participants in the discussion groups that formed part of the same study: Ipsos Mori (2006) were particularly attracted to the idea of sustainable housing developments creating a psychological community to foster sustainable behaviour.

Ipsos MORI (2006) also assessed overall priorities when moving to a new home. It is important to understand how eco-self-build community homes score against all the priorities and criteria people use to select a new home, not just priorities specifically related to sustainability. To assess them, Ipsos MORI (2006) asked respondents to select two or three priorities from each of three categories: area factors, home features and sustainability features. All the selected priorities from each category were presented back to the respondent, who was asked to rank them according to their overall importance when moving to a new home. Table 8.2 below reflects the overall priorities when moving to a new home with the mean scores provided for each feature. These are colour coded into area factors, home features and sustainability features. The categorisation is taken from the Ipsos MORI report (2006).

Table 8.2 Priorities when moving to a new home

Priorities when moving to a new home	**Mean score**[15]
Close to family and friends	7.2
Low crime area	6.8
Access to good local schools	6.6
Quality of construction and finish	6.5
Number of rooms	6.3
Access to good local healthcare	6.0
Good transport links	5.7
Energy efficiency	5.6
Parks and open spaces within walking distance	5.6
Internal design and appearance of the house	5.6
Size of rooms	5.5
Garden	5.5
Low noise and pollution	5.4
External design and appearance of the home	5.2
Good local shopping/leisure facilities	5.1
Aspect	5.1
Renewable energy	4.9
Environmental friendly construction material	4.7
Access to food from local producers	4.1
Quality of fixtures and furnishings	4.1
Convenient recycling facilities	4.1
Water saving appliances	3.9

Color coding:

	Area factors
	Home features
	Sustainability features

[15] *Priorities were assigned a score of 1-9, where 9 was the highest-ranking feature and 1 the lowest ranking feature as selected by each respondent. The mean score of all respondents was then calculated. Thus, the higher the mean score the higher the priority placed on this feature by the homeowners surveyed.*

We can observe that area factors dominate homeowners' priorities, followed by housing and sustainability features. These findings were supported by the discussion groups (held as part of the survey) who stated that the primary concern when moving to a new house is to secure "basic wants" such as security, minimal travel, child facilities, and space (Ipsos MORI, 2006). Only after these are satisfied (to an extent) do environmental features become more prominent in influencing the choice of house to purchase, even though ideologically they may be important to the participant. Market research by Knight and Frank (2007) supports the Ipsos MORI findings.

8.3.7 Conclusions

It is clear that in the UK many people want sustainable homes and there is demand for self-build homes. It is also clear that the quality of the local area, including having a close-knit community feel, is an important priority in house purchase decisions. Eco-self-build communities could meet all three demands. However, as identified in Section 8.2, few such developments have thus far taken place in the UK. If eco-self-build communities are to provide sustainable living in the UK, it is important to understand why so few projects of this type exist in the UK, whether there is scope for increasing this, and how this might be achieved.

8.4 Methodology

To investigate the questions outlined in the preceding section a number of interviews were held during 2007- 2009. A semi-structured approach was chosen in recognition that there may be unknown issues. A number of stakeholders and other relevant people were identified. Three representatives from each stakeholder group were interviewed. The exceptions to this are two groups, which were judged to be of greater importance: representatives from an eco-self-build community at Ashley Vale in Bristol (see box in Section 8.2), UK and potential customers. In these cases, 10 representatives were interviewed for each group.

The stakeholder groups covered are:

1. Potential customers: Individuals interested in sustainable housing and self-build communities were asked what in particular attracts them to this type of development, their characteristics and their expectations. (Individuals with insufficient financial reserves to realistically partake in a self-build project [i.e., with less than £70,000 available capital] were excluded.)
2. Self-builders and semi-self-builders from the Ashley Vale development to understand the lessons they have learned, what they would replicate and what they would do differently if they did it again, the types and profiles of

households that were attracted to the project. The idea was to improve on their business model and replicate it through an ethical enterprise.

3. People who would not be interested in partaking in an eco-self-build community project in order to discover what dissuades people from this type of scheme.
4. Financiers in order to test the perceived investment potential of eco-self-build community projects and to investigate what loans and investment agreements may be available.
5. House builders from conventional property companies in order to find out why conventional house builders are not interested in the proposed concept, and what the construction challenges may be.
6. House builders who build “green” homes in order to investigate the challenges and opportunities they have encountered and the lessons they have learned from building sustainable homes.
7. Land Agents to understand issues relative to purchasing land.
8. Entrepreneurs, particularly those with property experience and ethical entrepreneurship expertise, in order to understand how innovative, sustainable, community-led projects can be developed into a business. The entrepreneurs interviewed were all from the mentor network of the London Business School entrepreneurial summer school.
9. Local and regional planning representatives in order to understand the impact of current housing development policy, the impact of any likely changes in planning policy, how planning decisions are made, and how these may impact on the success of eco-self-build community projects.
10. Self-build organisations in order to better understand the challenges and opportunities of the self-build market and the customer demand.

The first two groups of interviewees - self-builders from the Ashley Vale site and potential customers - fall into the category of people who are specifically interested in eco-self-build housing and are likely to favour eco-self-build community developments. Their involvement allows us to better understand if and how eco-self-build community projects can be designed and structured to meet customer needs, and what support mechanisms may be required. The third group - people not interested in building or purchasing a home in an eco-self-build community project - is specifically included for their insights into the barriers and details that may dissuade people from purchasing a plot of land or home in such a development.

While the study sample cannot be considered representative of the original population of interest, generalisation of the results was not the primary goal - the major purpose of this study has been to determine the barriers to eco-self-build community projects, how they might be overcome, and whether and how such projects could be initiated and developed by private enterprise. The survey was designed to reveal the broad range of structural, psychological, legislative, environmental, and technically interrelated issues associated with the development of eco-self-build communities.

In order to fully comprehend the advantages and disadvantages of the eco-self-build communities and to gather enough information to understand who would be attracted to eco-self-build community development and how the development of eco-self-build communities could be supported, it was critical to understand what Mullins (2007) calls discovering the “Unk-Unks”. The “Unk-Unks” are the critical barriers and customer needs that the researcher does not know they do not know, and which the potential customer does not know they do not know. Mullins (2007) states that the most exciting breakthroughs that innovators bring to markets are innovations that customers have not known they needed. In order to provide the depth of understanding and exploration required, the “long interview technique”, as developed by McCracken (1998), was used. Schuman’s phenomenological approach to in-depth interviewing (Seidman, 1991) was also considered, but was decided against as it uses three separate interviews and this was considered to significantly reduce response rate and would have been difficult to complete within our time constraints.

In the long interview, the interviewer asks open-ended questions that allow the respondent to go where he or she may. A series of prompts, barely questions, since they are so short, are then used to encourage the respondent to say more about a theme just mentioned, or to address, again in an open and non-directed way, another topic that is on the interviewer’s mind but has gone unmentioned so far. In order not to influence the direction of the responses, direct questions are only asked as a second stage. Interview scripts were based on McCracken’s long interview methods (McCracken, 1998) and specific recommendations by Mullins for its application in business innovation (Mullins 2007). On this basis, a combination of direct and open-ended questions was prepared for each group. Initially only one person from each group was randomly identified for interview. During these interviews, each interviewee was asked if they knew anyone else whose views should be sought. These suggestions were used to help select two further candidates for interview from each category. Where another participant had recommended specific further interviewees, their general attitude towards the proposition was assessed through questions and considered in the analysis. Furthermore, they were specifically asked if they felt that their view was representative for other people in their profession. The final list of interviewees is given in Table 8.3.

Table 8.3 List of Interviewees

Stakeholder group	Description of interviewees	Interviewee reference
Potential customers	Ten people who visited the Ashley Vale eco-self-build site and stated that they would love to live there and would be likely to take up the opportunity if it was presented to them.	1-10
Self-builders, semi self-builders and residents	Ten representatives from the Ashley Vale self-build site. One representative from Findhorn self-build community.	11-20 21
People who would not be interested	Three people who came to the Ashley Vale eco self-build site stating that they would not do a self-build or would not live like this.	22-24
Financiers	Senior business manager from Natwest Bank Investment manager from Triodos Bank One business angel	25 26 27
House builders from conventional property companies	One representatives from Crest Nicolson One representative from Berkeley Homes Development Director of Tutti-Frutti self-build development at Urban Splash	28 29 30
House builders who build "green" homes	Managing director of Ecos Homes Director of Living Villages Developer of Springhill Cohousing in Stroud	31 32 33
Land Agents	Land sales representatives of Knight and Frank Land sales manager from Mag Allen Auctioneers and Land Agents Director of the Landbank Partnership Member of the Policy Team of English Partnership	34 35 36 37
Entrepreneurs	Three entrepreneurs from the mentor network at London Business School, who have relevant background (sustainable	38-39

	energy, property development, social ventures)	
Local and regional government	Planner in Stroud Town Council Planner for Bath and North East Somerset Council Member of Sustainable Projects Team, Bristol City Council	40 41 42
Self-build organisation	Representative from Buildstore Director of Ecomotive, a charity which supports self build housing Representative of NaSBA (National Self-Build Association)	43 44 45
Land owners	Three individual land owners	46,47,48

Ethnographic content analysis (Crabtree and Miller, 1991) was used to analyse the interview scripts. Content analysis is a systematic search for words, phrases or observations pertaining to each of a number of predefined broad areas. These are highlighted in colour and approached inductively; recurring dominant themes and subthemes are identified (Crabtree and Miller, 1991; Glaser and Strauss, 1967). Ethnographic content analysis is not restricted to predefined broad areas, but allows themes to emerge from data. As new categories emerge throughout the interviewing process the coded data are modified; this process develops themes by constantly going back and forth between the evolving interview scripts to verify or disprove findings. For validation, emerging theories and themes are verified or disproved throughout the evolving interview process. Relevant illustrative quotations are referenced to each code category, theme and theory. Guidelines described by Glaser and Strauss (Glaser and Strauss, 1967; Wood, 1992) were used.

8.5 Results

Interviewee responses in general confirmed the literature review findings, that there is demand for eco-self-build communities. Only one interviewee rejected the lifestyle robustly and another two interviewees clearly did not have the funds or know-how to do so. Some people at the Ashley Vale Site made reference to the number of people asking them how to get involved in a similar scheme, for example:

Interviewee 20: A tenant living at the Ashley Vale site (also referred to as the Yard):

> *"Whenever I tell anyone that I live in the Yard they say: Wow, how did you manage that, are there any other places coming up?"*

Interviewees 12 and 19 (eco-self-builders from Ashley Vale) report on the responses of visitors to the Ashley Vale site because they have heard about the interesting looking houses:

> *"This is amazing. How did you do it? Can you tell us how we can do the same?"*

Furthermore, the literature findings on the acquisition of land as the main obstacle were supported by the survey. All interviewees from the potential customer category stated as their main obstacle the availability of building plots. When Ashley Vale Eco-self-builders were asked why there were no other schemes like it in the UK, nine out of ten of them replied that they thought getting land was a major obstacle. Interviewee 13, for example, said:

> *"As a group you are up against professional property developers who can act quickly when a good plot of land becomes available. Compare this to a group of individuals who have to agree on price at which to bid, have to get funding individually, and have to agree on a structure to manage the community build. As a result it can take much longer, and there is a lot more uncertainty and delay for the landowner, who unless ethically driven, is more likely to accept a cash bid from a property company".*

The notion that the community dimension adds value to eco-self-build was also confirmed and 96% (18 out of 20) of potential customers and self-builders from Ashley Vale interviewed would prefer to build as part of a community scheme – like the Ashley Vale development – rather than on their own.

The following themes emerged from the stakeholder interviews, which are divided into categories: design of the community and site, barriers and support for self-build communities, financing and timing, customer types and characteristics, and critical factors in developing eco-self-build communities. Each category has a number of subthemes. The themes and subthemes are presented in Sections 8.6.1 to 8.6.5.

8.5.1 Design of community/site

Respondents were asked about their aspirations for the design of the site and their community. The following subthemes emerged:

1. A mixture of fully self-build, semi-self-build and completed homes is desirable
2. Design features and site characteristics
3. A good place to bring up children

A mixture of fully self-build, semi-self-build and completed homes is desirable

From a customer perspective:

Interviewing potential customers and the general public highlighted a range of people interested in living in a sustainable housing development. About half of these would like to build their homes themselves, and a quarter would prefer to move into a completed home. There is a group of “in-betweeners” (25%), who would like to have some input, such as completing the interior, but who would find building a whole home too challenging. Not all interviewees were certain about which category they would fit into.

From the perspective of the Financier:

Financially, this mix is also desirable. There is a limit to what people may pay for a plot and the uplift that can be charged. Experience at the Ashley Vale site, and at other eco-villages, has shown that the value of homes increases significantly once the site takes shape (Interviewees 8 and 35). One of the entrepreneur interviewees suggested that a route to benefiting from the value created would be for a company to build a proportion of the houses and sell them either half completed or fully finished. The other two entrepreneurs interviewed also backed this view.

From a construction perspective:

In terms of construction practices, smaller units such as flats would lend themselves well to the concept of semi-self-build, as partition walls and floors together with the shell could be built by a company rather than individual parties having to agree on timing and construction. The three “conventional” and the three “green” house builders expressed this view.

Desirable design features and site characteristics

All potential customers were attracted by the community features: shared garden, communal recycling facilities, bike parking, and pedestrian friendly streets, and safe place for children to play. The majority of people (8 out of 10) were less in favour of organised communal activities such as regularly cooking and eating together as done in many co-housing communities. Shared activities such as gardening, meals, or parties should be voluntary, ad-hoc, resident-led, and encouraged by the site facilities, for example, by building a barbeque in the communal garden.

Two of the potential customer interviewees (4 and 7) said that prior to seeing the Ashley Vale development they would not have been attracted to living in a community. However, as there was total freedom in the choice to participate in communal activities, they felt that the benefits were in the communal features such as the shared garden, and that this did not seem to compromise their privacy, which they valued highly. This was supported by one Ashley Vale (Interviewee 17) community member, who explained that residents choose different levels of engaging with the community – ranging from nothing whatsoever to attending every communal activity – and that, as the service charge is adjusted according to the level of individual contribution, there were no problems associated with giving people choice in the matter.

Sustainability features such as renewable energy sources, energy efficiency, recycling bins, opportunities for growing food, are also desired, particularly if people benefit directly from them, for example, a woodstove: which is not just a renewable energy source but also a nice design feature. Where people do not benefit directly there is a limit to what people are willing to pay purely to be green. On the Ashley Vale site for example, only two people chose to pay for solar hot water systems (these are costly and have no direct benefit) whereas nine people have a wood stove. Therefore, the focus should be on measures that combine benefit for residents with benefits for the environment.

Many interviewees emphasised how they were attracted in particular to the sense of community as well as to the sustainability features at the Ashley Vale site. Sample quotes are:

Interviewee 3: A pensioner visiting the Ashley Vale site:

> *"I would love to move to a place like this and finally build my dream home, a place where I'd love to retire to, with a real sense of community and life."*

Interviewee 5: A single man living at the Ashley Vale site:

> *"I was searching for opportunities to do the right thing. I buy fair trade coffee and organic food. It was great when finally the opportunity came up to make an ethical choice towards the purchase that most people take most pride in: your own home."*

Interviewee 11: A young man who built a house at the Ashley Vale site:

> *"I was not really aware or interested in sustainability prior to joining Ashley Vale Action Group. I was simply interested in building my own dream home. I have learned a lot about sustainability and climate change and have changed the way I am doing things."*
>
> *"Many of us are now working from home and have designed our homes and community to enable this. There is a yoga teacher who teaches yoga in the yoga room in her house, people working from home from a home office, and a furniture maker with a workshop. At the weekend many of us choose to stay on site rather than travel far to socialise. This means that we spend much less time in the car getting frustrated with traffic and polluting the planet".*

A good place to bring up children

This is something mentioned again and again by people as something that they value a lot. People already living on the Ashley Vale site and those visiting the site were very attracted to a safe place for children to grow up: car-free zones, pedestrian friendly streets, and a communal garden directly accessible by not needing to cross a main road.

Some quotes from the interviews, which exemplify this are:

> Interviewee 13: part of a young couple who purchased a home at Ashley Vale:
>
> *"We want to have children and we want to bring them up in a safe place and show them that one can make a difference."*
>
> Interviewee 17: part of a couple who built a house and are living at Ashley Vale:
>
> *"It's not just about doing what we believe in, it's also about improving our lives. It's much easier here to look after our children. They can play on the communal land or on the street safely and they spend time with the neighbour's children or the neighbour's children come round to ours. This way it is easy to leave your children with a neighbour when one needs to, and we do not spend an endless amount of time going to organised play schemes, etc. Our 5 year old is very confident at talking to other adults and children and is already organising his own play and sleepovers with his friends in our neighbourhood. It's like going back in time where people lived in big families, with all the benefits, but without being told off by your mother in law."*
>
> Interviewee 20: A single parent building a house at Ashley Vale:
>
> *"I had to move her. It wasn't really a question of how much money do I have and can I afford it, but how do I find the money that it takes. As a single parent I had to be in a safe community, with this support framework, the ability for my son to play with the other children and to mix with adults other than myself. I had no money myself at all but I managed to scrape it together and borrow from a generous relative who wanted to help me."*

After provision for children had been mentioned as a major feature for living in an eco-self-build development, we tested in further interviews whether this was attractive to the majority of potential clients. Five respondents from the potential customer category and five respondents from the Ashley Vale self-build group were asked how to rank the following according to their foremost priority:

- A good place to bring up children
- Green lifestyle
- A close-knit community feel
- Quality of construction
- Price

Of those interviewed who had children (normally those with small children), four out of ten made this their top or second priority. However, four of the respondents selected it as the last or second-to-last priority. Interestingly, out of the group without young children, the Ashley Vale self-builders gave child-friendliness a much greater priority than other potential customers interviewed and made specific comments about how they enjoyed having children around on site. It allows us to speculate that becoming part of their community may have changed their perception of children or that those who chose to participate in the Ashley Vale project had a positive attitude towards children's needs.

8.5.2 Barriers/support for communities

A range of themes evolved from the interviews which clarified the barriers and support mechanisms in relation to the formation of eco-self-build communities. Support structures and barriers are described and discussed below in the following subthemes:

1. A supportive Local Authority should be a site-selection criterion
2. A tight legal structure that achieves the right balance between choice and structure
3. Land owners and deal structure
4. All stakeholders, particularly the clients, value the shared purpose
5. Take people impact into account when choosing eco and low carbon features
6. Offer support to self-builders
7. Sustainable community eco-self-build developments can improve the neighbourhood overall

A supportive local authority should be a site selection criterion

The three local authorities respondents thought that local authorities would generally be in favour of the concept, and some local authorities, for example Bristol City Council, are actively encouraging self-build and sustainable housing within their boundaries. The concept may help local authorities to meet various sustainability targets. However, local authorities are also obliged to sell their land at its maximum value, and therefore opportunities to purchase land below the asking price are unlikely. A supportive local authority can still be very useful for the success of the scheme as it may help in the planning negotiation phase, which may effectively reduce the cost of obtaining planning permission and by potentially adding value to the land by allowing eco-self-build communities to build more or larger houses on it. It is therefore important to develop a relationship and liaise with local authorities prior to purchasing a site, but also during design and construction.

A tight legal structure that achieves the right balance between choice and structure

Interviewee 7 from the Ashley Vale site remarked that one main problem for them is an undefined structure specifying what one can and cannot build. This lack has led to endless meetings of communal decision-making, and in some cases decisions were perceived as unfair. Whilst Ashley Vale self-builders and potential clients highly value the flexibility of designing their own home, a structure to ensure that minimum sustainability and design criteria are achieved was thought to be useful - a framework that creates a culture where people feel encouraged, but are not forced as a group to go further. A tight legal structure to guarantee that the set framework is followed was seen as an essential way to avoid problems and pitfalls. This view was unanimous among the self-builders interviewed; opinions varied slightly only in so far as where the balance between structure and flexibility should lie.

Land owners and deal structure

One way to reduce risk and the need for investment and bank loans is to enter into an option of a joint venture agreement with the landowner. Here an option is agreed or purchased to buy the site by an agreed date for an agreed value. This buys time to advertise individual plots to self-builders and to do site specific work to refine the actual value for the proposed business. If enough plot buyers are found, the site is bought at the agreed date. If not, the sale does not go ahead. In a joint venture agreement each plot could be sold with a proportion of the sale price going to the landowner, and a proportion to the eco-self-build company.

Landowners are likely to be pleased to see a positive, innovative and eco-friendly development taking shape. However, two landowners interviewed (47 and 48) responded that they were not willing to accept a lower price for the site as a result. English Partnership sells land for lower value in exchange for high sustainability targets set by them. So far, these do not include some of the less tangible sustainable lifestyle and people empowerment achievements that eco-self-build communities may offer. However, a subjective judgement of the team or company and their proposed development is considered in the selection of the bidder (Interviewee 46, employee of English Partnership).

As the cost of land is by far the largest cost of any housing development, it is critical to the financial success of any housing development project that a low price is paid for the land.

All stakeholders, particularly the clients, value the shared purpose

All potential clients interviewees, local authorities interviewees and some landowner interviewees stated that they value the shared purpose of creating a brighter and greener future. At the Ashley Vale site it has led to many voluntary contributions and support crucial to the scheme's success (Ashley Vale self-builders: Interviewees 6, 8 and 9). Likewise, the responses received from potential clients and local and regional authorities indicate that they would be likely to put their energy into making a scheme a success on the same basis. When asked how to cultivate the shared purpose, they stated two main routes: firstly to communicate and celebrate the shared purpose, and secondly to be serious about it and have significant environmental and community achievements (Ashley Vale self-builders: Interviewees 6 and 8; Member of Sustainable Projects team in a local authority: Interviewee 37; and Member of Policy Team at English Partnership: Interviewee 42).

Take people impact into account when choosing eco and low carbon features

Both potential customers (Interviewees 11, 12 14, 15, 16, 18, 19 and 20) and conventional and "green" house builders (Interviewees 31, 32, 33) commented that they would be unlikely to pay for high-cost sustainability features (e.g., photovoltaics) which they do not benefit from directly. Lifestyle solutions such as communal gardens, pedestrian friendly streets with car share schemes, woodstoves, passive solar design, and the opportunity to grow food were popular.

Offer support to self-builders

The majority of potential customers approached stated that they dream about building their own home. Some, however, wondered if they could actually build their dream home, and if the opportunity arose were not sure if they would follow through. People were generally attracted to the notion of constructing a home as a group and being able to advise each other; they added that they would be amenable to support and training from a company.

The skills and motivation of the self-builders to contribute to their neighbourhood are crucial to the success of such a venture. A group of people each constructively contributing to the scheme would have a positive effect. In this scenario, plot sales should not be based purely on a highest bidder basis. Instead, customers could be selected on a financial basis and on a judgement of what each person could bring to the scheme: if they have construction skills or are able to manage the build of a sustainable home, and if they have the right attitude and personality to contribute to the scheme. A third criterion corresponds to an ethical perspective: on this basis people are chosen if they are most likely to benefit from joining the scheme. This could include people in need of affordable housing, families with young children, single parents, and older people who would benefit from living in the community.

Sustainable community eco-self-build developments can improve the surrounding neighbourhood and act as an inspiring example

Interviewee 44 explained that sustainable community self build developments (also referred to as eco-villages) have been built in many countries and are regarded as tending to have a beneficial influence on the surrounding neighbourhood in terms of creating community interaction, reducing crime rates, etc. Whilst no direct evidence for this is available, house price assessment in the neighbourhood suggests that this is indeed the case. House prices in eco-villages and neighbouring properties in the Ashley Vale Eco-self-build community in Bristol have risen above the trend line, a trend also reported in other self-build eco-housing communities on the continent (Ashley Vale Self-builders: Interviewees 5 and 9).

The support for the scheme by the existing community is also important to its success. Opposition from neighbours can lead to the withholding of planning permission for example. A scheme that benefits the neighbourhood overall is more likely to win support from the people in the vicinity. Neighbourhood consultations and information showing the benefits should therefore be integral to the process.

All interviewees from the self-builder and potential customer categories agreed that eco-self-build communities can act as a positive and inspiring example for eco and climate friendly living. The self-builders all stated that they had managed to reduce their carbon footprint by through joining the self-build scheme. The potential customers said that through visiting the Ashley Vale site and through speaking to its residents they had increased their understanding about eco-friendly solutions and three of them (Interviewees 2, 8 and 9) stated that because of this they had already taken small steps to reduce their carbon footprint, including purchasing eco-paint, growing some of their own vegetables and fitting good quality thermostatic radiator valves.

8.5.3 Financing and Timing

Here we discuss issues related to financing and timing of an organisation which catalyses eco-self-build community developments. The sub-themes here are:

1. Financing
2. Affordability
3. Customer types and characteristics

Financing

Banks will typically provide 50 to 70% of loan financing to building projects with an interest rate of about 4% above the base rate. Triodos and Nat West representatives both stated that the eco-self-build concept would qualify if an acceptable business plan was submitted. Additional financing would need to be provided by private investors. The self-build community concept may reduce the level of risk to be taken, especially if land is only purchased once individual plot purchasers have been identified. Having a mix of plots, semi-completed homes and completed homes would also help to spread the risk, especially if the site can be designed off-plan and plot purchasers already identified, thereby meeting the specific needs of interested buyers. For property projects, private investors typically want a 150% return on investment over a two-year period (Interviewee 11), although people in the UK have invested money into a green building fund of the ethical property company: Ecos Homes, which only gave them a 7% return on investment, suggesting the potential opportunity to set up a fund and allow for smaller investments by a larger number of investors, not people who are business angels, but rather those who would like to put small savings (£1000 +) into a fund on the guarantee of slightly greater returns than can be gained typically from putting their money into the bank.

Affordability

Eco-community self-builders at the Ashley Vale site (Interviewees 1-10) remarked that they had saved between 30 and 50% on build costs for several reasons. First, in avoiding the middleman and self-managing the build, management costs are saved. Secondly, self-builders contributed to the build themselves; they worked in exchange on each other's houses. A personal dimension lowered costs and increased build quality - other people were brought in to work on the houses. Most were friends or friends of friends, and where their work was exceptional, other self-builders would employ them consecutively. Interviewee 8 commented:

> *"Because it was a nice place to work with a vision for the environment, people were keen to work here and would typically charge less than for other projects. To get more work and be recommended on site they'd make a special effort. For us self-builders working on each other's houses, we also wanted to do a good job for our future neighbours and friends, as we knew they'd do the same for us. It was a bit of a culture where everyone took pride in what they were doing".*

A community self-build enables further savings through bulk purchase and through joining forces for researching new affordable sustainable building materials, haggling down prices and finding out who supplies at the best price. In addition to the 30 to 50% savings on build costs, self-builders save the profit margin that house builders would add onto the cost – which is typically around 20% of the total value (Conventional house builder

Interviewees: 28, 29, 30). A significant tax incentive is granted to self-builders: all self-build homes, provided they become the self-builder's primary residence, are exempt from capital gains tax (Interviewee 43: representative of self-build organization).

Some of these savings obviously come at an indirect cost to the self-builders. They invest their time managing their build and perhaps doing some of the work themselves. However based on the response from the self-builder interviewee groups (particularly interviewee 12, 14, 15 and 18) total financial gains, (excluding gains made due to the general upturn in the market), were still two or three times what they would have earned had they spent the time they spent on their build in employment. Plus they ended up with a better end product: a tailor made home designed to meet their needs and aspirations.

It here needs to be acknowledged that this for some is seen as a major saving and for others the stress and hassle of doing a self-build would never compensate for the savings that can be made (e.g. Interviewee 23 and 24). Some perceive self-build as an adventure and others as a nightmare, and some are somewhere in between. Therefore it is important that the business model can find a way to reduce hassle and worry which could then lead to increased uptake.

8.5.4 Customer types and characteristics

Based on the interview responses we notice a strong relationship between life stages, budgets and housing needs. Table 8.4 describes the different groups eco-self-build communities could serve which are organised by their life stages. The table is not based solely on the specific profile of the people interviewed.[16] Three of the Ashley Vale self-builders were asked to group and the sort of people interested in their concept.

A mixture of people (age, sex, race, income level, profession) was desired by most of those interviewed. However, the combined wishes to do something for the planet and live in a nice community were considered to be essential and were seen as fundamental for the success of an eco-self-build community venture that those involved are pro-active in contributing to their neighbourhoods, who share a common belief and are ready to act on it. Interviewee 4 and 5 stated that one person who is trying to be difficult can create significant problems whilst a solution focussed predisposition of the self-builder focussed on getting the best for the group had helped them in so many ways, such as reducing construction costs and achieving eco-credentials.

[16] *Three of the Ashley Vale self-builders were asked to group the sorts of people interested in their concept.*

Table 8.4 Customer Segmentation, profiles and characteristics

Constellation/ Age	**Detailed description**	**Total budget**	**Self-build or complete**	**Size required**	**What is important to them?**	**People interviewed 17**
1. Single parents or single parents to be (20–40)	These are single parents who have recently left a relationship and need somewhere to live. They are driven by finding somewhere good for their child/children, where being a single parent is made easier through access to playmates, sharing childcare responsibilities with neighbours and through the ability of their child/ren to simply go outside and play with the other children, which means that daily trips to playgrounds are no longer necessary. They have financial support from a family member or their ex-partner for buying into the scheme.	£100–£200k	Self-finished or fully completed	2 to 3 bed	Good place to bring up children. Easier to look after one's children	2
2. Single individuals, or couples on low income (25– 35), first time buyers	These are individuals or couples who would like to get on the housing ladder, but with a single income find it difficult to afford anything. They are likely to have a professional job. They do not need a large space, but are attracted to living in a quality home, in a safe neighbourhood and/or in an eco-friendly home.	£70–£140k	Self-build, self-finished or fully completed	Studio to 2 bed	One or all of the following: Good design, eco-friendly, good neighbourhood, good investment	4

[17] *For the first six categories potential customer interviewees and Ashley Vale self-builder interviewees were asked a reasonable number of questions in order to allocate them to one of the six categories. Where no full match could be identified, interviewees were allocated to the closest match. The numbers in the last three categories were the number of experts (financiers and entrepreneurs) who spoke about these categories when interviewed).*

3. Younger couples (25–40) /families	These are couples with children or are planning to have children in the near future. They are more cash constrained and may be first or second-time buyers, and use the self-build route as a means of building a house at modest cost. They need space, especially if they have or are planning to have large families. This is a group of self-builders for whom the greatest demand shortage exists in the UK. This group benefits significantly from the eco-self-build community concept due to its child-friendly design.	£ 150–£250k	Self-build or self-completed	3 bed or more	Getting more house/size for less money, good schools, and communal garden with direct access from their own home/garden, safe streets, other children.	5
4. Professional couples or individuals on high income (30–50)	These are hard working professionals with good careers and little time. They are attracted to the idea of living in a green community. Some of them may consider having children, others simply like the design of the houses and the fact that they are doing their bit for the planet. They may also like the feeling of community.	£250 to £500k	Fully completed or off-plan with design input	2 to 4 bed	Quality design, greenness, community, high ceilings, large windows, good sized rooms, extras.	3

5. Mid-career and retirement couples looking to build their dream home (50+)	These belong to the majority of current self-builders in the UK. They are couples in middle age or nearing retirement. They often own their own home, or a high proportion of the equity. With their children now grown they decide to build the dream home they have always been keen to have.	£250–£400k	Self-build or self-finished	2 to 4 bed home with garden.	Individual design, quality, security, local amenities, community, feeling that it is a place where they would like to spend their retirement.	3
6. Mid-career and retirement couples ready to downsize after children move out (50+)	These are simply looking to move into a place to grow old. Contrary to the previous category, they are not interested in getting involved in the construction process itself; rather they are looking to purchase something already complete.	£250 to £400k	Fully completed	2–3 bed	Feeling of community, quality design, greenness.	3
7. Buy to let investor	The likely investor is attracted to the idea of investing in something sustainable that delivers higher long-term returns than alternative investments. They are likely to feel that property is a good investment, and that the eco-self-build community concept delivers a long- term premium return on investment and rental value. Likely rental group targets would be young individuals who are attracted to the sustainability and community aspects and amenities.	£90 to £200k	Fully completed	Studio to 3 bed	Rental value attracts good responsible tenants, long-term growth in value of the property greater than its conventional counterparts.	2

8.5.5 Critical factors in building eco-self-build communities

Reviewing the listed themes, the following factors are crucial to the success of an eco-self-build community venture, both in terms of financial viability and social and environmental legacy:

1. **Select participants based on the social capital that they can bring and to what extent they benefit from joining the scheme** - therefore sell at a fixed price to people chosen via interview and require references. Participants must be motivated to live sustainably, have the know-how and financial resources to do it, be likely to contribute, and be proactive. The most important criterion here is that they have a can-do attitude. People in need of more affordable housing are chosen over people who already have property or the financial ability to purchase a good home on the conventional market.
2. **Create a child-friendly development** – this is by far the most important factor for many potential residents.
3. **The development should benefit the existing community** – where appropriate the community facilities such as a community room or communal garden can be shared with the existing surrounding community. Through this sustainable living is promoted to the wider public by the scheme and support from the local community can help gain planning permission
4. **Land deal** – land is the largest expense for self-builders. Therefore it is an important factor influencing financial profit margins.
5. **Community provision whilst creating spaces for privacy** – the design needs to allow for privacy yet encourage community interaction.
6. **Support to self-builders** – A hand holding support service for self-builders is very likely to increase the available market size. In addition, training in eco-construction methods is likely to lead to better environmental performance.
7. **A shared purpose** – the shared purpose of creating a brighter greener future is important for bringing the community together. The shared purpose is vital for achieving low carbon lifestyles within the development.

8.6 Further Analysis and Discussion

8.6.1 Meeting customer priorities

The literature review and interviews show that, in general, there is a case for sustainable housing and self-build. However, it is important to consider priorities when buying a new home through an eco-self-build community scheme. Table 8.5 displays the priorities identified in the Ipsos MORI survey (2006) on sustainable housing, and presents an assessment of how the self-build option could affect these valued characteristics. The assessment is based on an evaluation of the findings from the survey. The categories in the table are listed in order of priority with the highest priority first. For further details on the relative attractiveness of each category, refer to Table 8.1.

Table 8.5 Features that attract people to sustainable housing developments and the performance of the eco-self-build community approach

Row	Reasons for wanting to live in a sustainable housing development?	Potential impact of the eco-self-build community proposition, compared to conventional house building
1	It would help me do my bit to save the planet	Self-builders have more input in making decisions regarding the sustainability of their homes and can therefore go further.
2	It would reduce the amount I pay on bills	Self-builders can choose their own energy efficiency technology and directly financially benefit from this choice. They are therefore able to go further than property developers. They also have a personal stake in making sure that the installation is carried out to a high standard and that no energy is wasted due to bad workmanship (e.g., poorly insulated walls).
3	It would increase the quality of life for me and my family	The community self-build concept allows residents to make choices, for example, to compromise a larger personal private garden for a communal garden. They can have input into the design in a way that is suitable to their lifestyle, for example not allowing cars on some of the road, or locating the communal garden so that children do not have to cross a road to access it. Such choices can directly improve the quality of lives of families. For example, a communal garden with children's play features, safely accessible by children can improve the lives of children and parents. Instead of taking children to the playground, parents can get on with their responsibilities whilst children have continuous access to outdoor play, playmates, and physical activity whenever they need or want it.
4	It would be cleaner and "fresher" to live in	Being in charge of the design themselves, self-builders are able to design the home in ways that feel good, clean and "fresh" to them.
5	It would be a better place for bringing up children	In addition to remarks in row 4, the self-build concept brings together people with a can-do attitude, who do not shy away from the challenge of building/developing their own homes. They get to know and can support each other. They are able to make choices for creating an environment that is better for their children. They can make child friendly choices such as a communal garden where children can socialize with other children and adults. This supports the social development of the children and, for example, may teach them conflict resolution skills, speaking confidently to adults, etc.
6	It would have a close-knit community feeling	Building homes together as a group will by default enable people to get to know each other even before moving into their homes.
7	It would be safer than other places to live	In a place where everybody knows each, other criminals are easier to spot and it becomes harder to commit a criminal offence, thereby leading to a safer environment.
8	It would have cutting edge design and technology	Self-builders are able to choose their own design and technology.

The analysis in Table 8.5 depicts how the community self-build approach has the potential to positively affect the delivery of all the valued sustainable housing and community characteristics listed in the Ipsos MORI study (2006). The main ones are:

1. Reducing their environmental impact: 54% of people would like to live in a sustainable housing development to do their bit to save the planet. The eco-self-build approach gives people the opportunity at each stage of the design to choose the environmentally preferred option.
2. A better place to live: 16 to 25% of people were attracted to one or all of the following characteristics: a safer place to live, increased quality of life, cleaner and fresher, better for bringing up children, close knit community feeling.
3. Save money: saving money on bills attracts 35% of people. The survey did not explore other money saving options. However it is likely that people attracted to saving money on bills would also be drawn to other money saving opportunities. Here the self-build approach delivers many occasions for significant financial savings through taking part in the building process, as well as tax breaks.
4. Innovative technology features: 16% were attracted to cutting edge design and technology, something that many self-builders choose to integrate into their homes. Examples our interviewees mentioned: include a ground source heat pump with underfloor heating, a woodchip boiler, solar electricity, passive solar design and emerging sustainable building materials. All of the aforementioned would be difficult or impossible to retrofit into an existing home.

In order to assess the added benefits of the eco-self-build community approach, it is not only important to understand how well it meets sustainability priorities of potential customers, but also how well it meets overall priorities when moving to a new home. Furthermore, the relative priority of sustainability features compared to other factors needs to be considered. Based on the results from the interviews, Table 8.6 depicts a list of priorities when moving to a new home, listed in order of priority and taken from market research conducted by Ipsos MORI (2006). The prioritised categories start with the highest priority and are colour coded by feature type. Our analysis of how the proposed concept impacts upon these priorities. This assessment was made based on the results from the interviews.

The eco-community self-build concept scores positively on most priorities people have when moving to a new home and negatively on none. It is interesting to note that whilst conventional eco-housing is likely to score well among sustainability features, adding the community self-build component means that many prerequisite area and home features can be met as well. Examples of the area factors that the eco-community-self-build approach scores on are:

1. Being close to family and friends – doing a self-build together allows friendships to form, or to build a house for the whole big family, for example through including a granny flat.
2. Low crime – a place where the community looks out for each other can reduce crime.

Examples of the home features where the eco-community self-build approach scores highly are construction quality and design of the home, which with the self-design and self-build approach is fully in the hands of the home owner, and other design features such as size and number of rooms and garden, can also be decided by the home owner. Features such as open spaces, for example, communal garden could be chosen by the community to be incorporated into the overall design. Most area and home factors were given a higher priority by survey respondents than sustainability features, indicating that many people may prefer the eco-community self-build approach.

One needs to recognise, however, that all these positive aspects are achieved in exchange for the owner taking on some responsibility for building his or her own home and having the capability and time to do it.

Table 8.6 Ability of the eco-self-build community proposition to score against homebuyer priorities

Priorities when moving to a new home	Impact of the eco-self-build community approach	Overall rating of impact
Close to family and friends	Community formation and friendships encouraged through building their homes and community together, events, places to meet, community activities for volunteers.	+ positive
Low crime area	Spill over effect due to community formation, there is more care in the community, people know each other, and hence criminals are spotted more easily. Due to this cultural shift where altruism is appreciated, there may be less crime from within the community itself.	+ positive
Access to good local schools	This can be taken into account when choosing the location.	0 neutral
Quality of construction and finish	Quality of construction is in the control of the self-builders. Driven by personal interest, self-build homes are often of high construction quality.	+ positive
Number of rooms	Because with self-build people get more for their money, they can afford to have a bigger house than if they were to buy one.	+ positive
Access to good local healthcare	No impact, unless a health professional joins the scheme and offers service to the neighbourhood. At the Ashley Vale site people have done this and offered their services at a reduced rate to their neighbours.	0 neutral
Good transport links	A carshare scheme and good cycle parking will help. Other site search could use brownfield sites with good access to amenities as a selection criterion.	+ positive
Energy efficiency	Basic criteria can be that all homes are designed to meet	+ positive

	best practice standards on energy. In addition, self-builders can go further if they choose to do so.	
Parks and open spaces within walking distance	A communal garden forms an integral part of the site.	+ positive
Internal design and appearance of the house	The internal design of the house is done by the home owners themselves. Thus, it can be in accordance with the exact style and taste of the owner.	+ positive
Size of rooms	Because with self-build people get more for their money, they can afford to have a bigger house than if they were to buy one.	+ positive
Garden	The mixture of small private and communal gardens and balconies allows more flexible and accessible use of outdoor space. A barbeque and play features in the communal garden can encourage its use for communal activities.	+ positive
Low noise and pollution	Pedestrianized areas and encouragement of low carbon transport reduces noise from cars. Environmental paints and floor coverings can be used to reduce indoor toxins.	+ positive
External design and appearance of the home	With individuals designing their homes themselves using sustainable building materials, the homes are likely to look different and innovative. An overall theme and framework can ensure that the design works as a whole. Self-builders are likely to put more energy into making their homes and gardens look nice, as this is one of the reasons they decide to do a self-build.	+ positive
Good local shopping/leisure facilities	To be determined according to site selection.	0 neutral
Aspect	To be determined according to site selection.	0 neutral
Renewable energy	Renewable energy solutions will be part of the basic requirement.	+positive
Environmentally-friendly construction material	Environmentally friendly building materials will be part of the basic requirement.	+ positive
Access to food from local producers	Areas set aside for growing one's own food. Organic vegetable box schemes can be recommended. If viability permits, a weekly farmer stall can be arranged in the communal garden.	+ positive
Quality of fixtures and furnishings	These can be selected by owners themselves according to taste.	+ positive
Convenient recycling facilities	Convenient recycling facilities and their management are part of the site design and can foster a culture of waste minimisation, reuse, repair and recycling.	+ positive
Water saving appliances	Water saving appliances are part of the basic requirement and specific products will be recommended.	+ positive.

Colour coding:

(light pink)	Area factors
(green)	Home features
(red)	Sustainability features

8.6.2 Environmental sustainability check

Whilst the analysis in the previous section shows that the eco-self-build community concept may be better at meeting people's priorities and needs than conventional developments, will they really result in residents living a more sustainable lower carbon lifestyle? Despite the fact that measuring the carbon footprint and other sustainability criteria achieved by existing eco-self-build communities is beyond the scope of the present research, comments made by interviewees – existing residents and potential customers – give some indication about the capacity of eco-self-build housing development to meet this aim. They also permit us to better understand how the set-up of eco-self-build housing communities can lead to such achievements.

The Climate Challenge Tool (Chapter 6) was used to determine cost implications and carbon savings for various technical and behavioural sustainability measures. A list of sustainability measures which seem appropriate to eco-self-build communities and would achieve a similar level of carbon emission reduction to the carbon neutral homes policy were selected to be proposed to the self-builder interviewees. The CCT shows that the sum of the measures may add about £4000 to the cost of each self-build home. According to the Ipsos MORI (2006) and the Knight Frank (2007) research, about 20% to 35% of all UK home purchasing customers would be willing to pay this level of uplift. People wanting to buy into an eco-self-build community are probably more likely to belong to this group than the general public, as 19 of the 21 (90%) customer group interviewee respondents (Interviewees 1 to 19) stated that they belong to this group). Some said they would pay significantly more. Therefore from a financial perspective we may assume that this level of uplift in costs for sustainability measures may be acceptable for our proposition.

Table 8.7 below lists the chosen sustainability measures. Please note that these are generic and will differ slightly for each site, depending on site characteristics and client preferences. Assumptions on achievable sustainability measures were made based on what relevant survey participants thought could be achieved and based on measured and judged achievements in other eco housing developments. The total carbon emissions reductions achievable are broadly in line with those of a typical new home if it were to be designed as carbon neutral in their direct energy use of 2.9 t CO_2e per year, at a cost of over £20,000 (Chapter 6). Whilst it would most likely be cheaper to reduce emissions through widening the choice of options, i.e. including lifestyle choices, a five fold reduction in costs is significant, and shows that including the other four emission categories through the lifestyle approach is valuable.

Based on the discussions with the self-builders at the Ashley Vale and Findhorn Communities, the measures in Table 8.6 are seen as realistic. Interviewees 11-21 agree that the level of emissions reduction and types of measures are likely to mirror the achievements in their developments. They were asked whether they would have chosen eco-self-build anyway, and whether the savings were therefore additional due to the eco-self-build development. Most consider themselves to have already been environmentally-minded prior to joining the self-build, but they answered that, under normal circumstances, the infrastructure and community support would not have existed and therefore any progress would have been on a much smaller order of magnitude. Potential customers (Interviewees 1-10), generally agreed that the list of proposed measures were realistic. Four of the interviewees (2, 3, 8, and 10) would see themselves going much further. The responses from both experienced eco-self-builders and potential customers therefore support the thesis that eco-self-build communities are very likely to deliver significant emissions reductions. Although we are unable to confirm our findings through empirical measurement, the interview responses indicate that a similar order of magnitude is likely to be achievable with our proposition.

Table 8.7 Estimated CO_2e savings per household at generic eco-self-build community development for measures that exceed current building regulations

Measures	Annual CO_2e reduction (tCO_2e/household/year)
Low cost energy efficiency measures (air tightness, low CO_2e lighting, low flow tabs and showers)	0.3
Solar hot water or wood stove[18]	0.3
20% increase in waste reduction and recycling through good provision, awareness-raising and shared purpose	0.5
15% carbon emissions reduction of food carbon footprint through awareness-raising and advice on organic veggie box schemes, once a week local farmers market, and shared purpose	0.5
25% reduction in commuting transport emissions through choosing a location with jobs close to home, increased cycling, car share scheme and public transport, and the ability for people to design their homes in order to work from home[19]. Ability to work from home and stay at home for recreational activities and socialising through a communal garden.	0.6
Low cost building materials with low embodied carbon is chosen (timber frame, timber and tile flooring, timber cladding, site construction waste reduction, minimising use of concrete and lead).	0.3
Awareness-raising achieves a further 10% uplift in waste reduction and recycling rates, sustainable food uptake, uptake of sustainable transport options, and home energy management.	0.3
Total	*3.0*

An additional less quantifiable yet nonetheless important factor for the ability of the eco-self-build communities to influence low carbon and sustainable lifestyles and choices, is the spill over effect. A number of potential customers and even those responding that they would not want to move into an eco-self-build community (Interviewees 2, 5, 8, 22, 24) replied that visiting the Ashley Vale site inspired them to live sustainably. One person (Interviewee 24) who had previously not wanted to live in an eco-self-build community remarked that:

> *"Whist I would not want to move here because I'd think everybody would judge me for not being eco-friendly enough, I always thought that running around with woolly jumpers and eating yogurt is not fun. What has happened here is really*

[18] *Woodstoves may arguably not be the most sustainable choice as they cause local pollution and may burn wood which could be used more sustainable for example as construction material. They are however desired by many self builders and therefore, where used, DEFRA approved stoves for smokeless zones should be used. In addition a local sustainable wood-source such as off-cuts needs to be identified.*
[19] *BedZED Ecovillage in South London and Vauban in Freiburg, Germany achieved a 50% reduction in car use (Knight and Frank, 2007).*

cool. This is not about living in the cave and giving everything up. I didn't think you could be an eco type and live so lushly".

Her remark suggests that through portraying sustainable living in a positive light, and showing that it can be done in such a way that benefits both people and the planet, the eco-self-build community approach has the potential to influence attitude and behaviour outside its direct confines. It can thereby play a role in shifting attitudes and garner public support for policies that tackle climate change and other pressing environmental problems.

8.6.3 The proposed business model

The analysis of the interviews and literature review shows that eco-self-build community projects can have a role in delivering social and environmental sustainability and carbon emissions reductions in the UK. We propose in this section a business model, which could be used to encourage sustainable development. Our model is partially based on the interview analysis presented; it incorporates some of the priorities for new housing listed in Tables 8.4 and 8.5, and includes measures to further enable and encourage sustainable lifestyles. Measures for encouraging sustainable lifestyles were selected based on the findings from the Climate Challenge Tool (Chapter 6). This section provides a summary of the main relevant parts from which a full business plan could be developed. We also address issues that have not yet been mentioned. The text here supposes that such a company is called Bright Green Futures.

Detailed description of the company: Bright Green Futures

Bright Green Futures buys land in order to build and sell sustainable homes and to sell some of the land to individuals who are interested in building their own sustainable homes as part of a community.

Bright Green Futures has four profit channels:

1. from purchasing land and selling it on to individual self-builders at a premium
2. from providing advice and support to these self-builders
3. from building and selling sustainable homes
4. from purchasing land at a lower rate in exchange for meeting certain sustainability credentials.

Bright Green Futures offers four distinct products:

1. A plot of land to build a home, plus support. The plot of land will come with the outline of planning permission to build a home of a certain size. Sustainability credentials will be ensured through the contract, which specifies sustainability and design measures and conventions to be met. The support will include installation of service mains to the property, a document which informs about sustainable construction principles, provision of contacts with and

recommendations for local suppliers and tradespersons, architectural services, and one-to-one advice to support the self-builder during the constructing and/or managing the construction of their own home.

2. A flat or terraced home with the outer shell completed, plus support. The flats will have the outer shell completed, but the inside is to be finished by the “semi-self-builder” in accordance with his/her preferences. This avoids the difficulty of designing and building a block of flats as a group of people, whilst still allowing the client to individualise their design and save on costs by doing some of the work themselves. Another document outlining the sustainable construction principles, provision of contact, and recommendations of local suppliers and tradespersons will be provided. Architectural services and some one-to-one advice to support the self-builder in the constructing and/or managing of the construction will be included in the package.

3. A completed sustainable home is bought off-plan with optional choices of design at a premium cost.

4. A completed sustainable home in a community of active individuals who have already shaped and individualised it which would be sold after completion at the point when the development has taken shape.

This mixture of offerings has three main advantages for the company:

1. It creates heterogeneous communities, which are in their essence, more sustainable.
2. It makes living in a sustainable community accessible to a wide range of people.
3. It reduces the risk of Bright Green Futures.

Once a site is found, the constellation can be defined depending on demand and the balancing of risk. This constellation may include:

a) A number of distinct environmental sustainability features of the developments built by Bright Green Futures: Energy efficient, thermally comfortable designs with renewable energy features, which add ambience such as wood a stove.
b) Modern attractive green building materials: wood cladding, wooden windows, timber frame, oak floors and terracotta tiles, coloured render, tiled and grassed roofs.

c) Good communal provisions for recycling, and advice on purchasing ethical goods such as the best value organic veggie box scheme, or a weekly fruit and vegetable stall etc.

d) A communal garden with play provisions for children situated in the centre of the site and thus able to be overseen by the homes.

e) A home-zoned road to the homes, i.e., a road where it is save to play as where beautiful planting schemes and benches provide barriers that mean that cars need to drive extremely slow (5 mph speed limit).

f) Advice is provided and events are organised to bring to community together and raise awareness on sustainability.

In addition to the environmental benefits, there is a distinct neighbourhood benefit. The qualities of human value and individual/group decision-making, generally attracts people to the developments who are willing to get their hands dirty in order to create a good neighbourhood. By default, Bright Green Futures creates better location due to the social capital its customers bring. Bright Green Futures can work in partnership or joint venture with landowners or it can raise investment in order to purchase land outright for development.

Target customers

The main target customers who will benefit most from Bright Green Futures are parents with children, or people planning to have children, as well as people ready to retire to build their dream home where they will not feel isolated as they grow old. Another prime target group are young people trying to get onto the housing ladder who need to save money and can achieve this by doing some of the work (i.e., completing the insides of the flats themselves. We define the customer groups as the “bright and light greens”, people looking into the future, imaginatively and constructively playing a role to create a great community. These types of customers should bring significant social capital that will help create great locations to live in. The customer groups were identified in Table 8.4. All developments should include a mix of people from different groups. The precise mix of these groups within a particular development will depend on the location, size, and features of the land being developed.

Spill over effect

Bright Green Futures developments are not exclusive or fenced housing developments. They are designed to support their surrounding neighbourhood and to be accessible to all. As such they promote the fact that sustainable living can be fun. The company promotes sustainable living and itself directly through its developments. Site tours can be organised regularly which can be used to raise awareness of solutions to climate change and to inform others that they too may one day wish to build their own home in an eco-self-build community.

8.6.4 Perception of the Financial Viability of the Business Model

In order to test the financial viability of the proposition, we have assumed the following four income streams:

1. purchasing land at a lower rate in exchange for meeting certain sustainability credentials.
2. purchasing land and selling it on to individual self-builders at a premium
3. providing advice and support to self-builders
4. building and selling sustainable homes

We assume that land is purchased to build and sell sustainable homes and to sell plots of land on to individuals interested in building their own sustainable home as part of a community. The income streams and their ability to meet the associated costs of the services are described in this section in more detail.

Income from provision of support services to self-builders

Based on literature search and responses by interviewees 1-10 and 13 and 17, an uplift on plot value is judged to be acceptable for the inclusion of a variety of support services including:

a) Identifying, interviewing and selecting purchasers
b) Provision of on-going advice and support throughout design and construction and with setting up a community organisation
c) Master-planning and on-going support from an architect
d) Developing a site-specific legal framework for contracts and enforcement of contracts
e) Organising bulk purchases and negotiating prices on clients' behalf.

A group of 10 homes could be delivered at cost within an acceptable fee structure; for larger groups there is the potential for profit with economies of scale.

Income from Land Deals

Further profit could be made from buying multiple plots of land and selling these on individually. Interviewees 34, 35 and 36 reported that an uplift of 30% to 50% was charged per area of land for individual plots compared to the lower price developers pay for multiple plots.

Additional income could be generated in cases where land without planning permission (for example with commercial or agricultural status) is given planning permission because it meets the Government's aspirations towards sustainability in particular.

Income from building or part building homes

Where a company builds or part builds homes for the purchasers of plots the fee charged can be set in line with the competition, thereby providing similar profit margins that are typically around 3 to 5% (Interviewees 28 and 29).

Income from selling completed homes and from building a show-home

A further opportunity to generate income is to follow the conventional property development route and build some homes to be sold as complete properties. Experience at the Ashley Vale Site illustrates that once the first houses took shape, plot prices doubled and completed homes sold at a premium rate (Interviewees 13 and 16). Demand may rise once people can actually see the potential of the scheme. Building homes and selling them later adds risk but may also increase profit. There is also an opportunity to initially build one home as a show-home to be used for marketing and promotion purposes for a certain period and sell it at a later date.

Discussion and conclusion on financial viability

We can conclude that the proposition has a number of viable income streams; it could on one hand work in partnership with landowners and charge for its support and project management service through an uplift in plot prices. Conversely, however, there are a number of additional income streams through direct purchases of land, making land deals, and building and selling completed homes alongside the self-builds, which may have the potential to provide additional income and increase profit margins.

This business model is currently being applied to a start-up company: Bright Green Futures Ltd. See Appendix B for further details.

8.7 Conclusions

This chapter has examined eco-self-build communities as a viable option to traditional housing developments. Significant demand for the proposition was identified. This proposition is more complex than conventional property development as it requires people skills, a more complex set-up, more complex planning negotiations and the right contractual framework to ensure financial success and a high level of sustainability. A major driver is the political push for more sustainable and low carbon housing and the resulting opportunity for gaining planning permission with this concept for schemes and sites which otherwise may not.

Initial customers for eco-self-build community developments are likely to be environmental pioneers rather than the majority of UK customers who purchase new homes. However, the first trend setters who acquired plots for self-build as well as self-finish and completed sustainable homes would heighten the appeal for sustainable homes and communities to countless citizens of the UK. Eco-self-build community developments can be adapted to different locations and types of customer: high and low density, urban and rural, families and individuals, high and low budgets. Experience from other countries proves that, where market barriers to self-build are removed, a market penetration of 50% to 80% of new builds can be achieved (NaSBA, 2008). A removal of such barriers through the proposed approach and/or policy changes is therefore likely to lead to a much greater uptake of self-build in the UK.

Eco-self-build community development offers significant potential for reducing carbon emissions in the UK by 2050, through enabling low carbon lifestyles if the UK Government includes eco-self-build community projects in its sustainable homes initiatives. Similar emission savings as those likely to be achieved through the UK Government's zero carbon homes initiative can easily be achieved through eco-self-build community projects, and therefore it seems like a great opportunity to explore and implement alongside decarbonising the direct home energy consumption of all UK homes. Our analysis of the perceived financial viability assessment of eco-self-build communities has shown that it would be possible to cover the costs of the necessary inputs to launch the scheme through the premium people would willing to pay for this type of service.

Therefore eco self-build communities are likely to be feasible and have the potential to deliver low carbon lifestyles. Compared with conventional approaches to building new housing eco self-build communities have further advantages in terms of delivering wider social, environmental as well as economic sustainability objectives. If implemented correctly they could succeed in making sustainable lifestyles attractive, and foster the development of pro-environmental social norms.

9. Thesis Conclusions

9.1 Chapter overview

The central aim of the thesis has been to identify how housing development in the UK could play a greater role towards meeting the 80% carbon emissions reduction target by 2050 through a lifestyle approach, to investigate whether there is a business case for eco-self-build communities, and to verify if this model could be a route towards achieving low carbon living. In undertaking this research, various types of evidence and analysis have been employed, from a critique of UK Government energy policy, to an investigation of costs and carbon savings of options available for new housing, stakeholder survey, and a perceived feasibility study.

This chapter pulls together the key evidence from each of the preceding chapters and draws some overarching conclusions. Linkages between different parts of the research and findings from different chapters are emphasised. The analysis in this thesis has led us to the conclusion that in order to achieve the 80% emissions reduction target required to prevent catastrophic climate change, a lifestyle approach that combines behaviour change solutions with technical solutions is more convincing than an approach largely circumscribed by technical solutions. Furthermore eco self-build communities provide an opportunity for enabling low carbon and sustainable living.

Following the summary of our research findings, we return briefly to the methodologies used to conduct the research. Areas for further study and unanswered questions are identified, and suggestions for government policy are given. Finally, the original contribution to knowledge made by this thesis is clearly outlined.

9.2 Summary of key findings

Climate change is a pressing world problem. An 80% carbon emissions reduction target by 2050 appears to be an appropriate emissions reduction target for the UK, that is, if the country is to take responsibility for an equitable global share of the problem, and if dangerous unforeseeable or run-away climate change is to be avoided.

The UK's total carbon emissions have thus far fallen since 1990, but much of the reduction has been fortuitous, as a result of structural changes to industrial and energy sectors rather than resultant from fundamental shifts to a low carbon economy (see Chapter 3), therefore any further savings is likely to be harder to achieve, as the metaphorically low hanging fruits tend to be picked first.

Crucially, some UK-responsible emissions are not included in Government accounting methods. Therefore, an attempt was made to estimate their role compared to what is currently being reported (Chapter 3): In our calculation we included international aviation and shipping emissions, and the effect of radiative forcing in aviation emissions. We excluded emissions from goods exported consumed outside the UK and included emissions from goods consumed in the UK but produced abroad; we further included methane and nitrous oxide. The UK responsible CO_2e emissions calculated on this framework amounts to 1057 Mt CO_2e. However, only slightly more than half of this amount (556 Mt CO_2 in 2006) is currently reported to the UN and currently used to measure success against national climate change targets. Furthermore, the evidence presented here indicates that, rather than falling, UK-generated emissions have risen significantly since 1990. In the future they are forecast to increase further, largely driven by a projected increase in international air travel. A consumer-based approach, based on the emissions resulting from goods and services consumed by UK citizens, may allow for better accounting.

Households are also an important contributor to overall UK emissions, and their emissions footprints are directly affected by lifestyle choices. Household carbon equivalent emissions (as defined and calculated in Chapter 6) currently account for 29% of all consumer based carbon equivalent emissions (as calculated in Chapter 3). It was found that many current UK climate change policies focus on technology solutions, very few specifically focus on behaviours, whilst policies such as road tax and carbon price provide financial incentives that put technology solutions and behaviours on a level playing field (Chapter 4). Various analyses done by Boardman (2007), Hickman and Banister (2007), Tight et al., (2005), Bow and Anderson (2007), Audsley et al., (2009) (reviewed in Chapter 4), and the author of this thesis (Chapter 6), show that a technology-focussed approach is unlikely to achieve the UK 80% reduction target. A wide variety of behaviour change options for carbon emissions reductions were identified that have largely been ignored by UK policy but could, however, achieve significant savings (Chapters 4 and 5). We argue that the 80% target can only be achieved if both technological and behavioural changes are implemented.

New housing presents an opportunity for such technology and behavioural change because many design and set up decisions can be made which can make low carbon lifestyle choice easier. We here looked specifically at solutions that property developers and residents of new homes can choose to implement. If technological and softer behavioural measures are to be incorporated into new housing developments then this process can be supported by a tool, which allows developers and those in development control, to assess the resulting carbon reductions. None of the tools currently used within the housing construction sector do this satisfactorily. The Climate Challenge Tool has been developed following a lifestyle approach, which includes both technical and behavioural measures and allows them to be compared on a like for like basis (Chapter 6). Whilst carbon emissions and costs can be assessed for various measures with other tools, never before has a tool been developed which allow for the assessment and comparison of solutions from each of the five categories: direct energy, building materials, transport, food and waste with each other. By applying the tool, the household carbon emission footprint has been assessed in four scenarios: a typical UK home, a 2002 building regulations home, a "zero carbon" home based on the Government definition, and a home in a case study development designed for a low carbon lifestyle. The cost effectiveness of the carbon saving measures was also assessed for the "zero carbon" and low carbon lifestyle homes. We found that behavioural options can be more cost-effective than technological solutions. With the lifestyle approach we can achieve carbon savings equivalent to the Government's zero carbon homes approach, but at a fraction of the cost, and with additional social sustainability benefits.

Behavioural change requires economic incentives and/or a change in social norms. To maximise change and be capable of meeting the 80% target, both are needed. Communities affect social norms, therefore, if we can instigate value-driven communities in new housing developments that are strongly aware of climate change, there will be a greater chance to influence individuals' behaviour. A focus group based innovation workshop was held in order to identify business models for new UK housing, which may deliver such responsible communities (Chapter 6). In the workshop eco-self-build communities were perceived as a potentially promising opportunity. Furthermore, it was realised that a low carbon approach could work in mutual support of an overall sustainability approach.

The perceived feasibility of eco-self-build communities in the UK was explored through literature review and interviews with stakeholders including existing and potential customers, financiers, competitors, laggards, landowners, local government, and self-build lobby organisations (Chapter 7). We estimated that the addressable market amounts to £5.5 billion for building plots and £7.2 billion for completed homes, or 64,000 plots and 33,000 homes per year. Desirable features identified included communal aspects and room for privacy, support during the self-build process, prioritised low carbon features with people benefits, cultivation of a shared purpose, child friendly design, and empowerment of community to make decisions and contribute. The main barriers to eco-self-build communities were judged to be: land acquisition, financing, people management, and planning permission. The factors judged most critical to success resulting from these desirable features and barriers are the selection of customers based on their social capital, child friendly design, the land deal and deal structure, community provision, support to self-builders, and cultivation of a shared purpose.

Using the Climate Challenge Tool, the potential carbon savings of eco-self-build communities were examined (Chapter 7). The results were favourable and supported by interviewee comments. The interview results further supported the likely indirect effect of eco-self-build communities, which is to trigger awareness and behaviour change beyond the confines of the community as a positive and inspiring example of climate-friendly living.

The perceived feasibility study shows that there may be a viable business could be set up to sells building plots, semi-completed homes and fully completed sustainable homes, which are part of a sustainable low carbon housing development with community features. In addition the venture would generate income from selling advice and handholding support to the plot purchasers and purchasers of semi completed homes, assisting them throughout the self-build process. This business model adds additional social and environmental benefits, beyond what is currently achieved in conventional housing developments in the UK. Such benefits include wellbeing and empowerment of the residents of the eco self-build communities and carbon emissions reductions through enabling low carbon lifestyles. As such eco self-build communities are one route to deliver significant carbon emission reductions through a lifestyle approach. The success of this route has been demonstrated in that eco self-build communities may deliver carbon emission reductions at a much lower cost than the Government's suggested approach of building carbon neutral homes, and with additional social benefits.

In order to be able to achieve the Government's 80% carbon emission reduction target many opportunities, which enable and encourage low carbon lifestyles will need to be realised. Eco self-build communities have been shown to be one of these opportunities.

9.3 Addressing the key research questions

This section discusses how each of the questions posed at the beginning of the thesis (Section 1.3) have been addressed.

Question 1: Is a sector-specific strategy of relying largely on technical solutions likely to achieve the required savings? And if not, could a lifestyle approach offer an alternative route to savings?

Chapter 4 showed that a sector specific approach which is largely based on technical solutions is unlikely to be able to achieve the UK 80% emission reduction target for 2050. Behavioural choices will need to be included. The lifestyle approach, as described in Chapter 4, Section 4.3, includes technical and behavioural measures, and was applied in Chapter 6 to new housing developments. The findings from this application suggests that carbon savings achieved in new housing can significantly be increased through the lifestyle approach. In addition carbon savings were found to cost less than through an approach, which focuses on technical change only.

Question 2: If so, how can this approach be applied to the design and set-up of new property developments in the UK?

In Chapter 6 as part of the Climate Challenge Tool (CCT), a method was developed which enables to assess the "environmental cost effectiveness" (£/tonne of CO_2e saved) of technical and behavioural solutions, which save carbon emissions of new housing developments and their residents, and on this basis can support prioritising the options Our method (the lifestyle approach) focuses on significant emission categories which can be influenced by the way new housing is designed and set up including solutions which affect the lifestyles of its residents in addition to the conventionally applied solutions which reduce the emissions from direct home energy consumption only. This method has here been applied to a case study new housing development and shows significant potential for increasing carbon emission reductions and for doing so more cost-effectively (Chapter 6).

Question 3: Is there a case for enabling communities to build their own sustainable homes (eco-self-build communities)? If yes, how could it be set-up, what are the possible implications for climate change and sustainability, and is there customer demand for such an offer?

Based on literature review and stakeholder interviews, a social enterprise, which facilitates and supports eco-self-build communities in the UK is perceived to be feasible. The business model developed on the basis of this research is presented in Chapter 8, section 8.6.3. This business model is likely to be able to deliver low carbon and sustainable lifestyle solutions more effectively than the conventional way in which housing is currently being developed in the UK. Customer demand is judged to be significant and the addressable market for the developed business model amounts to about 60% of all new homes built which is equivalent to about 7% of all homes bought.

9.4 Limitations of this research and further work

This thesis has focussed on how low carbon lifestyles can be enabled in new housing in the UK. With a build rate of about 1% per year, new housing represents only a fraction of households. Of all homes inhabited in the UK by 2050, around 80% are already standing today (Boardman, 2007). Therefore, it is important to see this research as a potential stepping-stone towards replicating and applying the lifestyle approach to existing households and housing communities. In this context lifestyle options could be examined for existing housing communities, and a community approach to behaviour change could be developed to support implementation of such options.

Estimates of potential uptake, financial viability and carbon savings were necessarily crude as they have relied largely on limited data. A more in-depth understanding of how carbon emissions relate to daily activity, especially with regard to consumables such as food – where data is still scant – could serve as a basis for policy and action towards reducing emissions in these categories, and could allow us to expand the Climate Challenge Tool (CCT) to include more options and increase accuracy. As new research becomes available, the CCT could be updated and evolve.

The CCT was here developed to identify options that property developers and house builders can implement to reduce carbon emissions. The tool could be developed and expanded to include different target groups (other than property developers) and further emission categories, allowing other organisations, individuals and/or policy makers to understand the environmental cost effectiveness (£ per tCO_2e saved) of the choices available to them.

Within this thesis, the community and behaviour change link was based largely on theoretical assumptions and limited empirical evidence of the role that communities receiving eco-sustainable support may play in initiating behaviour change. The success is likely to lie in the details of execution of eco-self-build communities and we recommend that others seek to confirm the findings of this thesis with monitored empirical data and analysis in a pilot eco-self-build community project. Not only would a pilot project provide greater validity to the findings of Chapter 8, it would also enable the refinement of the business model in order to maximise its ability to lead to behaviour change and low carbon lifestyles.

In the new housing focus, detailed analysis was conducted for a particular business model: eco-self-build communities. If we examine the relevant market, we can observe that at full market penetration, an estimate of about 60% of all new homes could be built as part of sustainable communities with a large proportion of self-build or semi self-build (roughly 40%), and 20% completed homes. Whilst this is a significant proportion, there is a remaining 32% of newly built homes for which the concept is inapplicable, and where low carbon living would therefore have to be addressed differently. In addition, for 60% of new build homes to become eco-self-build communities, private sector activity alone is unlikely to be sufficient to reach this level of penetration.

Whilst there is a business case to promote, the marginal benefits do not outweigh the risks for mainstream house builders to change their mode of operation and shift to this business model for the majority of their developments. As a result, under the present circumstances, this approach is likely to be applicable to house builders, charities and social enterprises that are triple bottom-line rather than sheer profit driven. But these currently have a very small market share in the property market. Therefore policy mechanisms that could support eco-self-build communities and make them more attractive and competitive business models, need to be explored.

9.5 Policy recommendation

As has been discussed in Section 6.2, the UK Government needs to consider how to encourage developers to take a more holistic view and reward them for implementing lifestyle and behaviour carbon saving measures. New regulations and mechanisms for delivering sustainable low carbon homes beyond building regulation, the Code for Sustainable Homes (CSH) and the current planning system may also need to be considered.

Potential opportunities are:

- Land requirements: Land could be set aside specifically for these types of development within the Land Development Framework. An alternative would be to specify that in each local authority a percentage of land identified for housing developments should be for self-builds which meet a high level of sustainable low carbon living and behaviour change parameters.
- The removal of planning barriers to eco self-build communities. This may include the encouragement of local planning authorities to prioritise and provide support for eco-self-build development in their local plans.
- When local authorities and public organisations such as the Homes and Communities Agency sell their land, they could include credits for "sustainable lifestyle measures" in their best value bidding process.
- In a similar way that the Government requires and encourages house builders to meet minimum carbon targets for direct home energy consumption through Part L and the Code for Sustainable Homes, minimum standards could be set for other carbon intensive categories effected by new housing, Especially for building materials and transport such an assessment could be relatively straight forward: Using material quantities the carbon footprint of the building materials can be calculated. Transport assessments are already required for many developments, and tend to include increase in motorised transport journeys and distances per mode of travel caused by the development, and may include options to reduce travel activity (DFT, 2007c; DETR, 2001b). The resulting carbon implication could easily be calculated using government data on carbon footprint per mode per distance travelled.

In addition to these direct incentives for enabling low carbon lifestyles in new UK housing development, UK climate change policy may benefit from a greater focus on sustainable behaviours. Policies such as carbon taxation or consumer carbon rations could support sustainable behaviour choices not only in new housing developments, but in all emission categories to which they are applied. Such financial instruments provide the same financial reward for emission reductions achieved through behaviour change as through technical solutions, and therefore by default put technical and behavioural change on a level playing field. Thus they are more likely to lead to the implementation of the most cost effective ways of reducing emissions.

9.6 Contribution to knowledge

The Climate Challenge Tool, developed as part of this thesis, applies a lifestyle approach (including both technical and behaviour change solutions) in order to reduce carbon emissions in new housing developments. As part of the Tool, UK household carbon emissions have been calculated, including, not only energy used in the home, but also transport, waste, food and building materials. This novel approach was developed to calculate costs and carbon emissions implications of a wide range of opportunities to reduce emissions in the aforementioned five categories. Reduction opportunities include both technical and behaviour change options.

The application of the Climate Challenge Tool to a new UK housing development has shown that focus on enabling and encouraging sustainable lifestyles using a combination of technical and structural changes and awareness raising shows great potential for reducing carbon equivalent emissions in UK households. In addition, such an approach is likely to be far more cost effective than the current ad-hoc policies, which do not seem to be based on a thorough understanding of carbon equivalent emission implications, people's behaviour, wider sustainability impacts, and costs to the economy.

In a focus group workshop a possibly promising opportunity to enable low carbon lifestyles in new UK housing developments was seen to be eco-self-build community. The barriers and possibilities of eco-self-build communities for creating real lifestyle change have been assessed. This area has received scant attention in the literature in the past and shows real potential for reducing carbon emissions in new housing. A business model was developed to bring forward the idea of eco-self-build communities. The financial viability was assessed and found to be profitable. This is an opportunity for a social venture, which in addition to being profitable delivers additional social and environmental benefits.

Overall, we have concluded that the current Government approach relies largely on technical solutions and is unlikely to be able to meet its 80% emissions reductions target by 2050. A lifestyle approach, which includes behaviour change and technical solutions is needed and, as assessed for new housing, may indeed ease the financial burden and adverse social impact of achieving the target. Eco-self-build communities represent one opportunity to enable low carbon lifestyles in new housing developments.

9.7 Key benefits of the research for the sponsoring company

House builders are under increasing pressure to ensure their designs minimise resource use and carbon emissions. The sponsoring company Camco has a number of progressive property developer clients who want to go beyond legal requirements in their flagship developments and demonstrate social and environmental responsibility. The Climate Challenge Tool can help them identify the most appropriate and effective opportunities for reducing carbon emissions in their developments. Its thorough approach makes it suitable to be used as part of the planning application process and can also help property developers demonstrate their environmental commitment through their publicity material. The sponsoring company may use the basis of the Climate Challenge Tool to further develop and apply the approach of the tool to other questions and applications for low carbon solutions. Furthermore, the sponsoring company can follow up on the venture opportunities for eco-community self-build projects that have been assessed in Chapter 8 of this thesis.

Appendices

Appendix A Climate Challenge Tool description

A1 Climate Challenge Tool Summary

The aim of the Climate Challenge Tool (CCT) is to assess and compare the cost, carbon emission implications, resident acceptability and the wider impacts of both behavioural and technical options for reducing carbon emissions through the way new housing developments are designed, set-up and managed. Further the CCT is developed to be used by the sponsoring company CAMCO to support its work with housing developers advising them on sustainable energy and low carbon solutions and helping them to meet the aspirations and regulation of the local authorities which grant planning permissions for their developments.

The CCT contains data and calculations, which assess the cost and carbon implications of a wide range of options over a building's lifecycle. The options fit into five categories: direct home energy use, building materials, transport, waste and food.

A2 The Calculation Stages

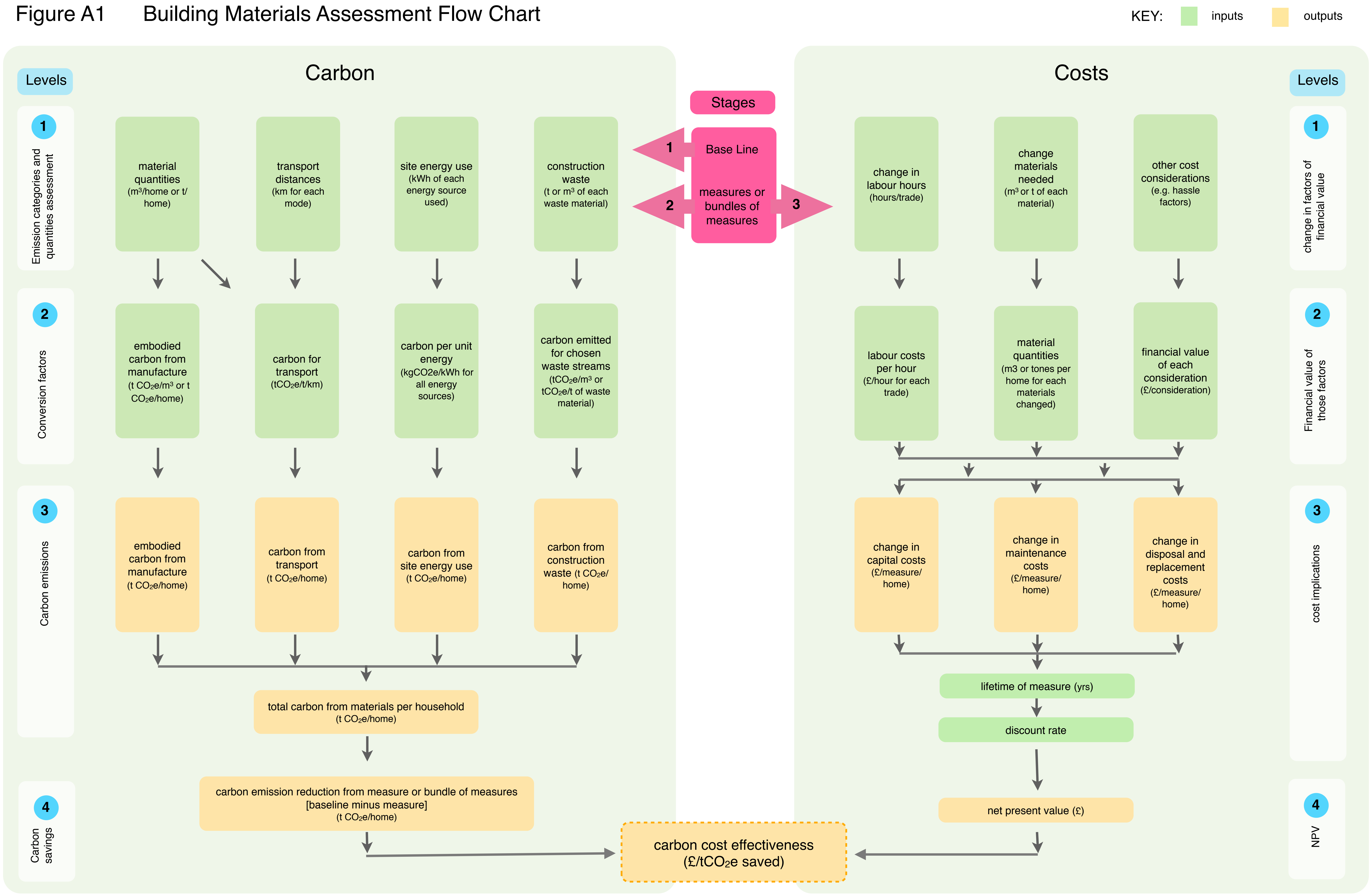
A graphical display of how the model works using the building materials emissions category as an example is provided in Figure A1. A detailed description is provided in this section (A2) and the next section (A3).

Initially for each emission category (direct energy use, building materials, transport, food and waste) the baseline carbon footprint per home is evaluated (see stage 1, Figure A1). The user sets the choice of baseline. In our application the baseline was set to be equivalent to an average UK housing. Our choices might include for example typical UK new build or new build at specific site designed to current building and planning regulations. (This process is discussed in more detail in the next Section A3).

The carbon footprint per home likely to result from the implementation of a measure or a bundle of measures is then calculated following the same procedure (see stage 2, Figure A1). Carbon savings are then derived as the difference between the baseline and the with measure carbon footprint. The change in build, maintenance and disposal costs per home as result of the measure and the resulting net present value (NPV) are then calculated (stage 3, Figure A1). The resulting carbon emissions savings (from stage 2) and the NPV allows calculation of a carbon cost effectiveness indicator: £ spend per carbon saved.

Stages 2 and 3 are repeated for each measure to be evaluated. The outputs, particularly the carbon cost effectiveness indicator are later used to decide which measures to include in the final package of measures or chosen scenarios.

Figure A1 Building Materials Assessment Flow Chart



Within each emission category carbon emissions are generally estimated on a per-household (per-home) basis. Site wide results can be obtained by multiplying the per-household results by the number of homes on site. Where measures are site wide such as the installation of a wind turbine or inclusion of a car club, the savings are converted to a per-home average by simply dividing site totals by the number of homes to be built on site.

Total savings can be calculated by adding up savings from each of the measures. The model does not handle synergistic or counteracting effects between measures explicitly. These can be taken into account by entering data on bundles of measures rather than individual measures in stage 2, level 1 (see Figure A1) through adjusting the input data.

A3 Calculating carbon and cost implications of measures

In order to assess the baseline carbon emissions, first the emission sources and their quantities in each category were identified. For example for building materials, these are the quantities of each material, the transport distances, the site energy use during construction and the construction waste generated of each material (see level 1 in Figure A1). Conversion factors are then used (level 2 in Figure A1) to convert the quantities into carbon emissions (level 3). The sum of all the emissions provides the total emissions embodied in the building materials of a home over its lifetime. The measures affect one or a number of the emission categories at level 1 and through this can change the carbon emissions. Similarly the measures affect cost categories such as labour time and building material costs (level 1, Figure A1), which using conversion factors (such as salary bill per hour) can be converted into change in costs. Through this the change in capital maintenance, replacement and disposal costs can be evaluated permitting the NPV of each measure to be calculated.

The tool includes default data for many of the required inputs, for example the conversion factors and typical quantities of emission categories and changes resulting from specific measures. The default values can be used or where seen as appropriate changed or adjusted by the user. In order to be able to conduct this research within the available time, it was decided that where research data or other tools existed which conduct some of the steps required for our tool, rather than replicating the calculations in our tool their data was used directly. An example is the cost calculation of alternative building materials where literature (Anderson and Shiers, 2002) provided the cost implications over the life cycle directly which meant that we could go straight to level 3 of the cost assessment for some of the measures assessed which were studied in the literature (op cit.).

Figure A1 shows a graphical illustration of the steps involved in the carbon and cost analysis of building materials. The other four categories (direct energy use, transport, food and waste) followed an equivalent process. The text below provides more detail on each of the other four categories.

For the direct energy use assessment the emission categories at level 1 were regulated emissions and unregulated emissions. Energy use (kWh of each energy source) from regulated emission categories were assessed using SAP 2002 (BRE, 2001). Unregulated emission categories were assessed using input data from the Camco database (Camco, 2009c). Conversion factors (level 2) for the direct energy use assessment are kg CO_2e per kWh of various energy sources (electricity, gas and fuel oil), and for costs pence per kWh saved for each energy source. The embodied carbon of the energy generator was not considered as judged to be negligible and therefore renewable heat and electricity was assumed to have a zero emission footprint. For fossil fuels only the emissions from burning fossil fuels were considered. The embodied carbon of the power station was not included. The sum of the carbon emissions from each source allows the calculation of the total carbon emissions per home per year. For the costs assessment the change in capital costs and disposal costs due to the change in technology and materials was calculated adding the costs of the new technology or material and deducting the costs of the material or technology that is replaced. Any change in maintenance costs was also included. The energy savings were translated into cost savings using SAP p/kWh data for each energy source included in SAP. Assumed energy costs for gas and electricity used throughout the calculation are listed in Table A1.

For transport, level 1 consists of national average commuting distances per mode of transport per year per UK household. Total UK commuting distances were used and divided by the number of households in the UK to obtain this figure. At level 2, to convert this into carbon emissions, this is multiplied by the average occupancy on commuting trips for each mode of transport, and the carbon emission per vehicle km for each transport mode. The sum of all transport modes then gives the average emissions from commuting for a UK household. For each measure, such as the introduction of a car sharing scheme or a bus route or measures that reduce commuting distances (e.g. mixed used developments or building close to work environments) or measures which encourage cycling or walking (e.g. save cycling or walking routes, cycle parking, etc.), an assumption is made on how they are likely to affect transport choices and distances at level 1. This then directly translates into a carbon saving at level 4, where the baseline emissions minus the with-measure emissions are calculated. On the cost side, again, the change of in the cost of capital, maintenance and disposal expenditure over the lifetime of the measure directly translate into costs changes, allowing the NPV of the measure to be calculated.

For food, a more simplistic approach was chosen, making use of the existing scenario analysis by Audsley at al. (2009). Audsley et al (2009) explicitly split total UK food carbon emissions into a number of categories (e.g. cooking, manufacturing, food storage, packaging, agriculture and travel) and then estimate the proportional contribution of home food consumption in each category. Out of these the ones, which could be effected, by the way housing developments are designed and managed were included in the assessment. To avoid double counting emissions from food waste and food packaging this is included in the assessment of household waste and excluded from the assessment of emissions from food. Audsley et al. (2009) also estimated emissions savings likely to result from a number of scenarios (e.g. 3% reduction in lifestock product consumption by residents (i.e. meat and diary); 3% red to white meat; 5% replacement of supermarket food with farmers market food: (minimal carbon emissions from transport, supply chain chilling, distribution system e.g. supermarket energy)). Their scenarios' emission savings and the proportions of carbon emissions attributable to household consumption were used to assess the likely household food carbon savings from similar scenarios. Costs calculations followed the same process as described above for the other categories.

For waste, UK household waste composition and quantities (by weight) per material were provided by Jones et al. (2004) and provided the quantities for level 1 (as shown in Figure A1 for materials). The Waste Reduction Model (EPA, 2007) provided the conversion factors (level 2) for each possible waste stream (landfill, landfill with gas capture of different proportions, recycling, incineration and composting) for each material category. This permits the calculation of a carbon footprint per household depending on disposal methods used, for example, the proportion of recycling of recyclable waste achieved. Average UK disposal methods could then be compared to alternative methods and different bundles of measures could be tested, identifying the most carbon saving disposal method for each material category. Again the cost assessment for household waste treatment followed the same process as for the other categories with cost data taken from various literature (Cyril Sweet, 2007; Camco, 2009c).

A4 Selection of packages of measures/scenarios

The selection of the final package of measures is done in four steps:

Step 1: The first and main step was described in section A3 and involves the carbon and costs assessment of a wide variety of measures in each of the five categories (direct energy use, materials, transport, food and waste). The measures and bundles of measure of all categories are then compared with each other.

Step 2: In addition to using the tool to derive carbon and cost data and the carbon cost effectiveness coefficient (£/tCO_2e saved) indicators and comparing the measures using these, the impact of the measures on residents, wider social and environmental impacts and practical considerations are assessed qualitatively in Step 2, as these need to be part of the selection criteria. The tool database lists some of the major impacts. It is planned that this database will be further developed and expanded with each new application of the tool. The user can both interrogate and add to this database.

Step 3: As the third step the user then uses the quantitative and qualitative assessment produced in steps 1 and 2, to establish an overall rating (on a scale of 1 to 5, with 5 representing "highly recommended" and 1: "not recommended") for each measure. This rating summarises the combined results of the quantitative and qualitative assessment.

Stage 4: The output from stage 3 is a long list of possible measures, each of which has been assessed, and given a recommendation rating for implementation. In stage 4, the user compares and selects those measures to be included in the final package of measures for the development, (or for each scenario if several different options are being explored). The calculator and database can then be used to provide the cost, carbon and qualitative outputs of the final package. These may include total tCO_2e saved, total capital costs, energy cost savings, residents' impact, practical implications, etc.

A5 Assumptions

The main assumptions made in the tool and its application to the scenarios described in Chapter 6 of the thesis are provided here. Detailed assumptions such as the inputs into each SAP assessment for each of the energy efficiency measures or the specific renewable energy assumptions can be found in the tool spreadsheets, which are provided electronically with the thesis. For the building material assessment and the waste assessment other tools (Camco, 2009a, and EPA, 2007 respectively) were used to assess the carbon emissions implication, and therefore here the inputs into these tools and outputs from these tools are shown. The assumptions are presented in a number of tables below (Table A1 to A17).

Main General assumptions

Table A1 displays the main general assumptions. Further assumption made in each of the five categories are listed in the additional tables of this section.

Table A1 Main general assumptions

Main General Assumptions				
Description		**Quantity**	**Unit**	**Source**
Typical UK household direct energy consumption				
	electricity	4290	kWh/yr/household	Derived DETR 1999 and ONS 2001
	natural gas	14528	kWh/yr/household	Derived DETR 1999 and ONS 2001
carbon factors (kgCO2/kWh)				
	electricity	0.43	$kgCO_2e/kWh$	DETR, 2001 and Camco, 2009c
	natural gas	0.19	$kgCO_2e/kWh$	DETR, 2001 and Camco, 2009c
	OFGEM certified renewables	0	$kgCO_2e/kWh$	DETR, 2001 and Camco, 2009c
	gas/diesel oil	0.25	$kgCO_2e/kWh$	DETR, 2001 and Camco, 2009c
Energy costs				
	Gas cost	2.375	p/kWh	SAP (BRE, 2001)
	Grid electricity cost	8.744	p/kWh	SAP (BRE, 2001)
typical UK household characteristics				
	number of occupants per household	2.36	people	ONS, 2008b
	average floor area	71	m^2	Camco, 2009c
	Regulated emissions footprint	26.47	$kg/m^2/yr$	calculated using SAP
	Unregulated emission footprint	14.62	$kg/m^2/yr$	Camco, 2009c
	average building materials emission footprint of a typical UK home	1.15	$t/CO_2e/yr$	derived from Entec (2005) and Camco Materials calculator (Camco, 2009,a) assuming 60yr lifetime of homes.
UK statistics				
	UK population	61.8	Million	National Statistics Online Population Estimate 2010 (http://www.statistics.gov.uk/cci/nugget.asp?id=6)
	UK population in employment	29.3	Million	National Statistics Online Employment, 2010 (http://www.statistics.gov.uk/cci/nugget.asp?id=12)
	percentage employed	47%		derived
	average working days per year	208	days/yr	National statistics Online, 2009 derived (http://www.statistics.gov.uk/pdfdir/lmsuk0111.pdf)
Food emission baseline data				
	Direct emissions from food and drink consumed in the UK	152	$Mt CO_2e$	Audsley et al, 2009
	emissions from land use change related to UK food	101	$Mt CO_2e$	Audsley et al, 2009
	total UK food emissions (consumer based accounting)	253	$Mt CO_2e$	derived from Audsley et al, 2009
	Total UK consumer based emissions	1057	$Mt CO_2e$	Chapter 3
	proportional constribution from food	24%		
	percentage of food emissions resulting directly from households including categories that can be influenced by the developer and are not counted in other categories: manufacturing, refrigerants, travel to outlet, packaging, carrier bags and take-away containers, agriculture and landuse change	32%		derived from Audsley et al, 2009
	total UK emissions from household food	81	$Mt CO_2e$	derived
	UK population	61.8	Million	National Statistics Online Population Estimate, 2010 (http://www.statistics.gov.uk/cci/nugget.asp?id=6)
	total household food emissions per UK household	3.1	t CO2e/household/yr	derived
Sustianable Living Officer				
	employment time period	5	years	
	salary	25	£k	Bedzed SLC salary in 2003, Riddleton, 2007
	overheads	130%		Riddleton, 2007
	total costs	287.5	£k	derived
Further Assumptions				
	discount rate	3%		
	Global warming potential (GWP): methane CH4	23	CO_2 equivalent	IPCC, 2001
	Global warming potential (GWP) nitrous oxide N2O	296	CO_2 equivalent	IPCC, 2001
	number of households at the case study site	1780	homes	

Further Assumptions: Direct energy use assessment

Table A2 shows the outputs from the SAP calculation showing the energy consumption of the modelled homes with a number of energy efficiency measures. Capital cost figures were sourced from Camco (2009c) and apply to the year 2008.

Table A2 Cost and direct energy use implication of different energy efficiency measures (Data Source: Camco, 2009c)

Individual improvement measure	Water heating (kWh/dwelling)	Space heating (kWh/dwelling)	Catering (kWh/dwelling)	Pumps and fans (kWh/dwelling)	Lighting (kWh/dwelling)	Appliances (kWh/dwelling)	Total (kWh/dwelling)	Total carbon (kgCO2e/dwelling)	Total (kWh/m2)	Total Carbon (kgCO2e/m2)	Total running cost (£/dwelling)	Total running cost (£/m2)	Total CO2 with 10% RE	Total CO2 with 20% RE	Total CO2 with 40% RE	Total Carbon Saved from measure (kgCO2e/dwelling)	change in capital cost (£/dwelling)	change in capital cost (£/m2)	Running cost saving (£/dwelling)	NPV (£)	carbon reduction over lifetime of measure (tCO2e)	£/tCO2e	SPP (yrs)	lifetime of measure (yrs)
Aerating or flow restrictor taps	2818	1088	515	175	417	2008	7021	2082	99	29	332	4.68	26	23	18	46	0	0.00	6	£49.32	-0.46	-£107	0.0	10
Shower flow rate max 6 l/min	1780	1088	515	175	417	2008	5982	1884	84	27	308	4.33	24	21	16	244	8	0.11	30	£252.02	-2.44	-£103	0.3	10
Shower flow rate max 12 l/min	2167	1088	515	175	417	2008	6370	1958	90	28	317	4.46	25	22	17	170	8	0.11	21	£173.48	-1.70	-£102	0.4	10
Low water use bath	3007	1088	515	175	417	2008	7210	2117	102	30	337	4.74	27	24	18	10	0	0.00	1	£22.65	-0.26	-£87	0.0	25
Good air-tightness	3062	947	515	175	417	2008	7123	2101	100	30	335	4.72	27	24	18	27	0	0.00	3	£58.43	-0.67	-£87	0.0	25
Good insulation	3062	946	515	175	417	2008	7123	2101	100	30	335	4.71	27	24	18	27	36	0.51	3	£23.80	-0.67	-£35	10.7	25
Improved HW Storage insulation	2683	1088	515	175	417	2008	6885	2056	97	29	329	4.64	26	23	17	72	100	1.41	9	£36.93	-1.44	-£26	11.1	20
70% low energy lighting	3062	1088	515	175	319	2008	7167	2086	101	29	330	4.64	26	24	18	42	150	2.11	9	£3.58	-1.05	-£3	17.5	25
A-rated Fridge-freezer	3062	1088	515	175	417	1708	6965	1999	98	28	312	4.39	25	23	17	129	250	3.52	26	-£18.95	-1.29	£15	9.5	10
Good glazing	3062	786	515	175	417	2008	6963	2071	98	29	331	4.66	26	23	17	57	150	2.11	7	-£20.93	-1.43	£15	20.9	25
100% low energy lighting	3062	1088	515	175	246	2008	7094	2054	100	29	323	4.55	26	23	17	74	300	4.23	15	-£30.90	-1.84	£17	20.1	25
Best insulation	3062	910	515	175	417	2008	7087	2094	100	29	334	4.70	27	24	18	34	100	1.41	4	-£23.75	-0.84	£28	23.7	25
A-rated boiler	2891	1027	515	175	417	2008	7032	2084	99	29	333	4.68	26	23	18	44	200	2.82	6	-£112.09	-0.88	£127	36.2	20
Hot water heat recovery	2774	1088	515	175	417	2008	6977	2073	98	29	331	4.67	26	23	18	55	350	4.93	7	-£220.66	-1.37	£161	51.2	25
Best air-tightness	3062	928	515	175	417	2008	7105	2098	100	30	334	4.71	27	24	18	30	200	2.82	4	-£128.01	-0.76	£168	52.6	25
Best glazing	3062	729	515	175	417	2008	6906	2060	97	29	330	4.64	26	23	17	68	600	8.45	9	-£434.07	-1.71	£255	70.4	25
A-rated dishwasher	3062	1088	515	175	417	1973	7230	2113	102	30	335	4.72	27	24	18	15	75	1.06	3	-£46.71	-0.15	£310	24.5	10
Micro-CHP	3629	1655	278	175	180	1771	8637	2038	122	29	344	4.84	26	23	17	90	500	7.04	-6	-£553.98	-1.36	£409	-87.1	15
A-rated washer dryer	3062	1088	515	175	417	1838	7095	2055	100	29	323	4.55	26	23	17	73	600	8.45	15	-£455.72	-0.73	£623	40.4	10
MVHR with best air-tightness	3062	378	515	484	417	2008	6864	2126	97	30	348	4.91	27	24	18	2	1700	23.94	-10	-£1,801.35	-0.04	£43,610	-167.6	20
MVHR with min air-tightness	3062	780	515	484	417	2008	7266	2202	102	31	358	5.04	28	25	19	-74	1500	21.13	-20	-£1,749.18	1.49	-	-76.2	20

Table A 3 shows the outputs from the renewable resource, cost and carbon assessment at the case study site in Cambridge. Further details and inputs can be found in the renewable energy spreadsheet attached on the CD rom.

Table A3 Cost and carbon implications of different renewable energy technologies at the Case Study site

RENEWABLES	annual energy produced (kWh)	annual CO2 emissions (kgCO2e)	capital cost (£)	capital costs per dwelling (£)	capital costs per dwelliing with technology	annual cashflow (£)	NPV life/tCO2e	NPV 15years/tCO2e	% of Renewables (energy)	% of Renewables (carbon)	other variables		simple pay-back	NPV life	NPV 15 years	Lifetime (years)
Medium/ Large Scale Wind Turbines	775,121	-333,302	286,579	161		28,059	-11	-11	6.1%	10.0%	287	Capacity of turbines (kWe)	10	56,739	56,739	15
Solar Water Heating	1,437,574	-317,603	3,317,477	1,864		40,678	265	574	11.3%	9.5%	2,212	m2 of solar panels	82	-2,440,301	-2,735,239	29
Biomass CHP	1,302,103	-333,302	1,294,142	727	2,583	-6,685	334	265	10.2%	10.0%	73	CHP size in kWe	-194	-1,336,256	-1,322,993	12
Ground Source Heat Pump	2,427,503	-333,302	2,269,674	1,275	3,900	1,313	438	438	19.0%	10.0%	1,746	heating capacity in kWth	1729	-2,187,896	-2,187,896	15
Small Scale Wind Turbines	775,121	-333,302	3,548,340	1,993	5,914	91,220	471	471	6.1%	10.0%	1,267	Capacity of turbines (kWe)	39	-2,356,006	-2,356,006	15
Roof Mounted Photovoltaic Panels	775,121	-333,302	5,684,218	3,193		96,646	612	873	6.1%	10.0%	7,656	m2 of PV panels	59	-4,080,805	-4,364,900	20
Biomass Heating	1,804,574	-333,302	2,321,547	1,304	2,319	-52,356	621	621	14.2%	10.0%	301	heating capacity in kWth	-44	-3,106,882	-3,106,882	15

Further assumption: Building materials assessment

For the building material assessment the following quantities of building materials were assumed using Camco (2009a).

Table A4 Building material quantities assumed for baseline (Source: Camco, 2009a)

Building element	Buidling material	Volume of material (m^3)
Foundations	gravel	11.9
	Precast and cast concrete	49.7
	blockwork	2.5
	brickwork	5.3
Roofing	plain clay tiles	2.9
	precast and concrete stone copings	0.1
	lead work	0.1
	aluminium pipes and gutters	0.3
	timber	3.2
Frame	timber	5.5
External walls	Precast and cast concrete	3.5
	blockwork	10.5
	brickwork	18.2
Internal walls	plasterboard	8.4
	timber	0.6
lower floors	ceramic tiles	0.1
	timber	1.3
	laminate tiles	0.2
	carpets (m^2)	68.6
windows	timber	0.2
	glass	0.0
interior and exterior doors	timber	1.4
	glass	0.0
insulation	rockwool	33.6

Table A5 shows the assumed embodied carbon for the construction materials.

Table A5 Embodied carbon in construction materials

Description	Amount	Unit	Source
emissions for weight gravel	0.02	kg CO_2e/kg	ICE, 2006
density of gravel	1650	kg/m^3	SI metric 2008
emissions for volume of gravel	34.7	kg CO_2e/m^3	derived from above
emissions for precast and cast concrete	187	kg CO_2e/m^3	Danish Technology Institute, 2005
emissions for blockwork	121.2	kg CO_2e/m^3	BRE, 1999
emissions for weight of brickwork	0.2	kg CO_2e/kg	ICE, 2006
density of brickwork	1950	kg/m^3	McKern Steel, 2008
emissions for volume of brickwork	390	kg CO_2e/m^3	derived from above
density of plain clay tiles	1900	kg/m^3	SI metric, 2008
emissions for plain clay tiles	0.3	kg CO_2e/kg	BRE, 1999
emissions from lead mining and processing	3.2	kg CO_2e/kg	Norgate et al, 2006
density of lead	11389	kg/m^3	SI metric, 2008
CO_2 from aluminium ingots	9.8	kg CO_2/kg	International Aluminium Institute, 2007
CH_4 from aluminium ingots	0.017	kgCH_4/kg	SAEFL, 1998
N_2O from aluminium ingots	0.00004	kgN_2O/kg	SAEFL, 1998
density of aluminium	961	kg/m^3	SI metric, 2008
emissions from kiln dried timber	-1.2	kg CO_2/kg	BRE, 1999
density of kiln dried timber	400	kg/m^3	BRE, 1999
emissions from plasterboard	0.24	kg CO_2e/kg	BRE, 1999
density of plasterboard	849	kg/m^3	SI Metric, 2008
emissions for ceramic tiles	0.43	kg CO_2/kg	BRE, 1999
density for ceramic tiles	2.4	kg/m^3	SI metric, 2008
emissions for PVC floor tiles	3.3	kg CO_2e/m^3	BRE, 1999
emissions for carpets	9.96	kg CO_2e/m^2	ICE, 2006
emissions for glass	1680	kg CO_2e/m^3	British Glass, 2008
emissions for rockwool	1.1	kg CO_2e/kg	BRE, 1999
density of rockwool	64	kg/m^3	SI metric, 2008

Table 6 provides further assumptions used to quantify emissions from transport, waste and site energy use during construction.

Table A6 Further assumptions used for building material analysis

Description	Further detail	Amount	Unit	Source
building material transport mode	HGV	78.90%	of building material transport by distance	DFT, 2005
	Vans	13.30%	of building material transport by distance	DFT, 2005
	waterways	6.80%	of building material transport by distance	DFT, 2005
	rail	1.10%	of building material transport by distance	DFT, 2005
emissions for each mode	HGV	160	kg CO_2e/tonne km	DFT, 2005
	Vans	210	kg CO_2e/tonne km	DFT, 2005
	waterways	20	kg CO_2e/tonne km	DFT, 2005
	rail	15	kg CO_2e/tonne km	DFT, 2005
building materials transport distance	average distance travelled	170.4	km	Larus, 2003a
site energy use	electricity used during construction	800	kWh	Camco, 2009a
construction waste	carbon embodied in costruction waste	5000	kg CO_2e/home	Camco, 2009a

Table A7 shows the materials options assessment and lists the cost assumptions.

Table A7 Cost and Carbon implications of building materials options assessed

measure	carbon material impact	tonnes of CO2e saved per dwelling per yr (tonnes)	replacement interval	costs £/m2	replacement interval alternative	maintenance	costs for alternative (£/m2)	life cycle cost of alternative NPV per m2	NPV of investment per m2	NPV per dwelling (£)	CO2 saved over NPV period (t/dwelling)	£/tCO2e
Source	*BRE Green Guide and Camco material calculator*	*derived and camco database*	*BRE Green guide*	*derived from BRE Green Guide and Spons*	*BRE Green Guide*	*Camco database*	*BRE Green Guide and Spons*	*derived*	*derived*	*derived*	*derived*	*derived*
construction waste reduction target of 14m3/100m2		0.022333		485	60		500	-£483.09	£14.49	£971	-1.34	-725
natural tiles or FSC wood flooring	13%	0.15	20	30	5		10	-£30.41	£1.43	£96	-2.04	-47
timber cladding (instead of brick or render) UK cedar or oak	0%	0.02	30	12	60		30	-£28.99	£12.97		-0.99	-13
40% of material by wt sourced from within 30 miles		0.05		5	60		0	£0.00	-£4.83	-£324	-3.00	108
FSC timber frame instead of blockwork or brickwork	0%	0.02		5			0	£0.00	-£3.57	-£239	-1.17	204
FSC timber windows (alternative PVC)	15%	0.17	25	210	25	10	200	-£193.24	-£25.56	-£1,712	-1.87	914
recycled cellulose insulation instead of rockwool		0.01								-£1,000	-0.60	1667
natural carpet with 100% natural underlay	13%	0.15	5	30	5		10	-£30.41	-£60.83	-£4,075	-2.04	1993

Further assumptions: transport assessment

Table A8 displays the commuting distances and carbon emissions per mode of average UK commuting transport. Please note that average occupancies are already taken into account in the emissions factors.

Table A8 Distances and emissions from UK commuting transport

modes of transport	UK proportional contribution to commuting trips	average distance travelled per mode (one way) (km)	average distance (km/employed person/yr)	emissions per mode of transport per passenger km (gCO2e)	Average UK commuting emissions per employed person kgCO2e per yr	Total UK emissions from commuting (MT CO2e/yr)
Source	*DFT, 2005*	*ONS, 2008b*	*DFT 2007b*	*DEFRA, 2008d and Camco database*	*derived*	*derived*
car	58%	15.9	6614	185	1224	21
passenger in car	10%	11.5	4784	0	0	0
bicycle	4%	4	1664	0	0	0
on foot	12%	1.4	582	0	0	0
bus, coach, minibus	8%	8.8	3661	56	205	0
train	4%	35.2	14643	72	1054	1
underground	2%	16.7	6947	171	1188	1
other	3%	14	5824	90	524	0

Table A9 an A10 show the specific data used to assess the commuting profiles of Cambridge where the case study site is located. Table A 11 shows the additional assumptions made for the transport measures assessed. Table A 12 displays the overall cost and carbon implications for the three measures assessed.

Table A9 Cambridge general commuting parameters

Parameter	Amount	Unit	Source
population of cambridge	108,863	people	*Census 2001*
people employed	60,814	people	*email stephen reynold, DFT taken from census 2001*
percentage employed	56%		*derived*
average distance travelled	11.37	km one way	*email stephen reynold, DFT taken from census 2001*
days at work	208	days/yr	*email stephen reynold, DFT taken from census 2001*
annual commuting distance	4729.92	km/yr	*derived*

Table A10 Distances and emissions from Cambridge Commuting Transport

modes of transport	Cambridge proportional contribution to commuting trips	average distance travelled per mode (one way) (km)	average distance (km/employed person/yr)	emissions per mode of transport per passenger km (gCO2e)	Average Cambridge commuting emissions per employed person kgCO2e per yr	Total UK emissions from commuting (MT CO2e/yr)
Source	*Steven Reynold, DFT*	*ONS, 2008b*	*DFT 2007b*	*DEFRA, 2008d and Camco database*	*derived*	*derived*
car	41%	16.2	6739	185	1247	15
passenger in car	4%	11.7	4867	0	0	0
bicycle	23%	4.1	1706	0	0	0
on foot	12%	1.5	624	0	0	0
bus, coach, minibus	5%	8.9	3702	56	207	0
train	3%	35.4	14726	72	1060	1
underground	0%	0	0	171	0	0
other	11%	14	5824	90	524	2

Table A11 Assumptions for transport options assessment

Measure	Assumptions	Amount	Unit	Source
Location Cambridge and provision of cycle storage andpedestrian friendly access	With the cycle and pedestrian friendly provisions cycling and walking rates will be the same as in the rest of Cambridge -i.e much better than national average.			Site transport Consultant Colin Buchanan (Fitch, 2006)
	costs of best practice cycle storage and pedestrian and cycle access provisions	410	£/dwelling	*Transport consultant Colin Buchanan (Fitch, 2006) and Cyrli Sweet, 2007*
Subsidized Bus Route	bus route distance (miles)	1.5	miles	*Transport consultant Colin Buchanan (Fitch, 2006)*
	trips per hour	10	trips/hour	*Transport consultant Colin Buchanan (Fitch, 2006)*
	hours run	12	hours/day	*Transport consultant Colin Buchanan (Fitch, 2006)*
	average number of passengers per bus	9.5	passengers/bus	*Transport consultant Colin Buchanan (Fitch, 2006)*
	assumed passenger km per day	2736	passenger km/day	*derived*
	passenger km per yr	998640	passenger km/yr	*derived*
	carbon saved	116	t CO_2e/yr/home	*derived assuming 90% replace car trips others cycle or walk*
	carbon saved per dwelling	0.07	t CO_2e/yr	*derived*
	One off subsidy required	£1,164,000	£	*Transport consultant Colin Buchanan (Fitch, 2006)*
	costs per dwelling	£654	£/dwelling	*derived*
k	lifetime assumed	15	yrs	*assumed based on conversation with transport consutant Colin Buchanan*
Car share scheme	emissions reduced due to one car share car	13.9	t CO_2e /yr	*derived from City car club, 2006 and Bioregional, 2009*
	proposed number of car share cars for the site	10	cars	*City Car club proposition*
	total emissions reduction	139	t CO_2e/yr	*derived*
olin Buchanan	reduction per household	0.08	t CO_2e /household/yr	*derived*
	Total costs of the scheme to the developer	£143	per household	*quote from City Car Club assuming developer purchases free membership for each household for 15 years. This is a significantly reduced rate based on all households being signed up.*

Table A12 Carbon and cost implications of transport options assessed

Measure	Total Carbon Saved (tCO_2e/dwelling/yr)	lifetime of measure (years)	total savings of measure/dwelling over lifetime (tCO_2e)	Capital cost (£/dwelling)	Running cost saving (£/dwelling /yr)	NPV (£)	£/tCO_2e
location (build homes in proximity to jobs to reduce communting emissions) plus cycle and pedestrial provisions	0.62	60	37.4	410	0	£398.06	£11
Improved public transport connection (subsidise bus route)	0.07	15	1.0	654	0	£634.89	£650
access to car share scheme	0.08	15	1.2	143	0	£138.83	£119

Further assumptions: Food assessment

Table A13 shows the detailed cost assumptions and carbon savings assumptions used for the assessment of measures to reduce carbon emissions from food options. The carbon savings and costs assumptions in Table A14 are based on the assumptions in Table A13.

Table A13 Cost and carbon assumptions for food assessment

Categories	Measures	Amount	Unit	Source
costs	Subsidise rent for themed Café/shop	£12,000	£ per year	Head (2007) and Aplin (2007)
	farmers market	£5,200	£ per year	Head (2007) and Aplin (2007)
	promote organic veg box scheme	£1,000	£ per year	Head (2007) assuming flyers to all homes
	raise awareness on low carbon and healthy food	£6,000	£ per year	Head (2007) assuming flyers and integration of awareness raising activity into community events
carbon savings	3% reduction in lifestock product consumption by residents (i.e. meat and	0.20	tonnes of CO_2e/house	derived from Audsley et al, 2009
	10% reduction in avoidable food waste by residents	0.14	tonnes of CO_2e/household/yr	derived from Audsley et al, 2009
	3% red to white meat	0.11	tonnes of CO_2e/household/yr	derived from Audsley et al, 2009
	5% replacement of supermarket food with farmers market food (minimal carbon emissions from transport, supply chain chilling, distribution system e.g. supermarket energy)	0.04	tonnes of CO_2e/household/yr	derived from Audsley et al, 2009

Table A14 Cost and carbon emissions implications from food package of measures chosen for case study development under the lifestyle scenario

Measure	assumed impact	carbon material impact	tonnes of CO_2e saved per dwelling per yr	lifetime	replacement interval	costs £/dwelling/yr	replacement interval alternative	life cycle cost of alternative NPV per dwelling	CO_2e saved over NPV period (t/dwelling)	environmental cost effectiveness
units	*all of the above mentioned impacts*	*Tonnes of CO2e/household/yr*	*tonnes of CO2e/household/yr*	*yrs*	*yrs*	*£/dwelling/yr*	*yr*	*£*	*tCO_2e/household*	£/t CO_2e
Subsidise rent for themed Café/shop, weekly farmers market, promote organic veg box scheme and raise awareness		0.49	0.49	20.00	1	-£14	1	-£202.27	9.8647	£20.50

Further Assumptions: Waste Assessment

Table A15 shows the typical composition of UK household waste. The EPA calculator (EPA, 2007) was used to convert this into carbon emissions under different waste treatment scenarios, and their software (EPA, 2007) contains the emission factors. Table A15 shows the scenario chose the emissions if all waste was landfilled. Table A16 shows emissions under the scenario proposed for the case study site.

Table A15 UK average household waste composition and carbon footprint of each source

Composition	pecentage	kg/household	tonnes/household	kg CO2e/tonne of waste if landfilled	CO2e/household/yr if landfilled
source	*Defra (2007d)*	*derived*	*derived*	*EPA Waste reduction model (EPA, 2007) and Camco waste calculator (Camco, 2009b)*	*derived*
Aluminum Cans	1.2%	9.4	0.01	38.42	0.36
Steel Cans	2.7%	21.1	0.02	38.42	0.81
Glass	14.2%	110.8	0.11	38.42	4.26
Cardboard and paper packaging	8.0%	62.4	0.06	1484.23	92.62
Food Scraps	24.5%	191.1	0.19	1425.85	272.48
Garden waste	13.8%	107.6	0.11	-29.10	-3.13
Mixed Paper, Resid.	17.5%	136.5	0.14	1229.26	167.79
Mixed Metals	0.5%	3.9	0.00	38.42	0.15
Mixed Plastics	8.1%	63.2	0.06	38.42	2.43
Other MSW	9.7%	75.7	0.08	1587.91	120.14
					657.90
Total waste carbon footprint per UK household if all waste is landfilled	0.66	t CO2e/household/yr		derived	
Total waste carbon footprint per UK household at typical waste treatment rates	0.4	t CO2e/household/yr		Strategy (Defra, 2007d for current waste treatment, EPA waste reduction model outputs (EPA, 2007) and Camco Waste calculator (Camco, 2009b)	

Table A16 Household carbon emissions with advanced recycling, composting and combustion rates (Source: EPA, 2007 and assumed rates for waste streams)

Material	Tonnes of waste produced	Total CO_2 if sent to landfill (tCO_2 e)	Assumed recycling rate	Assumed compost-ing rates	Assumed combust-ion rate	Total CO_2 if sorted (tCO_2e)	Waste not sent to landfill (tones)
Aluminium Cans	16.66	0.64	60%			-149	10
Steel Cans	37.49	1.44	60%			-40	22
Glass	197.15	7.58	60%			-30	118
Cardboard and Paper Packaging	111.07	164.86			60%	22	67
Food Scraps	340.16	485.02		40%		264	136
Garden Waste	191.60	-5.58		60%		-25	115
Mixed Paper	242.97	298.67	60%			-343	146
Mixed Metals	6.94	0.27	60%			-30	4
Mixed Plastics	112.46	4.32	60%			-100	67
Other MSW	134.67	213.85				214	0
Total	*1391.18*	*1171.07*				*-217*	*686*
Reduction						*119%*	*51%*

Table A17 lists the carbon and cost assumptions and outputs from recycling and composting and also those of the Sustainable Living Officer (SLC), a measure, which increases carbon savings in all categories.

Table A17 Cost and Carbon implications of waste options and the SLC

Measure	capital cash flow per household	annual running cash flow per household	NPV per household	CO_2e saved/household/yr	lifetime	CO_2e savings over lifetime per household	£/tonne CO_2e
source	*Cyril Sweet, 2007 and Langdon, 2008*	*Cyril Sweet (2007), Camco (2009c) and Cambridge City Council (2006)*	*derived*	*EPA waste reduction model (EPA, 2007) for recycling and composting and for SLO assumed based on conversation with Sue Riddleton: Bedzed expert (Riddleton, 2007)*	*assumed*	*derived*	*derived*
recycling	-100	-30	-£530.41	0.64	20	12.8	£41.44
composting	-100	-29	-£680.00	0.14	20	2.8	£242.86
Sustainable Lifestyle Officer (SLO)	-162	0	-£156.81	0.66	5	3.31929051	£47.24

Appendix B Interview Survey Scripts

Problem statement & Research objectives

We are specifically studying the concept of delivering more environmentally and community friendly homes and the concept of allowing people to build their own homes as part of a consortium.

Interview guide: Potential customers, Self-builders and not interested people

Generic questions for all three groups:

These interviews took place at the Ashley Vale site.

Preliminary information:

Name: ___________________________

Male/Female

Age (approx): ______

Job: _________________________

Income (approx. or give a range)_____

Company: ________________________

City: _________________________

Introduction:

This questionnaire concerns the question of how we can improve our housing stock to improve our communities.

- *Please would you describe your ideal neighbourhood?*

[Prompts]: *Oh really?*

Tell me more.

- *Please would you now describe your ideal home in this neighbourhood?*

[Further prompts for more detail.]

We are specifically studying the concept of delivering more environmentally and people friendly homes and the concept of allowing people to build their own homes.

[If respondent lives on the Ashley Vale site follow interview script c, otherwise continue.]

If you are considering buying or building a home in the next years we would appreciate a few minutes of your time.

Description of an eco-self-build community, with brief explanation of what happened at the Ashley Vale site and in what shape or form it could be replicated:

- *Is this something you would be interested in?*

Depending on response interviewer continues with either a or b.

<u>a) If not interested:</u>

You mentioned that you would not be interested to live in a place like this (the Ashley Vale site).

- *Please would you tell us what would detract you from joining an eco-self-build community?*
- *Oh really.*
- *Tell me more.*
- *Any other things you do not like?*
- *Anything you like?*
- *What would you do different?*
- *What, if anything, would make you want to join in?*

<u>b) If interested:</u>

[Brief discussion to make sure there is an understanding of sustainability, communities, environmental concerns and self build market]

Testing for interest and current activity in climate change and sustainability

[Conversation style]

- *At the moment, what (if any) activity are you involved in to support sustainability? Please describe:*
    - *House renovation*
    - *Recycling*
    - *Transport activity*
    - *Consumption choices*
    - *Campaigning/paid and voluntary work*
    - *Others:*

- *What service/organization did you use? Why? How did you know about them?*
- *What were your experiences?*
- *Would you like to do more?*
- *What support would you be looking for to help you do more?*

[If NOT]

- *Why not?*
- *Would you be interested in implementing carbon reduction / sustainability features in your existing home?*

Buying an "already" sustainable homes

- *<u>If you had a choice would you buy a home in a sustainable community?</u>*
- *What type of features would you expect in such a home?*
- *How do you think this should be communicated to the customer?*
- *Do you see a benefit? (To you …, to the environment…)*

- *<u>Would you doubt the validity of the sustainability proposition?</u>*
- *Why?*
- *What kind of organization would earn your trust?*
- *What kind of information?*
- *How would you feel more confident on the validity from this proposition?*

- *What premium would you be prepared to pay for a sustainability features?*
- *[0%-2%] ____ [3% to 4%] ____ [5% to 6%] ____ [7% to 9%] ____ [>9%] ____*

More detail on what people may want

- *What other ideas do you have about sustainability and climate change regarding homes?*
- *What would you be your preferred scheme: self build or buy or semi-self build? Would you rather be in a development where these are mixed or in a more homogeneous one?*
- *Why?*
- *What do you mean?*
- *Tell me more?*

- *What size of sustainable community would you prefer: Just one house on my own, 6 homes, 20 homes, 50 homes?*
- *Why?*
- *What do you mean?*
- *Tell me more?*

- *What type of area would you like to live in?*
- *Do you prefer a modern authentic look or a traditional look?*
- *How would you describe your ideal neighbourhood and neighbours?*
- *Assuming we were to set up a community sustainable homes/self-build homes project, what process should be used to select suitable applicants?*
- *Assuming a scheme could be set up along the lines of what you describe here how much more would you be willing to pay for a house in such a community in comparison to purchasing a conventional home?*

Testing for climate change impact

[Description of the possible low carbon and sustainability features and costs implications and carbon savings associated with them].

- *Assuming you were moving into a eco-self-build community, with good recycling provisions and access to sustainable food, cycle parking and communal garden and support with integrating renewable energy and energy efficiency measures and the use of sustainable building materials into your home, which features are you likely to choose, and to what extent is this likely to change your actions towards living more sustainable?*
- *Are you sure?*
- *Tell me more?* [ask to clarity to get concrete idea of how far people would go, and how this would effect carbon emissions.]
- *Would you say that eco-self-build communities such as the Ashley Vale site act as positive and inspiring examples for eco and climate friendly living?*
- *Has visiting the site changed your awareness and understanding of eco-friendly living?*
- *Really?*
- *Tell me more…..*
- *Has this personally led you to doing anything differently?*

C) Self-builders interview guide

Self-builder/ semi self-builders or resident at Ashley Vale:

____

g) P*lease describe your (and if relevant your families') background and why you decided to join the Ashley Vale community.*
h) *Please describe how it was for you to build your own home?*
i) *What is it like for you to live in this community?*
j) *Where the any problems? Tell me more….*
k) *What do you feel are the main benefits for you?*
l) *What do you see are the benefits for others?*
m) *Would you do it again?*
n) *If yes, what would you do different?*
o) *What would you keep if you were to make the rules for another eco-self-build community scheme?*
p) *How would you select the participants?*
q) *What eco-features are your favourites?*
r) *What community features are your favourites?*

- *Please describe the self-builders in your community including age, budget, family constellation and what is most important to them.*
- *How does your self-build home perform compared to the home you lived in before you moved here?* [Prompts on detail about the energy performance and building material of the previous place they lived and their current homes.]
- *How has your lifestyle changed since moving to the Ashley Vale Site?*

[prompts about recycling, food, and transport behaviour. Any other activity in the environmental arena, i.e. job changes, voluntary work activity]

- *Would you say that other residents at the Ashley Vale site have made similar shifts?*
- *Would you say that eco-self-build communities such as the Ashley Vale site act as positive and inspiring examples for eco and climate friendly living?*
- *Really?*
- *Tell me more….*
- *Finally what would you say are the 3 key priorities for a successful eco-self-build community?*

Financier interview guide

Preliminary information:

Name: ___________________________ Male/Female
Age (approx): ______

Job title: _________________________

Company: ________________________

Questions:

- *Please would you tell us under what condition you would invest in the property sector?*

[Description of the proposition.]

- *What's your initial view on this?*
- *Is this something you would invest into?*
- *What level of funding could you provide and under what conditions? What do you expect in return and what support would you be willing to provide to the company?*
- *If you know, what mortgages are available to self-builders? Please provide details. Where can we find out more?*

House builders' interview guide (conventional and green)

Preliminary information:

Name: ___________________________ Male/Female

Age (approx): ______

Job title: _________________________

Company: __________________________.

Questions:

- *Description of the proposition*
- *What is your immediate feeling about the proposition?*
- *In terms of construction practice do you feel this can work?*
- *In your view what are the main issues?*
- *Would your company be interested in such a proposition? Why or why not?*
- *What are the typical costs and profit margins in a development?*
- *How do you go about purchasing land?*
- *How could a community operate in this market? What would be in their favour and what would stand in their way?*
- *Is there anyone else you'd recommend we'd talk to?*

Additional questions for Green House builders*:*

- *What are the typical costs and profit margins in a development for you?*
- *How do you go about purchasing land?*
- *How could a community operate in this market? What would be in their favour and what would stand in their way?*
- *What sustainability criteria do you use for your homes? What features have been particularly successful and why?*
- *Has your performance of sustainability made things easier or harder? Please explain.*
- *Would you do anything different next time around and why?*
- *How have the local authorities responded to your proposition/schemes?*
- *How have you gone about getting finance?*
- *Have you ever though about self-build? Why or why not?*

Land agents and owners interview guide

Preliminary information

Name: ___________________________

Job title: _________________________

Company: __________________________

Introduction

We are looking to start a venture to build eco-friendly homes and facilitate groups on individuals in building their own eco-friendly homes. We are interested in exploring the best routes to purchasing land and would like to ask you a few questions.

Questions:

- *What are the criteria that you use for selecting a purchaser for your land?*
- *What are the greatest priorities for you here?*
- *Are there other selection criteria apart from price?*
- *Tell me more.*
- *Does the sustainability of the future development influence your decision?*
- *If yes to what extent would it make a difference?*
- *Are you open to a JV or partnership contract with the developer?*
- *Really?*
- *Tell me more.*
- *What are your concerns about this?*
- *[Description of the proposition, and how the land deal could work]*
- *What is your immediate response to this?*
- *Really?*
- *Tell me more.*
- *Any other concerns?*
- *What would need to be in place for you to be interested?*
- *Is there anyone else you'd recommend we'd talk to?*

Entrepreneur interview guide

Preliminary information

Name: ___________________________

Job title: _________________________

Company: __________________________

Introduction

We would like to ask you a few questions to feed into a feasibility study for an ethical enterprise we are considering to launch.

- *Please describe your background and experience as an entrepreneur.*
- *Really?*
- *Tell me more.*

[Description of the proposition]

Questions

- *What is your immediate view on the proposition?*
- *What returns and conditions would investors be looking for?*
- *Are ethical investments different? How? Would our proposition qualify?*

[Discussion of the land deal process, options, their view on what would work best and why]

- *In your view what are the critical success factors for this venture? Why is that? Really? How could these barriers be overcome?*
- *Would you invest in this venture?*
  [if yes] *Under what conditions?*
- *Is there anyone else you'd recommend we should talk to?*

Local and regional Government interview guide

Name: __________________________Male/Female

Job title: ________________________Job function: Sales / Marketing / Pricing

Company: _______________________Primary Industry: ___________________

City: ____________________________

Introduction:

We are researching the concept of housing developments, which enable communities to form, and which also enable living a more sustainable, “green” lifestyle. We would like to find out how this approach would fit in with the interests of local authorities.

Testing for interest and current activities regarding sustainable housing

[Conversation style]

- *In the public eye, “green” seems to be a red-hot topic, as people look for ways to lessen the ways they tax the environment. Looking at housing, they tend to consume large amounts of energy. Are end-users starting to show more of an interest in energy-efficient or greener equipment?*
- *How is your authority responding to this need?*
- *What drove you to focus on developing sustainable policy?*
- *What is your local authority doing to drive more “green” homes?*
- *How does this fit in with other priorities?*
- *Is your local authority doing anything to enable community autonomy?*
- *Why or why not?*
- *How does the authority deal with innovative individual approaches to sustainability? Would these seen as something to be favoured or would it be more difficult to obtain planning permission?*
- *Who is involved in granting planning permission? And what powers do the individual involved parties have?*
- *Is the estimated environmental impact built into your approval process for development schemes?* [Ask for criteria]
- *What are some of the ideas that developers are implementing that have impacted your decisions?*
- *What do you think is the best way for your authority to operate with the least possible environmental footprint?*
- *How about increased brand image?*
- *What regulatory compliance has the most impact on housing development?*

Testing for response to the eco-self-build community proposition

[Description of the eco-self-build community proposition.]

- *How would you feel your local authority would receive this?*
- *Are there any regulatory obstacles? Any support mechanisms?*
- *Would this differ from Local Authority to Local Authority?*
- *What powers do a local authority have to support the scheme if they are in favour? How would they be able to support such a scheme?*

Estate agent interview guide

Preliminary information

Name: ___________________________Male/Female

Job title: _________________________Job function: Sales / Marketing / Pricing

Company: ________________________ City and Area: ____________________________

Introduction

We are researching the concept of housing developments, where people get the opportunity to do a eco friendly self build as part of a group of likeminded individuals. We are studying the feasibility of replicating the Ashley Vale self-build scheme as a commercial venture. We would like to speak to the appropriate person in your company and ask a few questions in order to gain a better understanding of the barriers and opportunities for our suggestion.

Questions

- *How much interest do you get for individual building plots as compared to completed homes?*
- *In what price range and size are plots most popular?*
- *What prevents landowners of multiple plots from selling to self-builders?*
- *What uplift is paid per area of land for individual self-build plots as compared to multiple plots?*
- *How much interest to you get from customers for eco-features? Is the level of interest different between people who are looking to purchase a plot compared to those who want to purchase a home?*
- *Are you aware of the homes at the Ashley Vale Site in Bristol?*
  [if yes] *have you valued any houses there or any houses in the surrounding neighbourhood?*
- [if yes] *In your view what is there an uplift in value of these houses because of the overall set-up and community aspects of the site? What would the difference in value be of the same house in a conventional neighbourhood? Have the surrounding houses of the neighbourhood in proximity to the Ashley Vale site risen in value more than the average house in Bristol since the Ashley Vale self-build houses were built?*
- *In your view, what is stopping other developments like this from taking place?*

Appendix C Further Dissemination and Application

For further interest research findings and related information have so far been disseminated and applied through a number of channels other than the paper publications. This includes a company Bright Green Futures Ltd, which has been set up to exploit these findings. Details can be found here:

1. The company web-site: www.brightgreenfutures.co.uk.

2. Presentations and talks:

    - Broer S (2007) "*The Code for Sustainable Homes and Crest's opportunity for strategic position for a low Carbon Future*", Talk given to approx. 120 staff from House Builder Crest Nicholson, Oct. 07.

    - Broer S (2008a) "*Renewable Lessons from Austria and Challenges for the UK domestic sector*", talk presented in May 08 at Think 08 Conference – Sustainability in the Built Environment, London.

    - Broer S (2008b) "*Solutions to Climate Change through Eco-Community Self-build housing*" Lecture given in July 08 at UCL Bartlett School for the Built Environment to current and ex-students and lecturers.

    - Broer S (2009a) "*Enabling low carbon living in UK Housing Developments*", Conference paper presented at the Second International Conference on Whole Life Urban Sustainability and its Assessment, 22–24 April 2009, Loughborough, UK.

    - Broer S (2009b) "*Enabling Low Carbon Living in UK housing developments – A triple bottom line analysis*" presentation of conference paper at the International Conference on Sustainability in Energy and Buildings, Brighton, 29th & 30th April and 1st May 2009.

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