SCRI Research Report 5

A Review of the UK Domestic Energy System

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5 A Review of the UK Domestic Energy System

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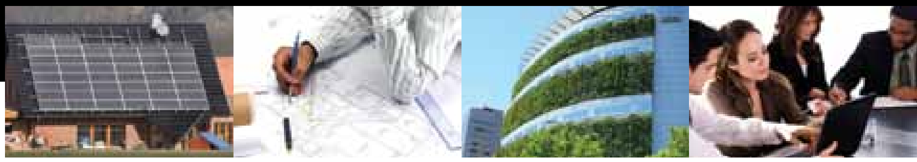

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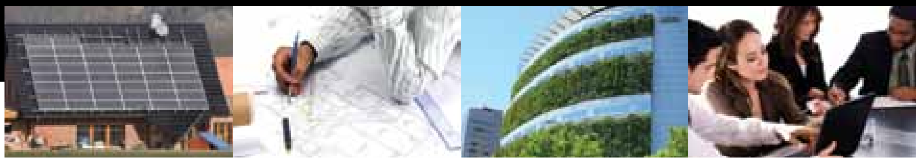

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Executive summary

- This report was developed by the SCRI Housing Application Area as part of a review of core issues for the UK housing sector. The 2007 strategy, Building a Greener Future (CLG 2007) identified two key areas; housing supply and domestic energy use. We recognise that many of the issues highlighted are also relevant for the wider built environment. However, domestic energy use represents a significant issue in terms of both energy use and carbon dioxide emissions. This has guided the focus in this specific area.

- An initial survey of the issue of domestic energy use identified that there were a wide variety of interlinked issues that might be addressed to meet the policy aspirations. This report uses the latest data, policy and regulation to identify the different elements that drive energy use in the domestic sector. It is chiefly aimed at people who work in the housing sector; registered social landlords, developers, designers, constructors and others with an interest in housing and energy. The goal of the report is to provide an understanding of the issues across the sector and provoke discussion about the wider implications of actions we are currently taking to address the issue of energy use in the domestic sector, and consider possible future directions. The goal of this report is not to offer solutions at this stage, but to allow readers to appreciate the context in which action may be taken.

- The provision of energy to the domestic sector is not just a technological issue. It involves a complex interaction of systems, regulations, technology and people, all of which must be appreciated if we are to understand how to effectively manage, and ultimately change, the make-up of our energy use by 2050. The domestic sector accounts for 29% of all UK energy use.

- Our energy use is still predominately fossil fuel based. The existing networks are very much geared towards fossil fuels, with a huge reliance on natural gas, of which the UK is now a net importer. Much of this energy is used directly for heating and hot water and provided through the gas network. Renewable energy contributes a small but growing proportion of our energy mix.

- Energy policy is driven by three core objectives; climate change, energy security and fuel poverty. Climate change and energy security have been given equal importance. The domestic sector contributes 26% of carbon dioxide emissions. Carbon dioxide is 85% of the total of UK greenhouse gas emissions in terms of impact. In respect to energy security, the UK is now a net importer of energy, and therefore reliant on supplies from other countries. The rising cost of energy has meant that fuel poverty has increased significantly over the last 5 years and is of particular importance for social housing residents and older people.

- The UK Energy system is currently highly centralised through the gas transmission network and the national electricity grid. This has been identified as creating a level of technological "lock in". Policy calls for an increase in distributed energy and microgeneration. A large scale take up of these small-scale technologies must rely on better management of energy through a smart electricity grid and smart metering to manage the balance of supply and demand in electricity generation.

- There are approximately 26 million houses in the UK, many of them built 50 or more years ago. They are predominately owner-occupied. Old homes are replaced at a rate of less than 1% per annum, meaning that much of the stock we currently have will still be in use in 2050, which is the target date for an 80% reduction in carbon dioxide emissions. This means we cannot only concentrate on the efficiency of new buildings, but must also consider the sustainable retrofit of existing stock.

- Energy consumption of new and existing buildings is regulated by 4 key elements; the building regulations, planning policy and guidance, the Code for Sustainable Homes and Energy Performance Certificates. These address issues ranging from off-site generation to specific regulation of lighting and heating within the homes. There is a certain amount of overlap between these different mechanisms.

- User behaviour is an essential component of the energy system. Patterns of living and values can have a significant impact on the way energy is used. Energy is used to fulfil a derived demand for other needs such as comfort, entertainment or cooking for example. The energy system, the homes in which people live and the appliances and systems within those homes provide a vehicle for that energy use, but there are considerable variations and complexities with regards to individual's patterns of use which must be understood and addressed if we are to establish an effective energy policy.

- A systems view of domestic energy use leads us to conclude that no single action to address the problem can be carried out in isolation. Policy makers and regulators must be linked to the practitioners, technical solutions must consider wider performance issues, and the research community needs to recognise that there is a real multi-disciplinary problem that needs to be addressed, potentially in new ways. A narrow view can lead us to taking actions that may solve the parameters of a specific problem but, overall, fail to address the real problems at a whole system level.

- This problem of perspective is not only the preserve of industry, but also has implications for the research community. At the close of the report we have highlighted some of the issues for the Salford Centre for Research and Innovation. At the core of these ideas is a need to be effectively engaged with the problem, collaborating effectively with a wide range of external partners. The multi-disciplinary nature of the problem requires that the traditional boundaries between the disciplines be broken down bringing together both the hard and soft disciplines and addressing the system from a national policy perspective down to an individual level to create a rich understanding of the problem.

1 Introduction

This report has been undertaken by the Housing Application Area within SCRI. The starting point for the report was the Building a Greener Future policy statement (CLG 2007) that identified housing supply and energy use as its central policy objectives. An initial survey of energy use identified that the issues of energy within the domestic sector were complex. The goal of this report is to provide a picture of energy use in the domestic sector, looking at the issues across a number of driving factors.

Moving towards zero carbon homes is a policy issue of increasing importance for the housing sector (CLG 2007). According to current policy, by 2016 the new housing stock will have to be zero carbon (CLG 2007). However, this is just a small part of the story. The issue of domestic dwellings fits into a broader energy policy (DTI 2007) which highlights the challenges of climate change, energy security and fuel poverty, all of which can be considered in the context of how we use energy in our homes. At the time of writing the UK Government launched the Warm Homes, Greener Homes Strategy (HM Government 2010), which seeks to address many of the issues highlighted in this document. We have addressed some of the implications of this policy here, but the impact on the landscape of domestic energy use will be more fully understood as the policy develops into more concrete actions.

This report considers the whole energy system (Figure 1) and how its different elements interact to create patterns of demand and supply for energy use. By considering this overview we can see how different elements of regulatory and policy action interact and how they meet the wider policy aspirations of the UK government with regards to energy (DTI 2006, DTI 2007). This view limits the scope of the study to energy supply and use within the domestic sector.

Merely making the new homes we build more energy efficient does not sufficiently recognise the complexity of the energy system. We need to consider how energy is generated, the current and potential make-up of the system (Government Office for Science 2008), as well as the fact that new buildings make up only a small proportion of the housing stock (Kelly 2009).

The issue of domestic energy use should be considered in the context that energy is a derived demand Government Office for Science 2008), that is, energy is used not for its own sake, but to fulfil other needs; heating, lighting, entertainment etc. It is often stated that homes themselves do not use energy; the people within them do. However, we need to consider the interaction of the buildings and systems and the people who use energy to meet these needs.

The report is for people who work in the housing sector; registered social landlords, developers, designers, constructors and others with an interest in housing and energy. The purpose of the report is to provide a single overview of the issues using the latest data, government reports and policy statements to provide a coherent picture of the scope of domestic energy use. By more clearly understanding this wider picture, it is hoped that people will feel better informed in making decisions related to the domestic energy sector. The report is designed to be accessible to people from a non-technical background.

Finally, the report is not designed to offer specific solutions to energy use issues in the domestic sector. It is about effectively understanding the problem and its context. It has been undertaken to provide a background to help SCRI, its partners from industry and other research organisations think about how we might move forward in addressing the issues. The report is part of the wider Industrial Reports series from SCRI, but is also the start of a wide-ranging research and industry engagement programme designed to address the problems facing the domestic energy sector, now and in the future.

2.1 The Domestic Energy System

The breakdown of the energy system has been simplified in Figure 1. This looks at 6 key stages of energy supply and demand as related to energy in homes. This systemic view appreciates that decisions made at any one of these points can make differences to the whole pattern of energy use by the end user, with potentially significant implications for the ways in which we design, build and use our domestic built environment.

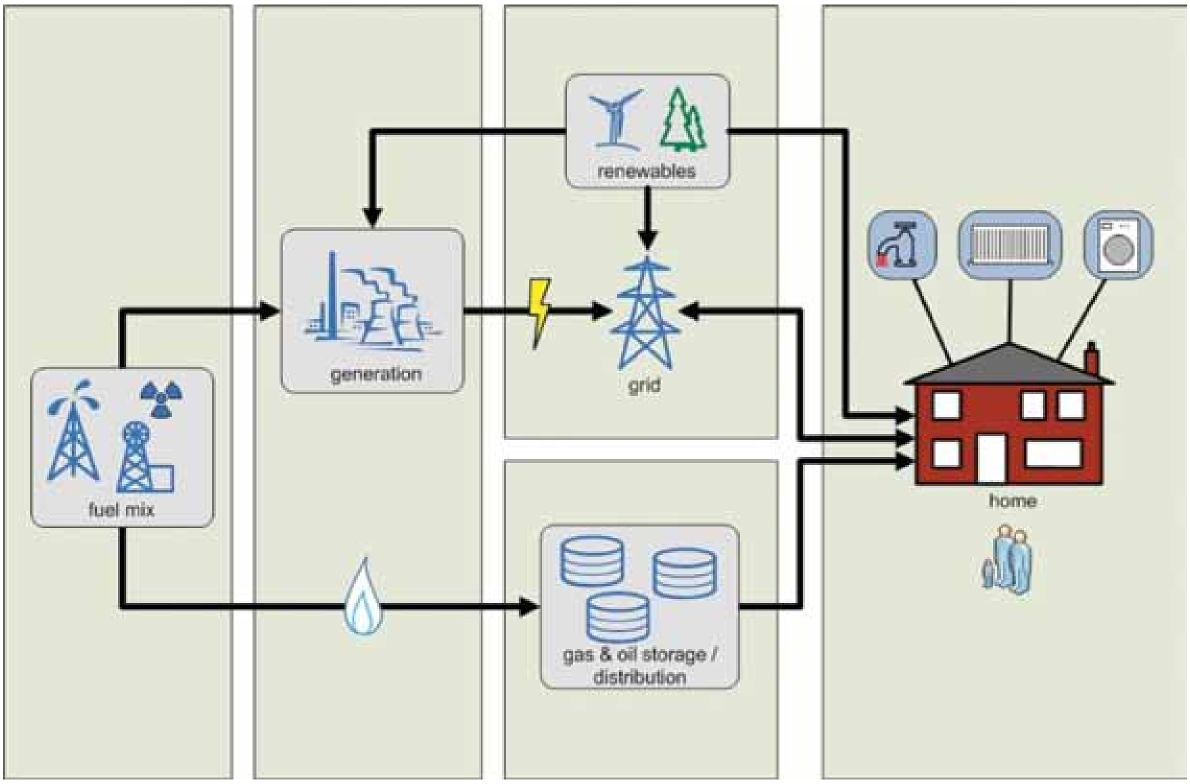
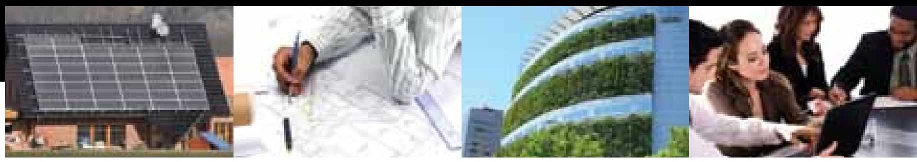


Figure 1 – An outline of the domestic energy system

The key areas which we will investigate are:

- Understanding the nature of the energy we use and where it comes from
- Understanding how our energy is generated
- Understanding how energy gets to our homes
- Understanding how our homes influence how we use energy
- Understanding the systems and appliances which generate the demand for energy
- Understanding the influence of individual behaviours on patterns of energy use

The technical aspects of the energy system are not only the way we delivery energy to our homes. It is a complex inter-relationship of technology and infrastructure, policy and regulation, tax and incentive, industry structures and attitudes and behaviours. This makes it a complex "socio-technical" system, specifically a macro socio-technical system; a large-scale system or domain that operates at a societal level (Emery 1981), where action in one area has implications in other areas. The report addresses this complexity by trying to take a whole system approach, bringing together a range of data and policy to understand how the domestic energy system works in the UK, and how it is being addressed to meet the key issues of climate change, energy security and fuel poverty (DTI 2007).



2.1 Where Does Our Energy Come From?

Overall our energy use can be broken down as shown in Figure 2 (ONS 2009a). Where possible we have tried to use the latest available data from the Office of National Statistics. This energy is largely used by transport, industry and the domestic sector.

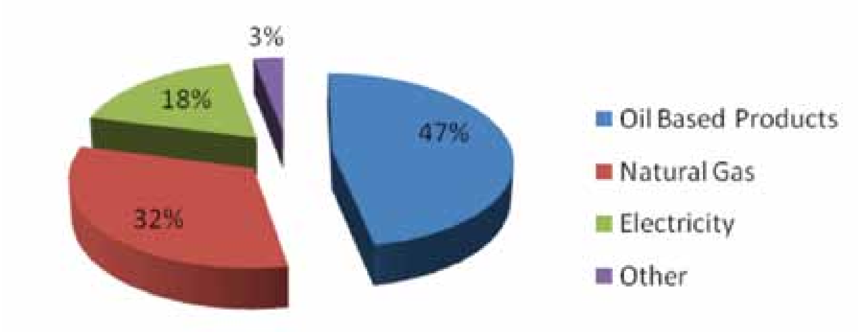


Figure 2 – Overall UK Energy Use by Fuel Type 2008 (ONS 2009a)

Figure 2 shows how we share all the main fuel sources between all users of energy in the UK for 2008 (ONS 2009a). Electricity is generated from a variety of fuels, with approximately 80% of energy being generated through the burning of coal and natural gas. Overall, total annual UK energy use is equivalent to approximately 165,000 million tonnes of oil.

2.2 Energy Supply in the UK Domestic Sector

The domestic sector accounts for approximately 29% (Figure 3) of this total energy use, or 45,642 million tonnes of oil (ONS 2009a).

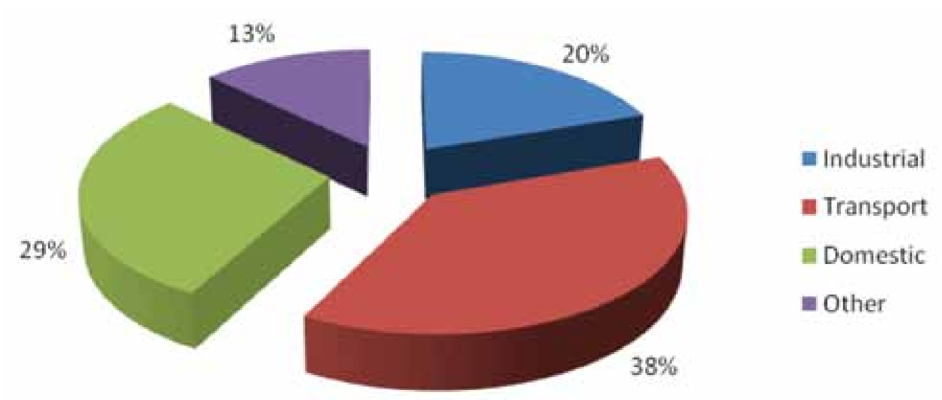


Figure 3 – % Share of Energy Use by End User 2008 (ONS2009a)

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Fuel	Primary Use (thousand tonnes oil equiv.)	Electricity Generation (thousand of tonnes of oil equiv.)	Total
Gas	31239	4357	35596
Coal	515	3445	3960
Nuclear	NA	1520	1520
Petroleum Based	3033	NA	3033
Renewables/ Other	430	506	936
Hydro	NA	101	101
Oil	NA	101	101
Heat	52	NA	52
	*Variation attributable to rounding errors	Total	45299*

Table 1 – Total Fuel Mix for UK Domestic Consumption (ONS 2009)

Table 1 illustrates the enormous reliance on fossil fuels of the domestic sector's energy consumption. This can be seen more clearly in Figure 4. Fossil fuels account for approximately 95% of domestic energy consumption when fuel for both heating and electricity are taken together.

Understanding how our energy is supplied is only part of the equation. It is also important to understand how energy is used in the home if we are to appreciate how policy may shape our energy future.

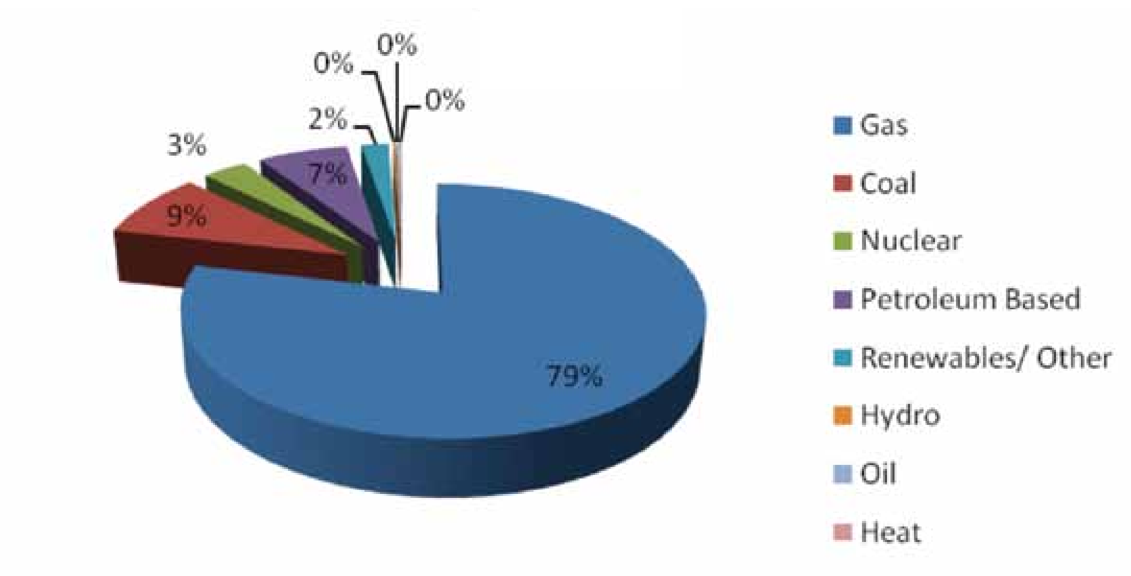
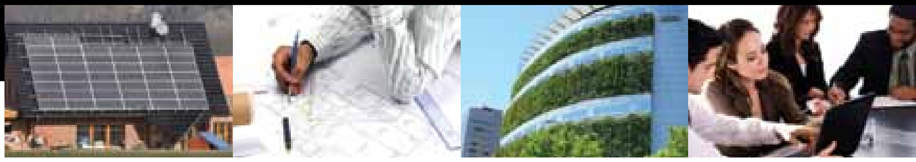


Figure 4 – UK Domestic Energy Consumption by Fuel Type 2008 (ONS 2009a)



3.0 UK Energy Policy

Energy policy has developed over the years, with the early focus being on the mining industries. With the advent of the first oil crisis in 1970-3 the UK government established the Department of Energy, that was responsible for establishing national energy policy, in 1974. The department was tasked with addressing the new development of oil and gas fields in the North Sea, the nuclear industry and, through the Energy Efficiency Office, the more effective use of energy.

In the wake of deregulation and denationalisation during the 1980s many of the activities of the Department of Energy were transferred either to regulators of newly private markets or within the auspices of the Department of Trade and Industry and the Department of Environment. Its renewed importance has seen the issue of energy moved back-from the Department of Trade and Industry, into the recently created Department of Energy and Climate Change. The current key UK energy policy documents are "The Energy Challenge" (DTI 2006) and "Meeting the Energy Challenge" (DTI 2007). These outline the core challenges for the UK in terms of energy; climate change, energy security and fuel poverty. These issues are inextricably linked.

3.1 Climate Change

In simple terms anthropogenic, or man-made, climate change is generally considered to have been driven by the burning of fossil fuels releasing carbon dioxide into the atmosphere. Carbon dioxide is a "greenhouse" gas which causes heat to be reflected back to earth producing a rise in temperature (MacKay 2009). This is predicted to have a wide range of potential impacts. Climate change has been identified as one of the worst examples of market failure (Stern 2006), where the potential costs that burning fossil fuels would have on future generations has not been considered.

Carbon dioxide is not the only greenhouse gas; there are total of 6 identified by the Kyoto Protocol (1998), but it accounts for about 85% of the total in terms of Global Warming Potential (National Atmospheric Emissions Inventory 2009). Each of these different gases has a different Global Warming Potential (GWP) based on their molecular performance and the time spent in the atmosphere. If carbon dioxide is valued at GWP 1, then Methane is 12 and Sulphur Hexafluoride is 3200. The debates around the exact impact of each of the gases in terms of global warming are complex and the relationships between the different elements are not linear, but we should bear in mind that climate change is not driven solely by carbon dioxide emissions. Figure 5 shows the change in greenhouse gases from 1990 in terms of their global warming potential (DECC 2010).

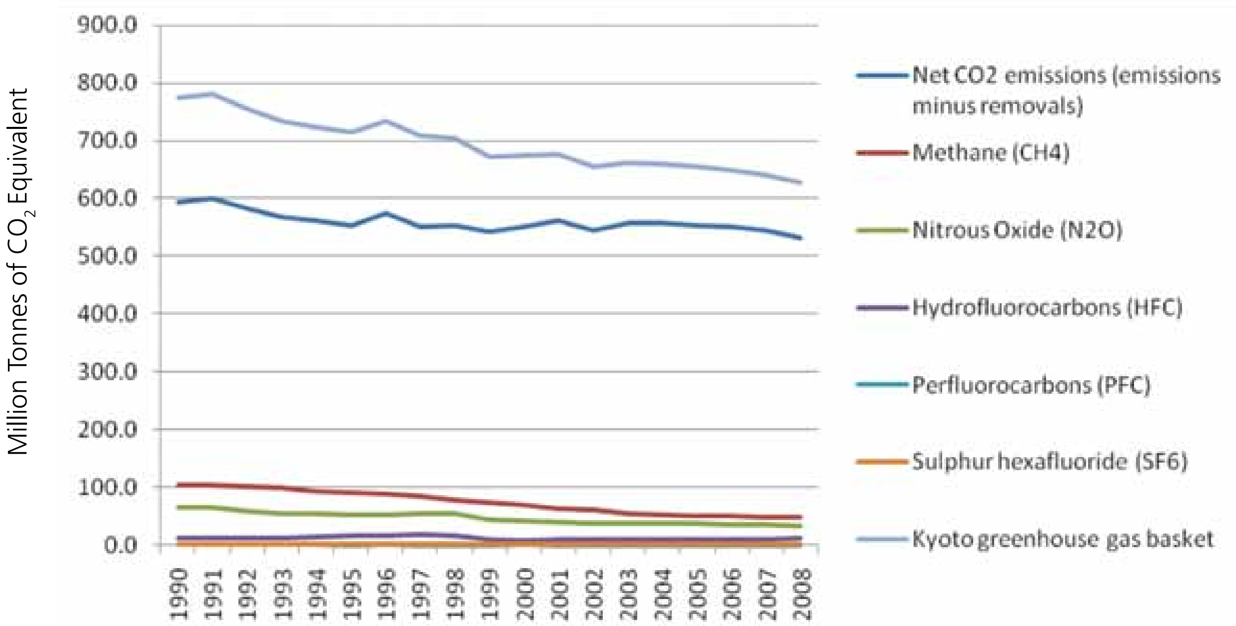


Figure 5 – Greenhouse Gases by Global Warming Potential in Million Tonnes of CO_2 Equivalent (DECC 2010)

3.1.1 Carbon Emissions Data for the UK

Total carbon dioxide emissions for the UK in 2007 were 543 million tonnes. Residential emissions accounted for approximately 26% of this (Figure 6).

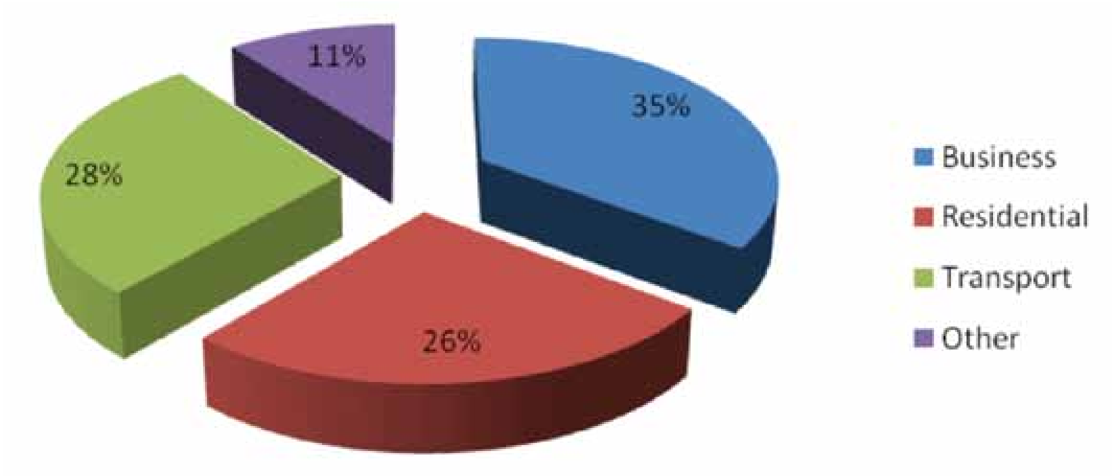


Figure 6 – Proportion of UK carbon dioxide emissions by end user 2007– (ONS 2009b)

We can see that over a period of 17 years (Figure 7), despite a 13% increase in the number of households over approximately the same period (ONS 2009c), residential CO_2 emissions fell by approximately 9% which is roughly in line with the overall picture (National Atmospheric Emissions Inventory 2009).

Total emissions, when the other basket of gases has been taken into consideration, have declined by nearly 20% for the same period (National Atmospheric Emissions Inventory 2009).

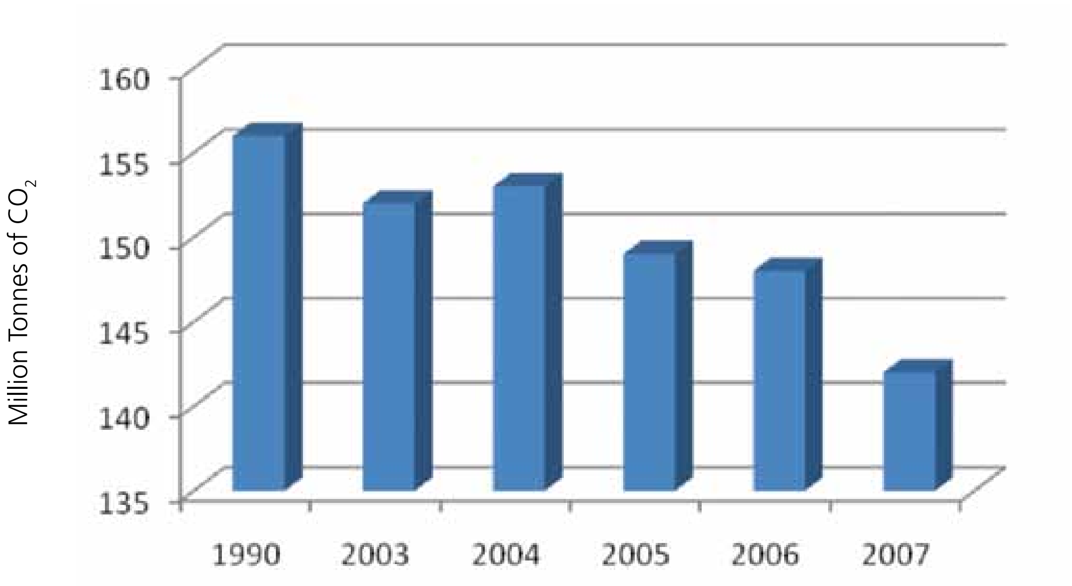
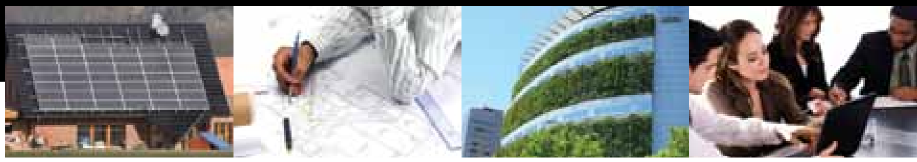


Figure 7 – Domestic CO_2 Emissions 1990 – 2007 (ONS 2009c)



However, recent figures from DECC (2010) indicate that much of the fall in carbon dioxide may have been driven by a fall in emissions from primary energy supply and industrial processes, possibly attributable to the European Union Emissions Trading Scheme which addresses large scale industrial production and energy supply.

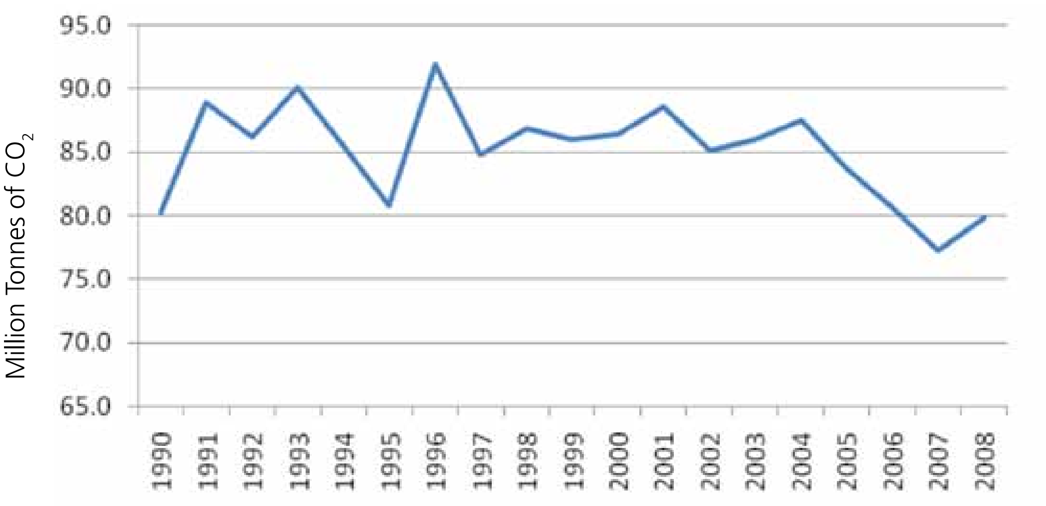


Figure 8 – Residential CO_2 Emissions from Domestic Combustion

Figure 8 looks at carbon dioxide emissions solely from residential combustion, the burning of gas, oil and coal in the home. This removes the carbon dioxide generated from the production of electricity. While this appears to show little change overall, given the change in the number of households, the carbon emissions for residential combusion per household fell from approximately 4 tonnes per household in 1991, to 3.7 in 2001 and 3.2 in 2006, suggesting that at the house level there may be some improvement. The remaining carbon emissions are determined by electricity use, of which the domestic sector uses approximately 35% of the total supply. Using DECC (2010) figures for emissions for energy generation, this indicates emissions of approximately 60MtCO_2. So while electricity accounts for approximately 22% of energy use (DECC 2009), it accounts for more than 40% of domestic carbon dioxide emissions (DECC 2010).

3.1.2 Climate Change Policy and Legislation

There are a large number of policy statements, white papers, legislation and regulation which are designed to address both the wider issues of climate change and the specific problems of the built environment. In this section we consider policy associated with climate change from the global to the local perspective. Many of the individual initiatives as they relate to the UK domestic sector are dealt with in more detail in section 6.

3.1.2.1 International Climate Change Protocols

Climate change is not just a UK issue; it must be tackled at an international level. The UK has signed up to the United Nations Framework Convention on Climate Change (1992), which has been further developed through the Kyoto Protocol (1998). The Kyoto Protocol commits countries to measure and manage carbon emissions against identified targets through a variety of policy mechanisms including energy efficiency, emissions trading, management of carbon sinks and new approaches to industry. The scope is broad, but forms the basis for the development of more specific national commitments.

The recent Copenhagen Accord (United Nations 2009) identifies the goal of keeping global warming under 2˚C through continued commitment to reducing carbon dioxide emissions, recognising the need to adapt to this change in climate, and identifying and addressing the emissions imbalance between developed and developing nations. What the recent summit does highlight is the complexity of both the climate issue and the politics that surround it. Additionally, although a 2˚C rise is the current scientific and political consensus, the extent of emissions control to achieve that target remains dependent upon the accuracy of the predictive models.

3.1.2.2 European Union Directives

The European Union has established a number of directives to drive down emissions through the European Climate Change Programme (EU 2006). The ECCP started in 2000, chiefly to meet the EU's obligations under the Kyoto Protocol. The Directive on the Energy Performance of Buildings (EU 2002) identifies a number of issues to which the UK government has to commit. It seeks to address:

- A methodology for the calculation of the energy performance of buildings
- The application of minimum energy standards for buildings
- The application of energy performance standards on large buildings that have been renovated
- Energy certification of buildings
- Inspection regimes of boilers and ventilation equipment

These have largely been driven through UK domestic policy which has been brought into line with the EU Directive. Also of relevance to the residential sector is the issue of energy performance of appliances, which are concerned with labelling to indicate energy efficiency (EU 1992) and improving energy performance (EU 2005).

3.1.2.3 UK Climate Change Policy and Legislation

The sheer volume of policy and regulation relating to climate change, energy and the built environment can make it difficult to report in a useful way. From a policy perspective the Energy White Paper "The Energy Challenge" (DTI 2006), which outlined the broad issues for climate change and energy, is the main policy document. This was supported by the Climate Change and Sustainable Energy Act (2006) which committed the UK government to a range of measures to address climate change and fuel poverty. A follow up report, "Meeting the Energy Challenge" (DTI 2007) outlines the core strategy to address the key issues of climate change, energy security and fuel poverty. The climate change targets have been enshrined in the Climate Change Act (2008) setting targets to reduce the levels of carbon dioxide emissions by 80% of the 1990 baseline set by Kyoto by 2050.

The importance of the climate change agenda and its previous cross-cutting nature has led to the establishment of a government department with specific responsibility for climate change and energy. The Department for Energy and Climate Change was established in October 2008, and has recently published a National Strategy for Low Carbon Transition (DECC 2009). This addresses not only how to avoid climate change, but also how the UK might live with some level of change of climate. The adaptation agenda is not addressed in this document specifically, but is of growing importance.

3.2 Energy Security

Energy Security has been given an equal priority to Climate Change (DTI 2007). This recognises that the UK has, since 2004, become a net importer of energy as North Sea oil and gas reserves are reduced (Figure 9).

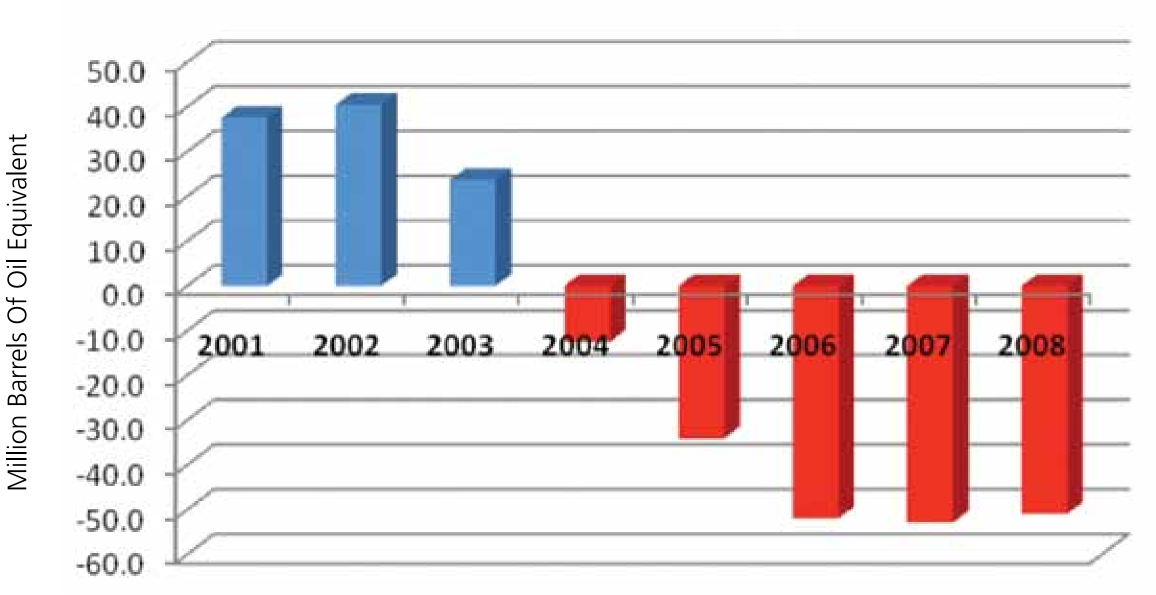


Figure 9 - Net UK Exports of Energy 2001 – 2008 (ONS 2009a)

This has been driven by large falls in UK production of both oil and natural gas, mainly from the North Sea (Figure 10).

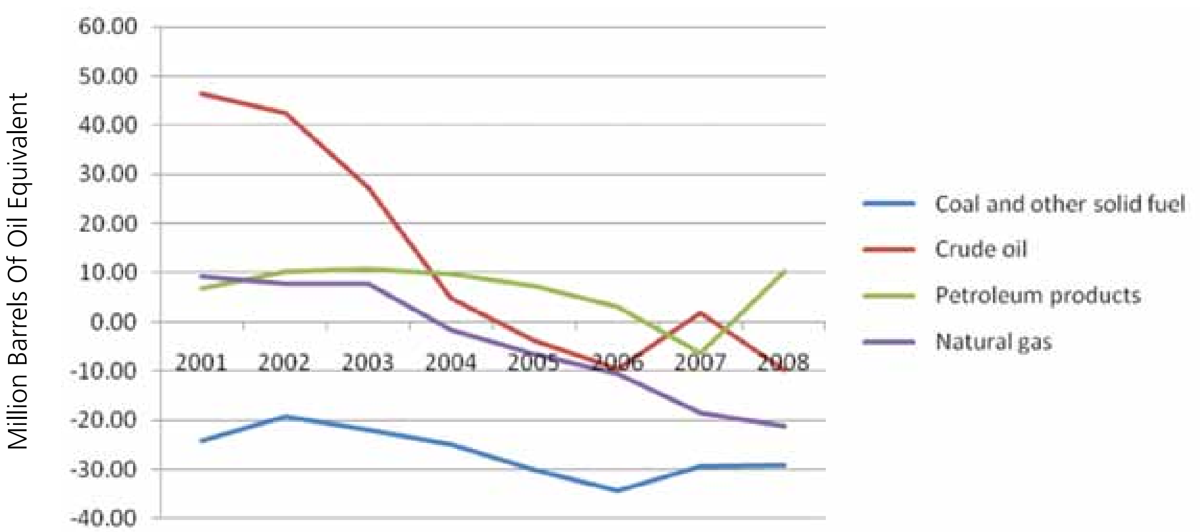


Figure 10 – Net UK Exports of Energy 2001-2008 by Fuel Type (ONS 2009a)

Over the longer period, the policy (DTI 2007) identifies that many of the areas from which energy is imported may be considered politically unstable which, should supplies be interrupted, will expose a lack of resilience in the UK energy system. This can clearly be seen in the recent dispute between Russia and the Ukraine over gas supplies, which led to the Ukraine and a number of Eastern European countries being without gas during the winter period. These types of issues suggest that the UK should look to greater energy independence to avoid being at the mercy of both the markets and international politics. Given the Housing Sector's huge reliance on natural gas, some 85% of total energy use, the security implications for supply are enormously important.

3.3 Fuel Poverty

The issue of fuel poverty was first recognised by the UK Government in the legislation in the Warm Homes and Energy Conservation Act (2000). Fuel Poverty is defined as a household that uses 10% of its income on energy (DTI 2001) when heating their home to a "satisfactory level", which is defined as 21°C in the main living areas and 18°C in other rooms. Fuel poverty is defined by what a household needs to spend to attain this level of heating rather than what it actually does spend. Fuel poverty can be driven by three key factors; energy costs, energy efficiency of the home and the income of the household.

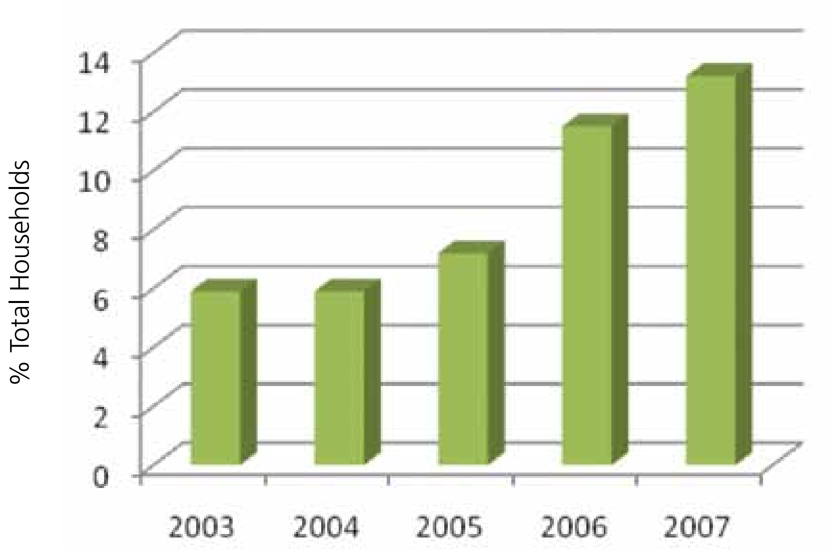


Figure 11 - % of Households in Fuel Poverty 2003 – 2007 (DECC 2009b)

We can see a steady growth in fuel poverty overall in the period 2003-2007, with nearly 3 million households in fuel poverty in 2007 (Figure 11). When assessed by tenure some 21.6% of social housing residents are considered to be in fuel poverty.

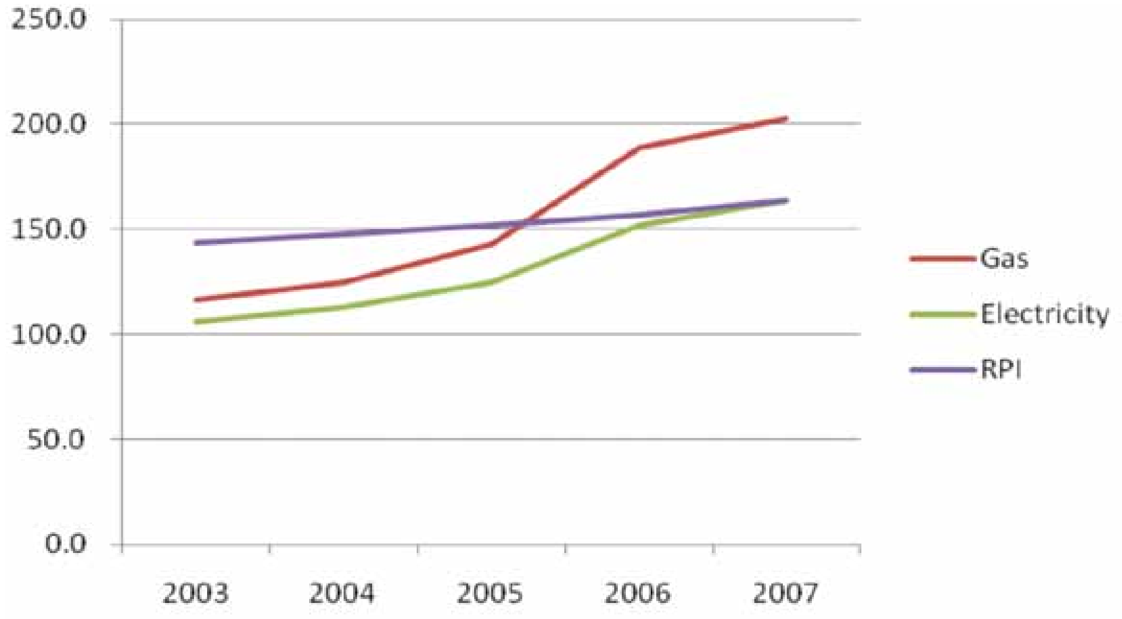


Figure 12 – Change in Gas and Electricity Prices compared to RPI – 1990 =100 (DECC 2009c)

Considering gas and electricity, which form the vast majority of domestic energy use, we can see that energy prices have outstripped the Retail Price Index (RPI), from a base where energy was relatively cheap to a point where gas specifically started to greatly outstrip the cost of living generally. This has led to an increase of domestic energy expenditure for gas and electricity, weighted by proportional expenditure, of approximately 70%, compared to a 14% increase in the RPI, over the period 2003-2007 (Figure 12). It can be see that the increase in gas prices aligns with the point at which the UK became a net importer of gas.

3.4 Energy Hierarchy

The energy hierarchy is a decision-making structure which is appearing in a number of energy strategies throughout the UK (City of London 2004). It identifies a prioritisation of approaches to meet the policy drivers. Figure 13 shows a version from the Institute of Mechanical Engineers (2009). This is based on the Waste Recycling Hierarchy (Renewable Energy Association 2006).

Looking at the types of activities that people may undertake to reduce energy use, we can see how different types of actions, such as insulation or smart metering, might fit into this Energy Hierarchy. The Energy Hierarchy can help policy makers understand how different actions address different levels of priority (Table 2).

This helps policy makers understand how different decisions can change patterns of energy use.

There are a number of variations of this approach, but they all follow this similar basic pattern.

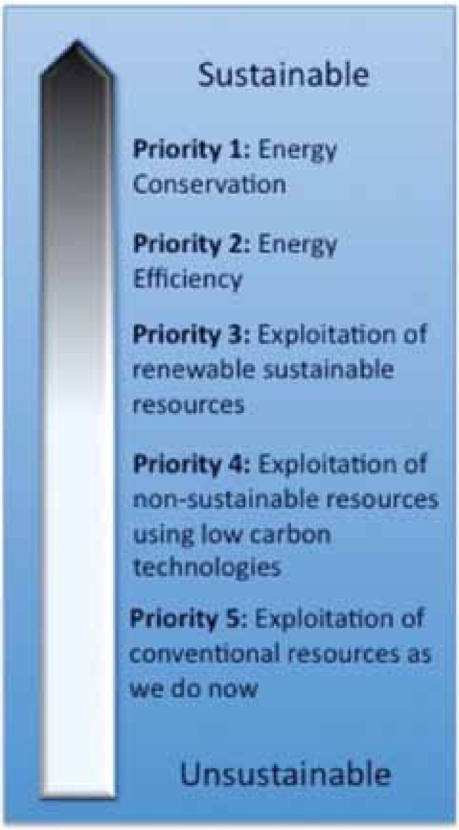


Figure 13 – The Energy Hierarchy (IME 2009)

Priority	Requirement	Mechanism
1	Changing wasteful behaviour to reduce demand	Information for domestic users through advertising and the use of smart metering.
2	Using technology to reduce demand and eliminate waste	Use of insulation such as loft insulation and cavity walls to make properties more energy efficient.
3	Exploitation of renewable sustainable resources	Ensure that domestic energy use is from clean technologies, such as wind, biomass or wave power.
4	Exploitation of renewable non-sustainable resources using low carbon technologies	Use of distributed Combined Heat and Power to ensure more efficient use of gas.

Table 2 – Examples of the Energy Hierarchy in the Domestic Sector

4.0 The UK Energy System

In this section we will consider how energy is generated for, and distributed to, the domestic sector. This considers not only electricity generated in power stations and the gas distribution system, but also the issues surrounding infrastructure and generation at the "micro" level. While this may seem far removed from the choices made by decision-makers in the housing sector, there are important concepts and issues which must be considered. A rush to microgeneration, or the development of distributed systems, has implications for the energy generation and distribution system and vice versa. Understanding the structure and constraints these systems have is important in helping us shape our thinking as to how we seek to address the problem at the level of new and existing homes.

4.1 Gas Supply and Distribution System

UK gas infrastructure is broadly split into two networks; transmission and distribution. Gas is taken from the high pressure transmission system and distributed through low pressure networks of pipes to industrial complexes, offices and homes.

The Gas Transmission System receives gas from coastal reception terminals around Great Britain, and transports it for approximately 70 gas 'shippers' to industrial, commercial and domestic consumers. The network is made up of nearly 133,000 kilometres of pipeline, comprising high pressure national and regional transmission systems, and lower pressure local distribution systems. Gas is pumped through the system by compressor stations located around the country.

Several European interconnectors link the UK gas transportation system to other continental high pressure gas grids. A further two interconnectors supply gas to Ireland and Northern Ireland (National Grid, 2009).

There are eight gas distribution networks connected to the transmission system, with each covering a separate geographical region of Britain. In addition there are a number of smaller networks owned and operated by Independent Gas Transporters – most, but not all of these networks have been built to serve new housing (Ofgem, 2007). Unlike the electrical national grid, the gas distribution system has the ability to store gas and buffer supplies to cope with varying demand.

As noted previously, the UK is heavily reliant on gas as a primary and power generation fuel for both domestic and commercial use and since 2004 we have become a large-scale net importer. Any zero-carbon policy driven move away from dependence on gas as a primary fuel will obviously have significant impact on this situation.

4.2 The Electricity Generation and Distribution System

Electrical power accounts for approximately 22% of the energy used in homes. The electricity grid is the nationwide infrastructure that enables the transport of power from where it is generated to the end user. The majority of electricity is generated through gas (39%), coal (33%) and nuclear (21%), with the remaining 7% produced through a number of other small scale sources, including renewables.

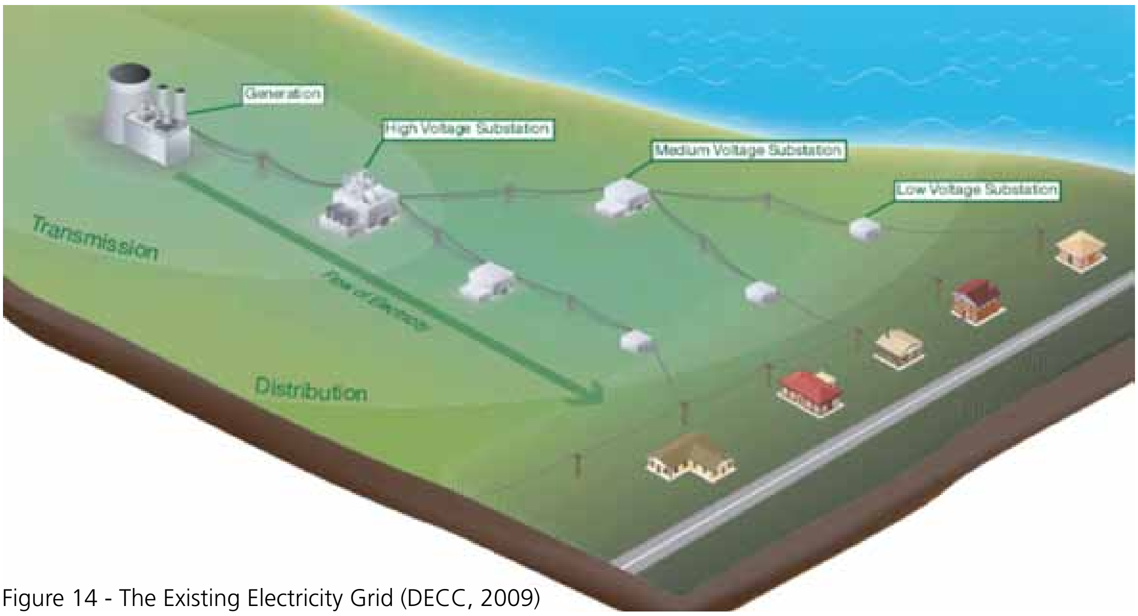


Figure 14 - The Existing Electricity Grid (DECC, 2009)

What is usually called the 'national grid' has two distinct parts. One part is the transmission network which is the backbone of the grid and carries power at high voltages (between 132kV and 400 kV) over long distances. Most of the transmission network is carried on the large pylons that are the most visible part of our electricity network. The second part of the grid are the regional distribution networks, of which there are 14 in the UK. In these distribution networks the voltage of electricity from the transmission network is reduced down through a series of transformers to the 230 volt supply that reaches most homes and businesses.

The distribution networks in particular have been designed for a one-way flow of electricity from generator to user (DECC, 2009). Due to differences in regional demand and generation capacity there is a net flow of electrical power from north to south which means that new generation capacity situated on the south coast has a 5% greater effectiveness due to the reduction in transmission system power losses compared to similar capacity in the north (National Grid, 2008).

4.3 Supply and Demand

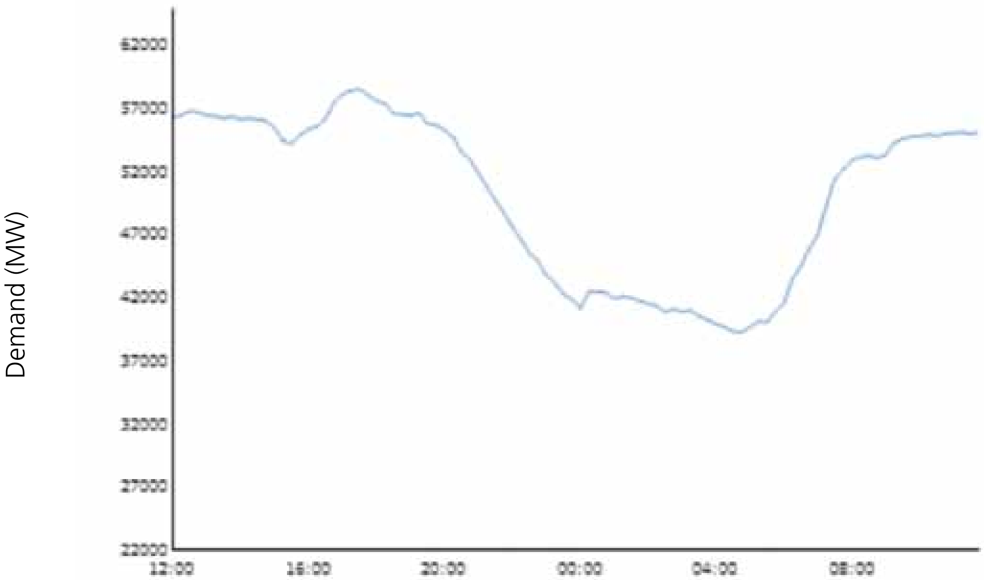
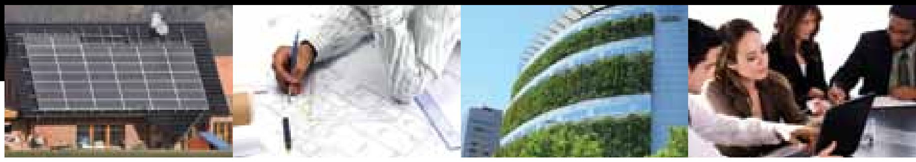


Figure 15 – UK Electricity Demand (MW over 24 hour period) – Sampled 14/01/2010 (National Grid, 2010)

Electrical power cannot be 'stored' by the grid, only in the form of fuel for power stations. The supply is constantly adjusted to suit current instantaneous demand, which is variable over the course of the day (Figure 15). This balancing of electricity supply and demand is performed mainly by the supply side, with fast-acting, controllable and flexible power plants, which are usually carbon intensive and less efficient than steady state generation, and some pumped storage hydro-electrical generation, which responds to the demand changes (ENSG, 2009). The balancing of supply and demand across the electricity grid is an important factor when considering renewable energy production. As McKay (2009) points out, certain renewable energy sources, such as wind and solar power, are prone to quiet periods where they may produce a fraction of their rated output, or indeed none at all.

The grid needs to retain sufficient fast reacting generation capacity to cope with this variable supply. The move from the current "passive" grid comprised of large scale power stations with flow in a single direction from generator to consumer, towards a distributed "smart" grid comprising many smaller regional or even domestic generation sources has inevitable implications regarding the network. The grid will need to be able to cope with bi-directional flow, with consumers sometimes exporting surplus electrical power back to the grid, generating income through a Feed-In Tariff (HM Government 2010). This will inevitably lead to a much more complex network which must have in-built fault tolerance and control mechanisms. (Carbon Trust, 2009)



4.4 Microgeneration

The drive for low carbon housing has several important implications when considering the provision of electrical power in homes. In 2006 the Government published a Microgeneration Strategy (DTI, 2006). The objective of this strategy is to "create conditions under which microgeneration becomes a realistic alternative or supplementary energy generation source for the householder, for the community and for small businesses".

The term 'microgeneration' encompasses many forms of small scale electrical power and heat production which may take place in individual homes or at a 'district' level; the aim being to reduce dependence on carbon intensive grid delivered energy in housing. Some forms of Microgeneration only produce electrical power for use in the home, or for export back to the grid should there be a surplus. Some, known as Combined Heat and Power (CHP) systems, also produce heat as a by-product or as a main energy output. This heat may be used to directly heat the home and/or provide hot water. Some microgeneration technologies do not produce any electrical power and only produce heat.

The main microgeneration technologies currently in use or under development include:

Technology	Features
Biomass systems	Wood and other biological waste fuelled heating devices
Solar photovoltaic (PV) systems	Electricity production directly from solar cells
Solar hot water systems	Domestic hot water production directly from solar collectors
Wind power systems	Electricity production from wind turbines
Ground source heat pumps	Heat collection from the ground using the refrigeration cycle
Air source heat pumps	Heat collection from the air using the refrigeration cycle
Absorption heat pumps	Heat collection / transfer from another fuel source (e.g. natural gas) using the refrigeration cycle
Small-scale hydroelectric systems	Electricity production from small water turbines
Micro combined heat and power (CHP) systems	Heat and electricity production using natural gas fuel (conventional boiler replacement)
Renewable combined heat and power (CHP) systems	Heat and electricity production using biogas fuel (currently only viable at district level)
Fuel cells	Electricity and CHP production through chemical conversion of hydrogen rich fuel sources (natural gas, hydrogen, propane etc). Emerging technology not yet commercialised at a domestic level

Table 3 – Microgeneration Technologies

As can be seen in Table 3, microgeneration technologies may use energy sources viewed as inherently 'renewable' (solar, wind, biomass etc) or may use other less renewable energy sources such as fossil fuels. However, when evaluating a particular technology, it is important to consider the 'whole life' impact including, but not limited to; the manufacture of the particular device, fuels and their processing / transport, device lifetime and ultimate disposal / recycling etc. Assessments of this nature are challenging but necessary in order to properly evaluate the many potential technologies which exist or are under development.

4.5 Smart Grid and Smart Homes

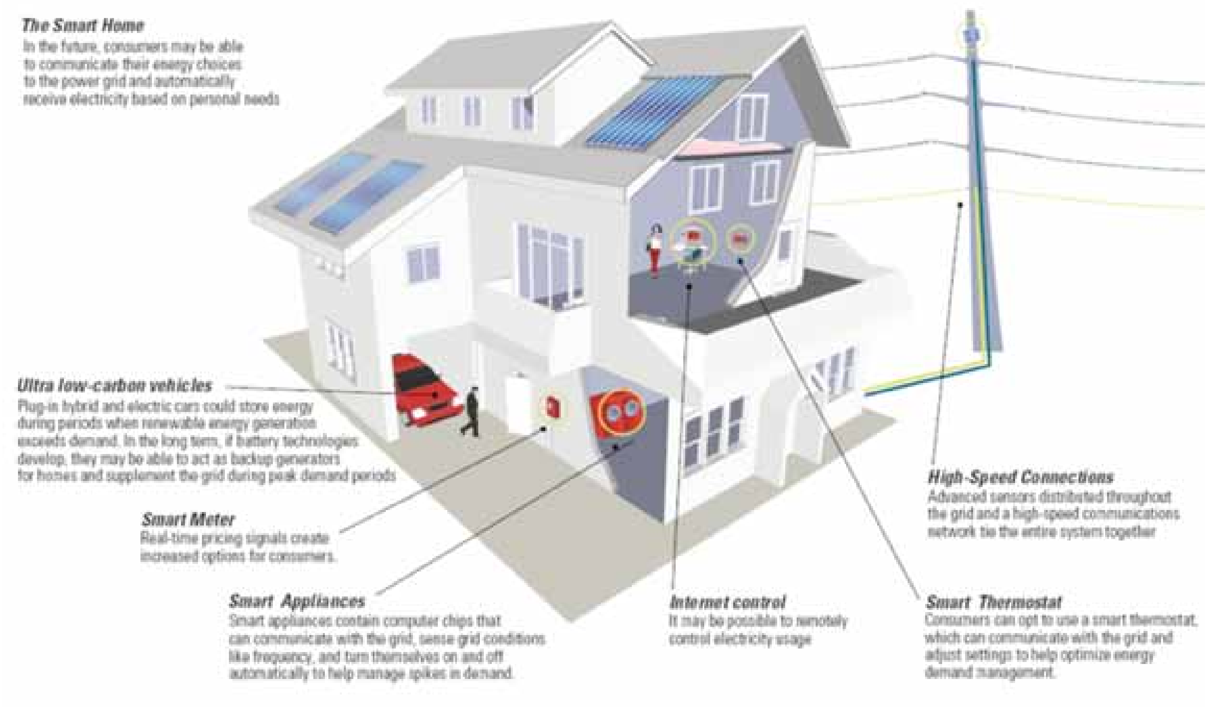
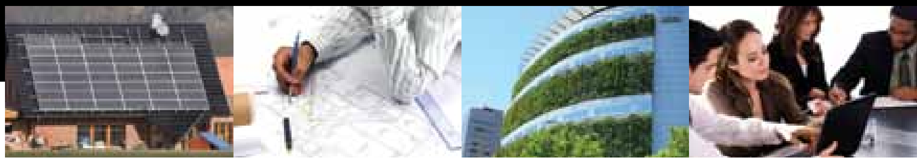


Figure 16 - What a Smart Home may look like (© Xcel Energy)

In conjunction with microgeneration, the concepts of a 'Smart Grid' and 'Smart Homes' would enable the most efficient use of the envisaged highly distributed power generation grid. Smart Grid and Smart Homes utilise information and communications technologies (ICTs) linked to the electricity system, enabling more dynamic 'real-time' flows of information on the network and more interaction between suppliers and consumers. These technologies can help deliver electricity more efficiently and reliably from a more complex network of generation sources than the system does today. (DECC, 2009e)

Among other benefits, a smart grid and smart homes would enable homes and the power provider to intelligently control the demand of appliances which do not require continuous power, such as refrigerators, in order to help balance demand on the electrical network. Similarly, homes which produce their own electricity through microgeneration will be able to sell surplus power back to the network, receiving payment through the new Feed-In Tariff. While many of these technologies are in development and have not been implemented, certain aspects of the smart home are being installed in homes today. These include concepts such as intelligent metering which communicates usage directly back to the provider for billing purposes and real time consumption meters which allow the home owner to view instantaneous power usage.



5.0 Housing Supply and Energy Use

The home is one of the main mechanisms through which domestic users consume energy. Energy use by individuals is driven by a range of factors such as numbers of homes, house types and, to some extent, tenure patterns.

5.1 Make-up of the UK Housing Stock

There are a total of 22.2 million homes in the England (English House Condition Survey 2007), and approximately 26 million homes in the UK as a whole. The types of houses for England are shown in figure 17.

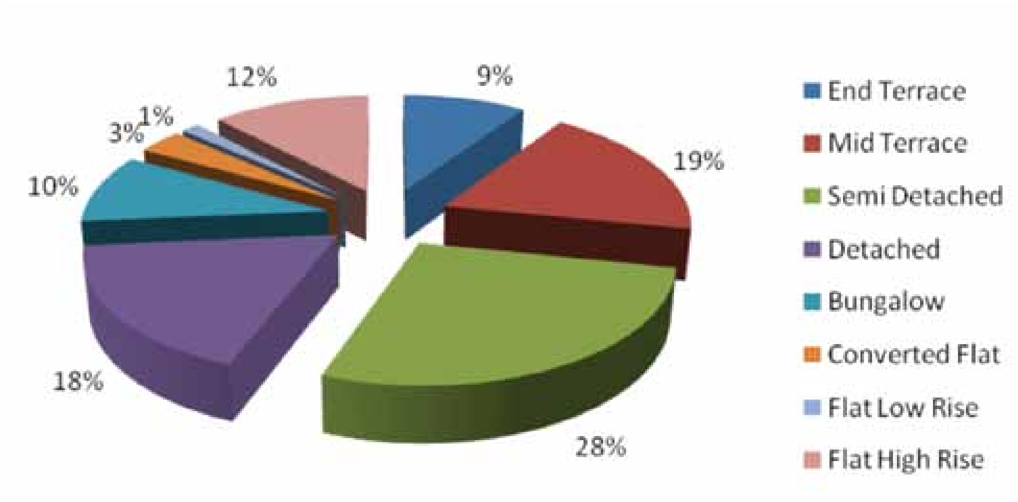


Figure 17 – House Types in England by % 2007 (EHCS 2009)

The type of home is important. Large detached homes have different energy use patterns when compared to small flats. In addition, the types of solutions that may be applied to these different homes in an effort to make them more energy efficient will vary.

The majority of homes are owner-occupied as seen in figure 18. Tenure patterns are important in terms of the different approaches that may be taken to improve energy efficiency. Social landlords may have opportunities and finance to upgrade their stock to improve energy efficiency. They may have professional knowledge that owner occupiers or buy-to-let landlords may not have. The recent Warm Homes, Greener Homes strategy (HM Government 2010) recognises this difference and adopts different approaches to address the needs of different tenure types.

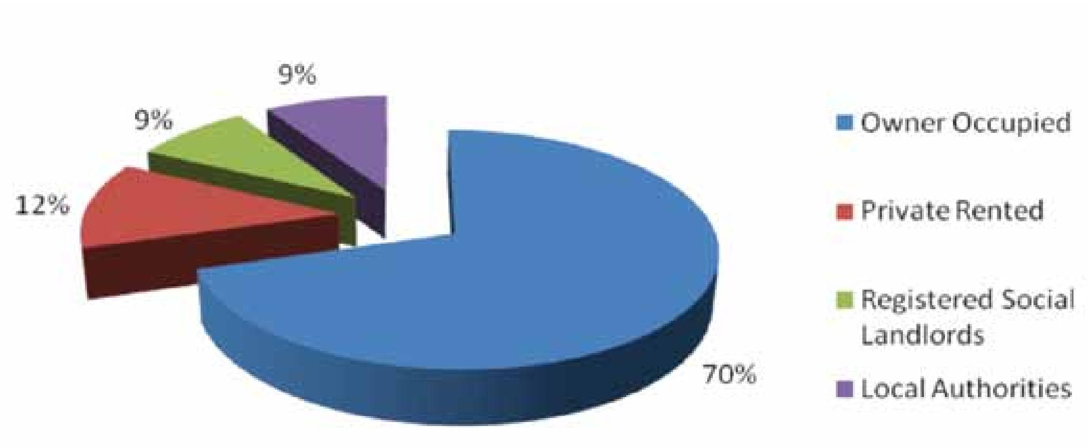
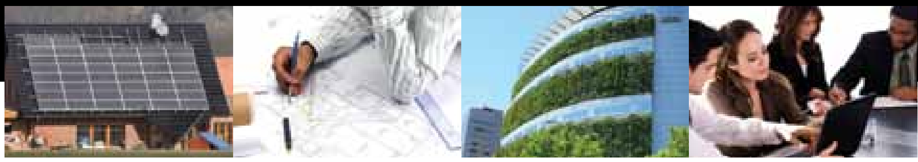


Figure 18 – % Housing Stock by Tenure 2007 (EHCS 2009)

This has implications for energy as the owner occupied sector displays far higher carbon dioxide emissions (figure 18) when compared to social housing. Tenure can be seen as a key issue when considering not only what to address in terms of policy for housing, but also how to address it.

Figure 19 - % homes emitting more than 5 tonnes carbon dioxide per annum by tenure in 2007 (English House Condition Survey 2009)

Some caution should be taken with the figures of owner-occupiers and their carbon emissions. The fact that there are more emissions from owner-occupiers does not directly follow that they have less efficient homes; they may have larger properties or use more energy due to their comparative wealth.



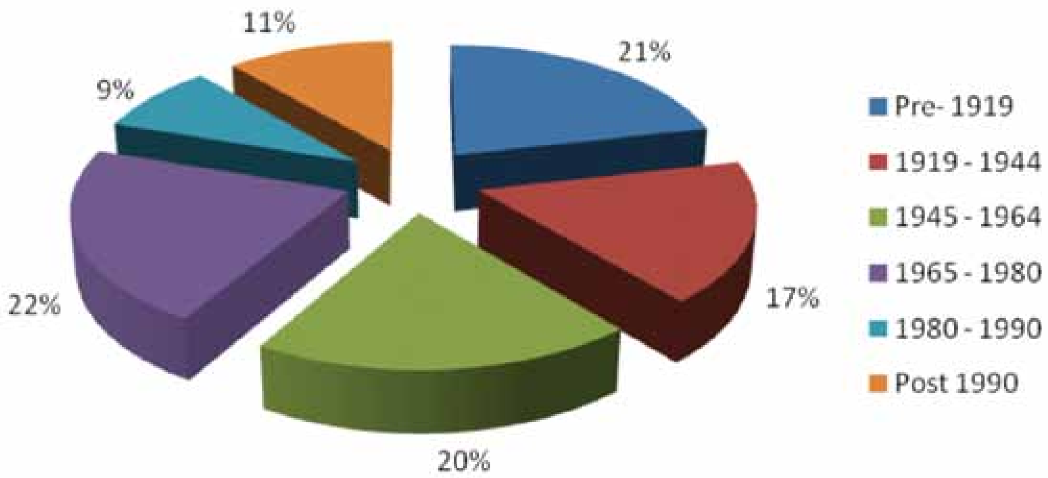


Figure 20 – Age of English Housing Stock by % (CLG 2009)

Figure 20 identifies the age profile of the current housing stock. The age of the stock has implications for its energy efficiency. Older stock is generally built to less energy efficient standards, especially as newer stock is governed by more stringent environmental building regulations. In Figure 20 we can see that approximately 11% of the housing stock has been built in the last 18 years to 2007.

Housing stock is replaced at less than 1% a year. This means that policies to address new homes, such as the Code for Sustainable Homes or planning requirements (see section 6) will only make a small difference to the UK domestic energy use in the short to medium term. The key issue to address is the retrofitting of old homes to meet new environmental standards. Warm Homes, Greener Homes (HM Government 2010) identifies retrofit as a major priority for the UK, making a commitment to 7 million eco-upgrades by 2020.

The age of the stock also has implications for some of the options we might take to address its energy efficiency. Older properties may not have cavities which can be insulated for example. Additionally, individual owners may be resistant to making external changes to properties with character.

5.2 Components of Energy Use in Homes

We have seen in section 2 that the UK domestic sector uses approximately 29% of the UK's total energy consumption per year and generates approximately 26% of the UK's carbon emissions. If we are to effectively understand how we might improve that position we must understand the patterns of energy use within the home, consider where the major impacts are and how they might be managed.

Figure 21 outlines the overall breakdown of energy use by type of activity. This should be viewed as a broad average as the specific data will vary from home to home (see Section 7), but this gives us a good picture from which we can consider how to address managing energy in homes. We can see the main energy use in the home is for space and water heating, which are often provided by the same system (English House Condition Survey 2009).

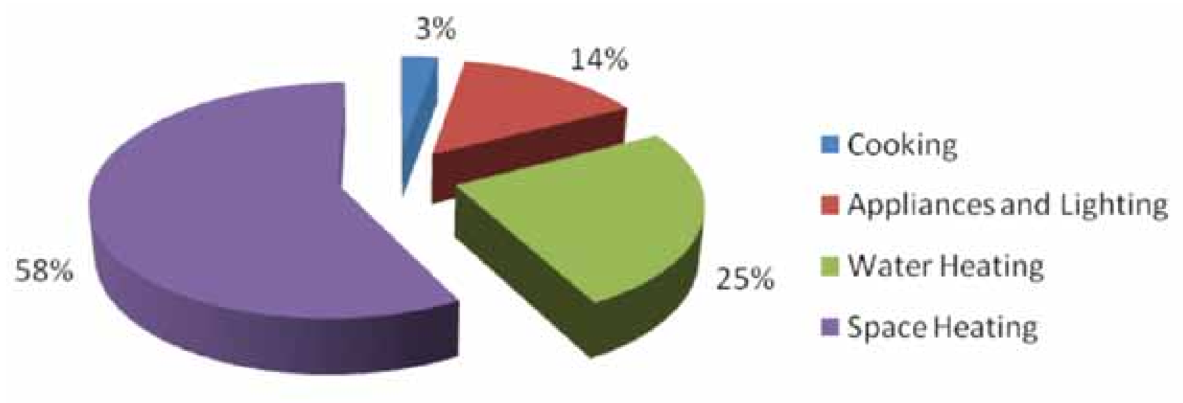
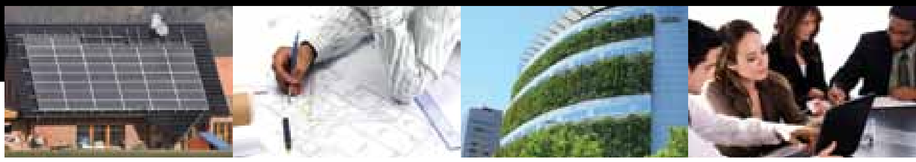


Figure 21 – Approximate Breakdown of Energy Use within Homes 2007 (DECC 2009d)



6.0 Regulating Energy Consumption of Homes

There are 4 key tools that regulate the overall energy consumption of homes currently in use; planning, Part L of the Building Regulations, the Code for Sustainable Homes and Energy Performance Certificates.

They vary in the way and level at which they act, but are closely linked and in many cases overlap. Although they are mainly concerned with energy efficiency, they also address elements of energy generation. Table 4 looks at the main criteria of domestic energy use and supply and how different elements of energy supply and use are addressed.

Supply and Use	Energy Drivers	Tools and Regulations	Notes
		Supply Side Issues	
Off Site Generation	Grid Distributed Generation Off Site Renewables	Planning	Core strategies of local authorities will vary in their approach to planning and linking developments with offsite energy
On Site Generation	Microgeneration On Site Renewables	Planning Part L Code for Sustainable Homes EPCs	Core strategies may highlight the Code as their main vehicle to deliver sustainable homes. Planning has more power than the Code and will override where there is conflict.
		Demand Side Issues	
Heating and Hot Water	Heating Systems Building Fabric	Part L Code for Sustainable Homes EPCs	
Lighting	Quantity Type	Code for Sustainable Homes EPCs	See section 6.6 for more details
Appliances	Quantity Type	Code for Sustainable Homes EPCs	See section 6.6 for more details

Table 4 – Overview of 4 main tools to regulate energy consumption in homes

6.1 Planning

The planning system is designed to control the level and nature of developments within a given area in a co-ordinated and coherent way that meets the objectives of national policy and local needs. It covers a wide number of issues beyond energy use. It is a layered system which starts with National Planning Policy and follows through to how decisions are made at the local level (HM Government 2007), as shown in figure 22. The goal is to ensure that planning decisions are made at the appropriate local level (CLG 2006), while recognising national priorities.

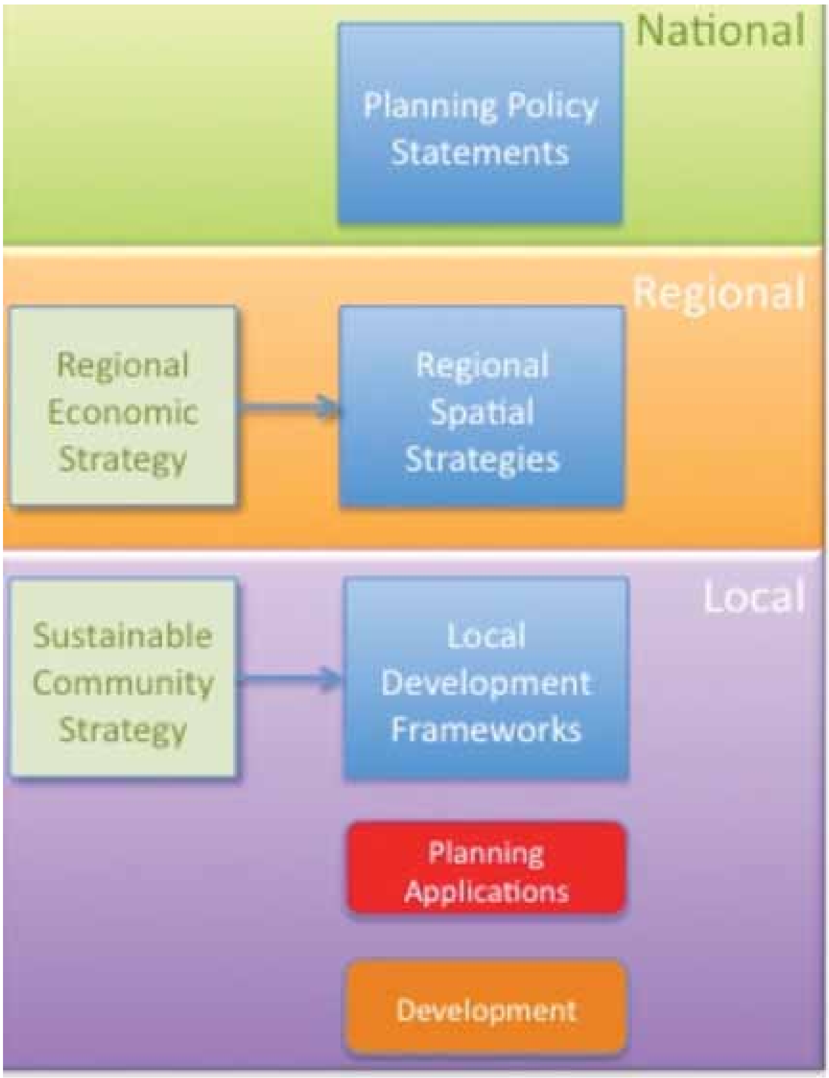
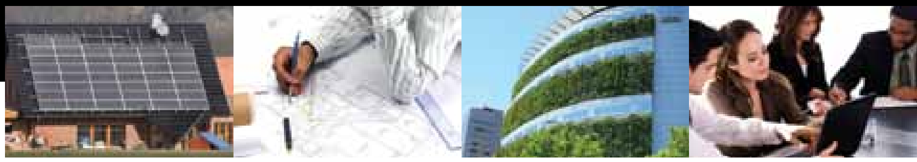


Figure 22 –Outline of the Planning System (HM Govt 2007)



6.1.1 Planning Policy Statements

Planning Policy Statements are a series of policy guidance documents which are used to inform regional spatial strategies and local development frameworks to ensure the planning system is delivering UK policy objectives.

In 2005 the overarching Planning Policy Statement 1, which formally outlined general principles of the planning system, was changed to specifically address the need of the planning system to deliver sustainable development (ODPM 2005). Energy and climate change were highlighted in a supplement to PPS1, in the document Planning and Climate Change (CLG 2008). This guidance outlines a series of objectives and principles which should be considered by planning authorities including the reduction of emissions and the adaptation to potential climate change. The key decision-making principles are:

- New development should be planned to minimise carbon dioxide emissions
- New development should be planned to make use of decentralised, renewable and low carbon energy
- New development should be planned to mitigate climate change impacts
- New development should be planned with both mitigation and adaptation in mind
- Sustainability appraisal should be applied to shape planning strategies
- Monitoring and reporting should be undertaken through regional and planning authorities reporting mechanisms and should form the basis for future decision-making

6.1.2 Regional Spatial Strategies

Regional Spatial Strategies are designed to cover a 15-20 year period for a region. These strategies are mapped onto the areas of the Regional Development Agencies and they provide a framework for plans which are undertaken at a more local level. They cover issues such as housing, transport, communities and economic development (ODPM 2004). They also take into account issues such as energy infrastructure and climate change mitigation and adaptation, which make them of particular interest within this report.

The North West Regional Spatial Strategy covers the period to 2021 (Government Office North West 2008). Of key interest is the response to reduce emissions and adapt to climate change. The main issues that are of interest to housing are;

- Better built homes with improved environmental performance with reference to the Code for Sustainable Homes (see section 6.3)
- Increased renewable energy capacity
- Increased use of distributed energy systems
- Designing for adaptation for climate change

In addition, there is a clear direction towards a number of detailed strategies to promote a more sustainable energy system. We can see that the planning system takes account of the links between the infrastructure and the built environment that we have highlighted in this report:

- Double CHP use within the region
- Reduction of energy use
- Increase renewable energy
- Decentralised energy supply

These approaches are outlined in a very broad way, with much of the detail to deliver these higher level objectives being devolved to the Local Development Plans (see section 6.1.3), which can be used to drive more specific targets suitable for each individual local area.

6.1.3 Local Development Frameworks and Core Strategies

Local Development Frameworks (CLG 2008b) are made up of a series of documents which cover a wide range of interrelated issues in relation to development for a specific local authority. The most important of these, in relation to housing and energy, is the core strategy. The core strategy outlines a local approach to addressing the national policy objectives.

Taking the core strategy for the City of Salford as an example, there is a commitment to climate change mitigation and adaptation. This is specifically covered in detail in the energy section which highlights:

- Code Level 4 with an aspiration to level 6
- Increase in renewable energy with specific identified developments
- Increase in Combined Heat and Power projects
- Linking developers into a distributed energy network
- Developers should effectively engage with the energy hierarchy (see section 3.4)

This means that planning decisions about developments, including housing, will be taken in the context of this document. Core strategies mean that different local authorities may take individual approaches. Merton, in London, have indicated they would like to be an exemplar in the context of climate change, leading to more stringent requirements on developers than in other authorities when addressing climate change through the planning system (London Borough of Merton 2009).

6.1.4 Implications for Development

The planning process is being used as a vehicle to deliver homes that address energy policy needs, through a series of national, regional and local strategies which inform the decision-making element, that of planning applications. This cuts across a series of government departments indicating the complex nature of the relationship between policy and the planning system.

Sustainable development (DEFRA 2005) has been put at the centre of policy through the Planning and Compulsory Purchase Act 2004. While the chief focus of this report is on housing, consideration should be given to changes to the planning system with regards to major energy infrastructure projects, particularly with respect to maintaining the security of the energy supply following the recommendations of the Barker Report (2006). While large infrastructure projects, which will be managed through the National Policy Statement process, are important; the majority of planning applications are small and managed at the local level. This very much applies to housing.

The planning system controls energy and climate change through informing planning decisions which address:

- The building of zero-carbon homes, which are low energy and emissions
- Reducing the need to travel
- Making walking and cycling essential components of development
- Ensuring integrated public transport
- Supporting the move to low carbon and renewable energy

The planning system can be used to make national policy effective at the local level. This can lead to a variation in approaches at the regional and local level as planning bodies align local needs with national policy.

6.2 Building Regulations

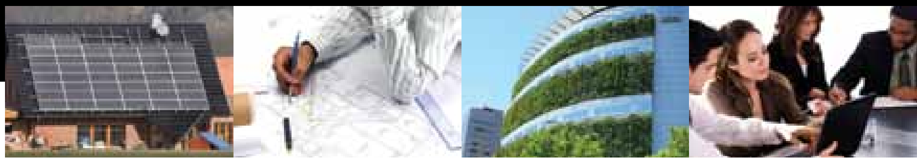
The UK building regulations exist principally to ensure the health, safety, welfare and convenience of people in and around buildings, together with the water and energy efficiency of buildings. Building regulations have developed from the 13th Century, where issues of fire safety meant individual cities set regulations, culminating in the London Building Act of 1667, passed as a response to the Great Fire of London. Public health issues of the Victorian era extended powers to local authorities to create building by-laws. In 1966 the first set of national standard Building Regulations came into force in England and Wales, although these excluded London (Manco 2009).

They currently are comprised of fourteen sections, each accompanied by an 'approved document' which outlines the required standards under the regulations. In 2006 the UK Government reviewed and updated Part L of the building regulations: "Conservation of fuel and power" in order to make buildings more energy efficient and tackle climate change. In terms of housing, part L1A (ODPM, 2000) covers new buildings and part L1B (ODPM, 2000) covers existing homes. These regulations set out mandatory and optional minimum standards to which all building works must comply, with the latest revision introducing some new requirements.

6.2.1 Approved Document L1A – New dwellings

A key requirement introduced in Approved Document L1A is the concept of carbon emission targets. This requirement captures most aspects of domestic energy consumption and sets a minimum overall standard: the carbon dioxide Target Emission Rate (TER). In order to demonstrate compliance with this requirement, a Domestic Emission Rate (DER) must be calculated and shown to be no greater than the TER. (Energy Saving Trust, 2009). The DER is a complex calculation which takes into consideration; building design, materials and methods of construction, building performance, fittings and fixtures, as well as a number of other elements.

The regulations also set out design limits related to heat loss performance of the building fabric and fixed services, the aim being to reduce heating related energy demand by reducing heat loss. A further aim of this requirement is to restrict the use of inappropriate design trade-offs, such as compensating for poor insulation performance by improving in another area.



6.2.2 Approved Document L1B – Existing Dwellings

To take account of existing housing stock, several minimum requirements and standards have been introduced in Approved Document L1B, which must be adhered to where improvement or renovation is carried out in existing homes. These requirements include such aspects as the insulation of walls and other fixed building elements such as floors, windows and roofs and the energy efficiency of heating and lighting.

6.3 Code for Sustainable Homes

The Code for Sustainable Homes was introduced in England in April 2007 as a voluntary national standard to improve the overall sustainability of new homes by setting a single framework within which the house building industry can design and construct homes to higher environmental standards. Where it is used, the Code also gives new homebuyers information about the environmental impact of their new home and its potential running costs (Communities and Local Government, 2009).

From April 2008, all new social housing must be built to a minimum of Code level 3, which is to be increased to Code level 4 in 2010.

The Code uses a sustainability rating system indicated by 'stars', which are awarded to indicate compliance at each code level, to communicate the overall sustainability performance of a home. A home can achieve a sustainability rating from one to six stars depending on the extent to which it has achieved Code standards. One star is the entry level, indicating performance above the minimum level set by the Building Regulations; and six stars is the highest level – reflecting excellent performance with relation to sustainability (Communities and Local Government, 2006).

In 2010 Code level 3 is to be mandatory for privately developed homes, having previously been voluntary to this point. Since May 2008 all new homes are required to have a Code rating (or a zero rating certificate) in the Home Information Pack (HIP). Similarly, all homes marketed for sale in England after May 2008 must include a Code sustainability certificate as a part of the HIP. The timetable for all new homes is outlined in Table 5:

Date	2010	2013	2016
Efficiency Improvement of the Dwelling Compared to 2006 Part L Building Regulations	25%	44%	Zero Carbon
Equivalent Standard Within the Code	Code Level 3	Code Level 4	Code Level 6

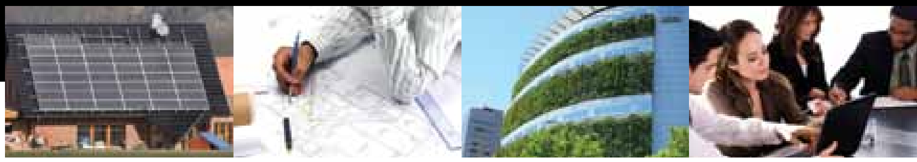
Table 5 – Mandatory Code Ratings for New Homes Timetable

The sustainability 'star' rating reflects overall performance across nine code categories. Minimum standards exist for a number of categories which must be achieved to gain a one star rating. Water and energy performance also have minimum standards which must be achieved at every code level.

Within each code category, there are a number of 'issues' which are scored in the assessment process. These are summarised in Table 6 below together with the flexibility afforded in each category. Words highlighted in bold denote mandatory elements.

Category	Issue	
Energy and CO2 emissions	**Dwelling emission rate** Building fabric Internal lighting Drying space Energy labelled white goods External lighting Low or Zero Carbon technologies Cycle storage Home office	Minimum standards at each level of the Code
Water	**Internal water use** External water use	
Materials	**Environmental impact of materials** Responsible sourcing of materials – building elements Responsible sourcing of materials – finishing elements	Minimum standard at Code entry level
Surface water run-off	**Management of surface water run-off from developments** Flood risk	
Waste	**Storage of non-recyclable waste and recyclable household waste** **Construction waste management** Composting	
Pollution	Global Warming Potential (GWP) of insulants NOx emissions	No minimum standards
Health and wellbeing	Daylighting Sound insulation Private space **Lifetime homes**	
Management	Home user guide Considerate constructors scheme Construction site impacts Security	
Ecology	Ecological value of site Ecological enhancement Protection of ecological features Change in ecological value of site Building footprint	

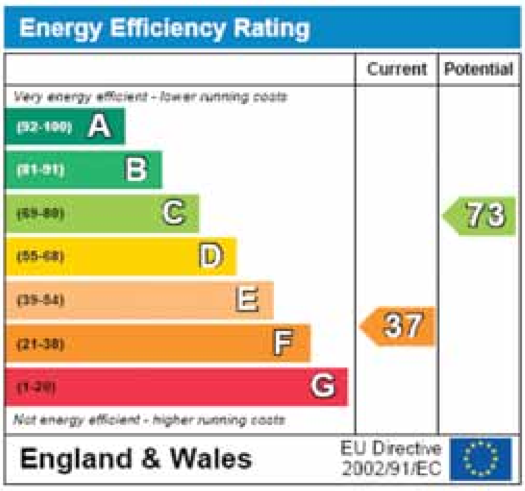
Table 6 – Elements in Code for Sustainable Homes



The definition of Zero Carbon is currently under review (CLG 2008, Zero Carbon Hub 2009), potentially introducing a more flexible view of zero carbon, removing issues such as energy used during the construction process and embodied energy, defined as the energy required to maufacture materials. In addition it allows investment in off-site renewable energy for developments to support their move to zero carbon. How this translates into more concrete guidance and its impact on development activity will emerge in the next few years.

6.4 Energy Performance Certificates

As part of a series of measures introduced to help cut carbon dioxide emissions from buildings, the UK Government has introduced Energy Performance Certificates (EPCs). From October 2008, these certificates have been required every time a building is bought, sold or rented. EPCs are prepared by accredited energy assessors alongside an associated report containing recommendations for building efficiency improvement and they rate the energy performance of a building from 'A' (most efficient) to 'G' (least efficient). An example EPC is shown in Figure 23.



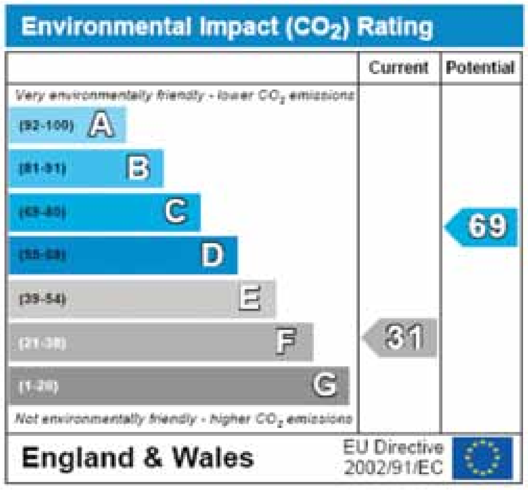


Figure 23 – Example EPC rating graph (communities.gov, 2009)

When domestic properties are marketed for sale, the EPC forms a compulsory part of the mandatory Home Information Pack (HIP) which is made available to all prospective purchasers. When a home is rented, the landlord is required to make an EPC available to the prospective tenant. Unless a building is subsequently modified, EPCs and their associated reports are valid for ten years from the date of issue and are submitted to a national register where they are kept for twenty years.

While there is currently no mandatory action required as a result of the findings of an EPC, it is hoped that they will act as a stimulus to encourage homeowners and builders to think in terms of improved energy efficiency. In the future it could be envisaged that improved energy performance may be incentivised via tax breaks and grant aid tied to EPCs.

It is clear that retrofit of existing housing stock to improve energy efficiency and reduce carbon emissions is inevitably a much more complex problem than the incorporation of best practice into new-build. EPCs along with regulatory imperatives arising from the Building Regulations and the Code for Sustainable Homes may help to clarify the issues in this area. The Warm Homes, Greener Homes Strategy (HM Government 2010) indicates that the Energy Performance Certificates will be improved to create a more robust, understandable model and be extended to wider forms of tenure.

6.5 Other Home Energy Assessment Standards

There are a number of other existing and emerging standards which may be considered. The current status of the standards as applied to the environmental performance of homes is developing quickly, as definitions are adapted, approaches changed and different tenure types affected. Over the coming few years it is envisaged that the landscape may well change radically.

6.5.1 Warm Homes Standard

The Warm Homes, Greener Homes Strategy (HM Government 2010) indicates that there will be an increasing level of standards in the rented sector. The Warm Homes standard will be applied in the social rented sector which will be achieved by 2020. Consultation is currently underway and the exact nature of this standard is yet to be fully understood.

6.5.2 The Private Rented Sector

The Warm Homes, Greener Homes Strategy (HM Government 2010) indicates that the private rented sector may be more stringently regulated in terms of energy efficiency than it has been in the past. There is an indication that basic energy measures, such as cavity wall and loft insulation, may be a condition of allowing a property to be rented out.

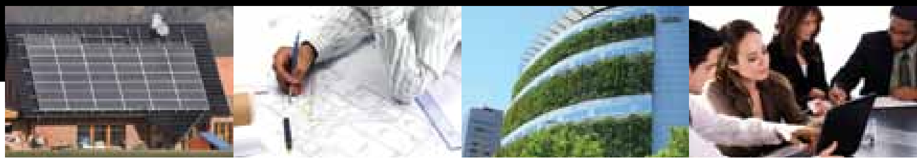
6.5.3 Eco Homes XB

The Building Research Establishment has developed the EcoHomesXB (BRE 2006) standard which is designed to help Registered Social Landlords undertaking a range of minor improvements to assess the environmental impact on the properties. This is not currently a regulatory standard, but as EcoHomes developed into the Code for Sustainable Homes (see section 6.3) it is worth considering how this may fit into the assessment and regulatory frameworks in the longer term.

6.6 Appliances

The Code for Sustainable Homes and Energy Performance Certificates focus largely on space heating and hot water. However, both address the use of lighting and appliances in the home (see Table 4). The issue of appliances in the home is worthy of more detailed consideration in terms of energy use and the related regulation designed to reduce these levels.

As can be seen in Figure 24, consumer electrical products, lighting, kitchen appliances and other electrical goods account for a large proportion of the total domestic electricity consumption. It is projected that by late 2010, total electrical consumption by domestic appliances may rise to 100 Terawatt hours (Energy Saving Trust, 2006).



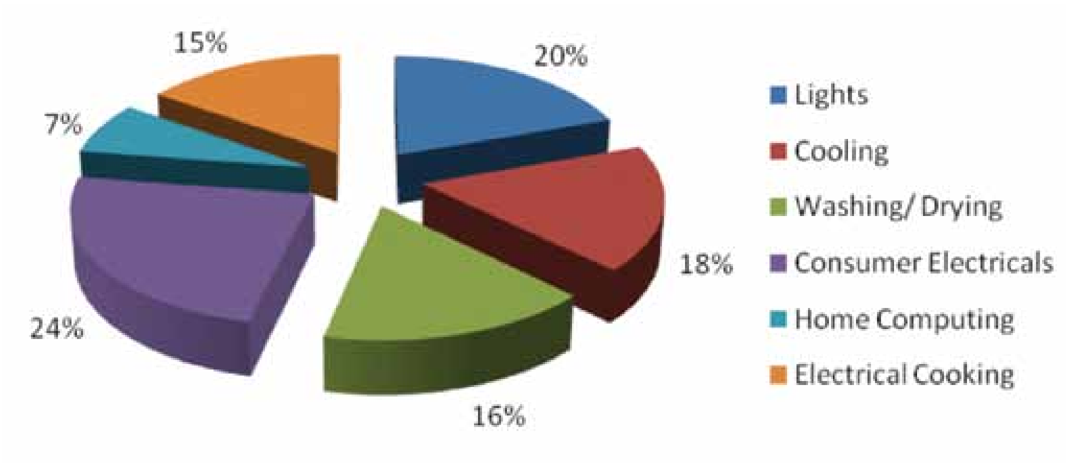


Figure 24 – Domestic electrical consumption breakdown, Source (ONS 2009d)

These appliances can be split into five broad categories:

- Washing and drying (washing machines, dishwashers, tumble driers etc)
- Cooking (Electric hobs / ovens, microwave ovens, kettles etc)
- Cooling appliances (refrigerators, freezers etc)
- Consumer electricals (audio visual, entertainment, communications etc)
- Home computing (PCs, printers, networking etc)

6.6.1 Energy Use by Appliances

Recent government studies indicate that there has been a substantial increase in both the choice and usage of energy consuming electrical appliances over the past three decades (Energy Saving Trust, 2006). While the efficiency of most domestic appliances has improved significantly over the last two decades, this improvement has been more than offset by a growth in both the number and choice of appliances available. There are also a greater number of remote controlled appliances which use standby switching and which are never truly switched off.

Figure 25 shows the increase in appliance energy use from 1970 to 2008. This does seem to indicate that much of the rise in energy use occurred prior to 1990, with a smaller proportion occurring over the last 18 years. This may indicate that although there are more appliances, there is a growth in their energy efficiency.

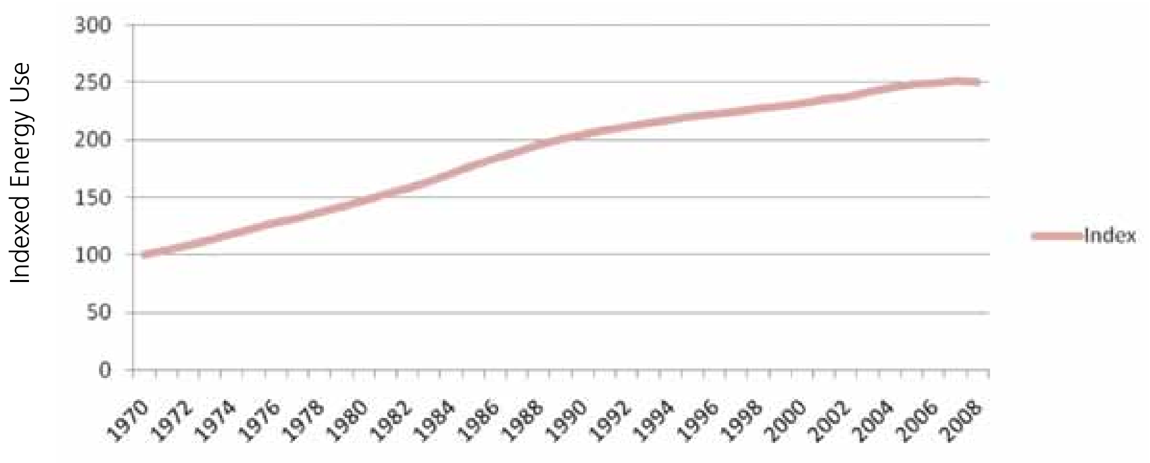


Figure 25 – Appliance energy use increase (indexed to 1970

Recognising the potential energy and carbon implications of this increase, there have been several initiatives which seek to both educate and change the behaviour of appliance users, and through the use of legislation, to encourage the design and manufacture of more efficient, lower energy appliances. In the UK, the Energy Saving Trust has produced several publications which highlight the impact of appliance use, notably the recent campaign regarding 'phantom loads'; devices left on 'standby' or 'powered up' serving no useful function but still consuming energy. These publications have been backed up by high profile media advertising campaigns. In addition, the Energy Saving Trust has introduced an optional UK specific 'recommended' labelling scheme to denote the most efficient appliances.

6.6.2 Regulation for Energy Use by Appliances

The EU has also introduced legislation which aims to mitigate the impact of appliance use. This is most commonly seen in the form of an EU 'Energy Label' (EU, 1992), which by law must be shown on all refrigeration appliances, electric tumble dryers, washing machines, washer dryers, dishwashers, electric ovens, air conditioners, lamps and light bulb packaging.

While there is no specific legislation to cover the labelling of home entertainment and computing products, the EU has introduced the 'Stand-by' directive which, amongst other requirements, from January 2010 regulates the availability of 'stand-by' modes in appliances and the energy consumption in 'off' and stand-by' modes (European Commission, 2009). It should, however, be noted that despite the sometimes emotive language used when they are discussed, phantom loads are something of a 'drop in the ocean' when considered against other forms of domestic energy consumption – MacKay (2009) observes that "The energy saved in switching off [a mobile phone] charger for one year is equal to the energy in a single hot bath".

7.0 People and Behaviour

The issue of people and behaviour is complex and challenging. Energy use differences in households can be driven by all of the technical issues we have already highlighted; fabric, heating and hot water systems and appliances. However, given the same property, systems and appliances, similar households can have very different patterns of energy use. Some of the issues are quite practical while others may be driven by more complex factors.

There is a large amount of economic, sociological, psychological and behavioural theory around this issue (ESRC 2009). We have tried to break down some of the key issues into factors which may be considered independently, but accept that many of these interact in many different ways. What should be understood is that there is no such thing as an "average household". Even given constant factors, human elements can impact energy use in quite diverse ways. Recent studies in the UK have shown that energy use in homes may vary by 2-3 times in similar properties (Summerfield 2010).

7.1 Influencing Factors

7.1.1 Households and Patterns of Living

Put simply, the size of the household and the way they live will govern domestic energy use. Individuals who remain at home all day, such as older or retired people, will generally use more energy than those who go to work. This does not mean they use more energy overall, as travelling and energy used at work should be considered. Families may use more energy than single people with a greater requirement for hot water, cooking and cleaning energy, as well as more rooms in a house being occupied at any one time. Current data indicates that there is a trend towards more and smaller households which will change the pattern for domestic energy use at a national scale (ONS 2009d).

7.1.2 Wealth

Some households, such as those in fuel poverty, may have constraints on their energy use. They may have to make economic choices that households with greater disposable income may not. This also has implications for energy saving options which may be applied to these households, where they may choose to spend money on more heat, rather than take a financial saving.

This is known as the "rebound effect" (UK Energy Research Centre 2007), which can sometimes be 10-30% of energy savings. Understanding how these impacts effect energy use is important when attempting to calculate any predicted energy saving. For wealthier individuals, where energy is a lesser component of overall expenditure, they may be less concerned with regards to small changes in their bills, potentially leading to less energy efficient behaviours.

7.1.3 Understanding Energy Use

We can see that energy use is a complex issue and it can be difficult for people to understand how energy is used. They can be subject to a disconnection between their energy use and its implications. Smart metering is designed to address this issue by giving individuals real time data. Connecting people to the financial implications of their energy choices may be considered important, but evidence of the variation in how people's behaviours change given this information, indicates that the other factors driving energy use by households and this can undermine the idea of a "rational energy consumer". Studies have shown (Darby 2006) that smart meters can offer savings of 5-15% for households, but are better supported by additional interventions.

An additional issue is that householders do not really understand which different components of their energy use have the greatest impacts. Most people do not understand the costs of leaving things on standby as compared with walking instead of using the car for short journeys. This is because it is difficult to obtain and understand the data which could better inform these choices.

7.1.4 Managing Energy Use

Most of our domestic energy use is for heating and hot water, but many people do not understand how to manage their heating systems in the most effective manner. Controls may be difficult to understand, the need to service the equipment may not be appreciated, and they may not know what patterns of use will deliver their desired outcomes most efficiently. Many people tend to rely on trial and error when operating systems and appliances (Government Office of Science 2008).
In addition, individuals may not have the knowledge required when considering upgrades for their homes. Inaction can be driven by a lack of knowledge, which individuals may perceive as a risk factor.

7.1.5 Customs or Norms

Customs or social norms are concerned with the way people do things as groups (ESRC 2009). They are accepted shared ideas that mean people will do things in a certain way or demand certain outcomes. They are subject to change over time. Older individuals may have a different attitude to energy use than younger people. Customs will also vary from country to country. Quite often customs can be established for rational reasons, but while those reasons change, the custom remains in place. At other times they may be established for no rational reason. Choices we make about our expected levels of comfort are very different to those in developing countries, or those previous generations may have made in the UK. They may not only be the customs of individuals and households that affect energy use, but also those of builders or energy systems providers. A stark example is that of our comfort expectations which has seen the average internal temperature of residential buildings rise from 12°C to 18°C since 1970 (Committee for Climate Change 2008), which has potentially been driven by changing attitudes towards acceptable comfort levels.

7.1.6 Habits

Habits tend to be more ingrained than custom, being concerned with individual behaviours. Habits are, sometimes unconscious, patterns of behaviour we adhere to. Some people may turn off lights as they leave a room, others may not. Some may shower every morning, others may not. The link between what is a habit and what is a custom can be hazy. Habits are powerful behavioural patterns that may act against rational behaviour and can be very difficult to change. Generally, energy use is not considered price sensitive and is often driven by habitual use (ESRC 2009).

7.1.7 Values

Some people may categorise themselves as environmentally aware or "green". Given these values, people will then make specific conscious decisions about managing their energy use. Some people may find it less important. This is a question of the different values that people hold. For "green" individuals, energy, and wider resource use, is an ethical decision. They will generally have more knowledge about the impacts of their choices, but there is an ethical dimension which makes their decision-making more than rational. The model is not as simple as whether someone is green or not. The Foresight Report "Powering Our Lives" identified 7 categories of consumer energy values, ranging from "positive greens" to the "honestly disengaged" (Government Office of Science 2008).

7.2 Influencing Peoples Behaviour

We have seen that people's decisions about their energy use are complicated; rational and irrational, conscious and unconscious. Looking at the data regarding the reasons why people have not installed cavity wall insulation (Figure 26), the reasons for not improving the energy efficiency of their homes can cut across many of these issues.

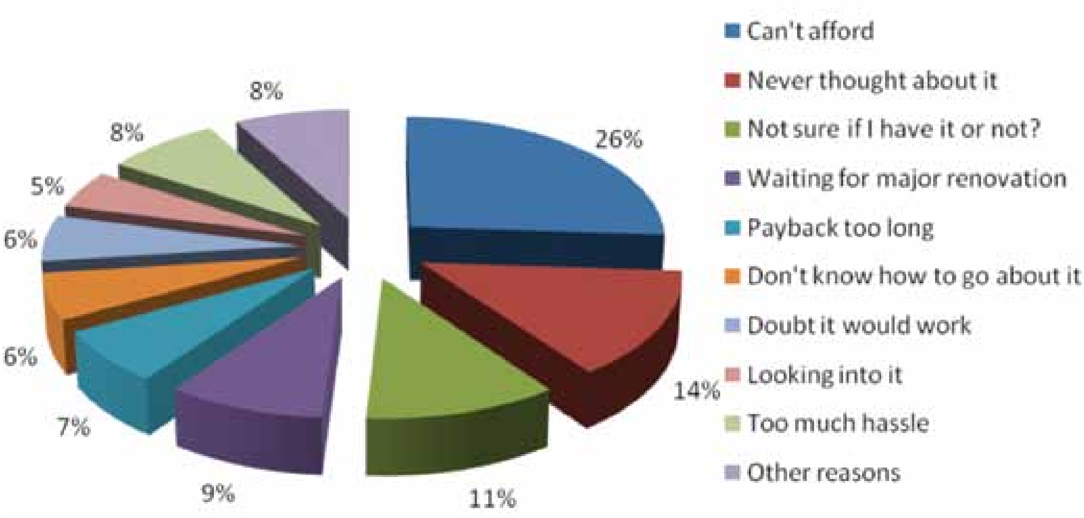


Figure 26 – Reasons stated for not installing cavity wall insulation (HM Government 2010)

This is of particular relevance for the owner-occupier market, which accounts for approximately 70% of all homes. With ambitious targets for eco-upgrades (HM Government 2010), how to motivate behaviour change and activity on the part of this sector is an important problem.

7.2.1 Taxes

At the most basic level, taxes and incentives (see section 7.2.2) are designed to change the price of a particular commodity or activity to encourage or discourage its consumption. They make take the form of direct taxation, subsidies or grants. Taxation is applied to make something more expensive. However, in the case of energy for heating homes, taxation can be viewed as regressive and increase the risk of fuel poverty (Bichard and Kazmierczak 2009).

7.2.2 Financial Incentives

As stated above, incentives are designed to encourage the consumption of a particular commodity or service. Subsidies through CERT (Carbon Emissions Reduction Tariff) or through other grant regimes are designed to increase the uptake of insulation and renewable energy technologies. The feed-in tariff, for example, is designed to subsidise electricity sold back to the grid to encourage the installation of microgeneration technologies. However, incentives can sometimes have the law of unintended consequences and must be closely monitored to ensure that they meet the policy objectives rather than create a narrow behaviour which is not beneficial.

7.2.3 Other Financial Models

Pay as You Save (HM Government 2010) is neither a grant nor a subsidy. Rather it removes the need for up-front capital investment on behalf of the home owner, using the income stream from savings or generated electricity to pay for a loan which covers the investment in any environmental upgrade on a property. This model is still in the pilot stage and the longer term consequences are still unknown.

Another approach, which has been highlighted in the Warm Homes, Greener Homes Strategy (HM Government 2010), is the issue of how energy efficient homes are valued. Discussions are ongoing with the RICS to reflect this benefit into the value of a home which may encourage homeowners to view eco-upgrades as having a greater financial benefit.

7.2.4 Other Reward-Based Incentives

Work undertaken at Salford, on behalf of the Environment Agency (Bichard and Kazmierczak 2009) looked at the possible influences of non-financial rewards. These may take the form of reduced fee services already provided at the local level such as free travel. This approach has benefits over the tax or subsidy system as it does not discriminate against low income households. Taxes may further exacerbate the difficulties of those already in fuel poverty, while subsidies support those who may have an initial capacity to invest, excluding low income families.

7.2.5 Education and Advice

As we can see from Figure 26, the lack of knowledge, or even basic awareness about the issues and how to go about resolving them, is clearly a huge influencing factor on the actions and behaviours of people. The Government has a wide ranging programme of advice and support through organisations such as the Energy Savings Trust and the Carbon Trust.

This is further supported by enormous amounts of coverage and information available through various media outlets. We should consider that this does not impact all people in the same way. There are those who may not have access to education, or do not engage with media outlets which discuss climate change or energy conservation as an issue.

The Warm Homes Greener Homes Strategy (HM Government 2010) identifies the weaknesses in the current information system and proposes a series of developments to improve the quality of advice on domestic energy efficiency.

7.2.6 Community Engagement

Bichard and Kazmierczak (2009), in their study of motivational factors on energy use and flood defence, identified the complex nature of change behaviours. They looked specifically at the adoption of new behaviours at a community level, which has resonance with the Warm Homes, Greener Homes Strategy (HM Government 2010) in identifying that education and awareness raising is only a small part of changing behaviour. Issues such as the "social norms" people hold, their own internal values and the values they perceive as held by wider society have a huge influence on behaviour. In addition, their own sense of connectedness to a particular problem or issue makes a huge difference to their behaviour.

This section is designed to highlight the high level concepts across a wide range of interrelated factors. While we are not able to fully address all the debates that surround people and energy use, we can see the importance of understanding these issues for wider energy policy and effective intervention. As stated at the start of the report, the problem is not only technical, but socio-technical. An effective understanding of potential outcomes should a given strategy be pursued; tax, subsidy or community intervention, for example, needs to be developed if the approach is to be effectively evaluated in light of the high level policy objectives we have discussed.

8.0 Conclusions

- Any path to a low carbon future must include the domestic sector. It accounts for a significant amount of both energy consumption and carbon dioxide emissions and currently relies on a system that is predominately driven by fossil fuels. The UK Government recognises this, having published a wide variety of policy documents designed to consider the issue of domestic energy use. However, we must apply a whole system approach if we are to address the issues in a coherent way. While the housing stock is a large part of that system, placing obligations on just the physical parts of the system will not work; we must consider the role of energy infrastructure, regulation and the people who live in the homes. There is an argument for a better understanding of the specific impacts of each part of the system in order to evaluate where action might most effectively be taken for the improvement of the whole.

- The regulation and enforcement of a low carbon domestic sector needs to be consistent and "joined-up" in approach. We have seen that the regulatory models currently in use cut across one another and have varying levels of enforcement. When combined with the high volume of advisory and policy documents a, perhaps unnecessarily, complicated picture is presented. It may be considered that these issues need to be simplified to enable those tasked with the delivery of energy efficient housing; either new build or existing stock, to more clearly understand which of these elements should take precedence. Also, the regulation should not lose sight of the broader policy objectives that have been set. While it may be desirable to take a particular course of action given a narrow view of the problem it must be considered as to whether it is delivering the policy objectives of fuel poverty, carbon emissions and energy security. We must avoid hitting narrow targets and whilst missing the big picture. It may be viewed that regulation is driving change in the sector, with the environmental performance of homes at the forefront of people's minds.

- If energy policy objectives are to be achieved, there are a number of options available to us. Considering carbon dioxide emissions, we have the option of changing either the way we generate energy, or the way we use energy in our homes. Each represents a different kind of challenge. While the energy supply system has limited numbers of stakeholders that need to be influenced, technological lock-in makes it difficult and expensive to change. However, making changes to the way the domestic sector uses energy is possibly even more complex and, given the wide variety of impacting factors, the returns on a specific investment acting on these parts of the system could be far from predictable.

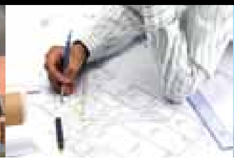
- The financial environment and the mechanisms used to fund any changes are essential. The Warm Homes, Greener Homes Strategy makes positive strides in starting this conversation. An understanding of the outcomes of the financial models is essential to avoid the law of unintended consequences. However, the actions committed to so far do provide a starting point for innovation around the financial and regulatory aspects of the system. More thinking of this nature needs to take place, while effective understanding is gathered to appreciate the impacts on individual homeowners, markets and the wider policy objectives.

- Housing professionals, supply chains and trades must be able to effectively deliver both the quality and volumes of work for the extensive programme of change that will be required. As it stands, it appears as if the firms within the market are playing "catch-up" to the problem, with fragmented and under-developed supply chains. We could consider we are still at the experimental stage, with a large number of demonstration projects. However, the problem is one of what to do at scale. The "right thing to do" at this level still appears to be some way off, with the evidence not entirely clear with regards to the best action to take. If retrofit is to be effective in the owner-occupier market, it must progress towards being a consumer product that is trusted in the market place and ultimately delivers improvements. In determining these "right things to do", we need to look not only at products, but also the "green" services jobs and skills that are very much part of this agenda.

- Compared to 10 years ago, there is a wider understanding of not only the importance of energy efficiency, but also the wider implications of energy use and climate change. However, energy use may be described as invisible consumption, where there is disconnection between how energy is used, its financial and social costs and environmental impact. There has been good work to change this situation; prevailing norms and values can be seen to have changed over time. What is less clear is how this has translated into long-term behaviour change. There does need to be a better understanding of how our behaviours and lifestyles affect our patterns of energy use.

- The low carbon domestic energy system needs low carbon people. However, behaviour change and motivation to action are still not well understood. Although education and behaviour change have a role, this should be supported with innovative design around how people use energy in their homes. The design community, including architects and product designers, have an opportunity to design in such a way that people are helped to live low carbon lives. A recent design award for a slim line plug indicated that we had not changed the design of the plug for over 40 years. If design is, to some extent, the "art of seeing", then there may be some real opportunities to look again at the home, the systems and appliances within it and bring innovation to bear.

- We must recognise that the ground is moving very quickly under our feet in terms of the problem and our responses to it. We have had a recent change of government which creates some uncertainty as to what the policy response might be in the short to medium term. The Warm Homes, Greener Homes strategy was launched in March, while this document was being written and its content has still to be reiterated by the incoming government. The Home Information Pack has been scrapped as of mid-May, although Energy Performance Certificates still have a role to play. Given the rapidity of change, we must balance the ability to be fleet of foot against the fact that retrofit represents a long-term strategic challenge for the housing sector as a whole. The systemic nature of the problem we are addressing means that changes in policy, regulatory frameworks or standards have implications for the wider system and we must be aware of their consequences.

9.0 Implications for the Salford Centre for Research & Innovation

The Salford Centre for Research and Innovation (SCRI) is a multi-disciplinary research centre which looks to drive change in the industry. Working towards addressing the problems of housing, and specifically the energy aspects of these problems has been underway for some time. There is currently agreement from both policy makers and the industry for the need to find solutions to the issues we have highlighted in this report. As researchers, we need to consider the fundamental issues underlying the problems and shape our response accordingly. Some of the main considerations for SCRI are:

- The problem of domestic energy use is systemic. As such it needs a trans-disciplinary approach. This means we cannot rely solely on engineers providing technical solutions, or behavioural scientists telling us how best to change people's behaviours. It requires a collaborative approach to the problem, where there is a shared understanding of how the different disciplines can bring something to the whole. SCRI has made strides in this direction by bringing together academics and industry partners to create this shared space, as well as developing projects which address the problems.

- The problems are pressing and real and require effective engagement between the research base and industry. Research cannot be done in a vacuum and then transmitted to industry; there needs to be a more profound engagement where ideas are shared and solutions are "co-created". Research questions must be developed in unison with partners and the results shared and acted upon. SCRI has a long tradition of working in this way, and these principles form the basis of the Housing Application Area.

- Understanding regulation and its power and influences on the sector is vital. It is clear that regulation is shaping how industry is responding to the problem, but we need an understanding as to whether this is driving the right behaviours in the medium to long term. Equally, new models, such as "pay as you save" and the feed-in tariff, present new ideas which need to be fully understood. We have to comprehend how effectively these regulatory or financial models are driving innovation and supporting the development of the industry in response to what is a complex and long-term problem. SCRI is undertaking work in this area looking at the Code for Sustainable Homes, as well as working within the social housing sector and considering their response to the retrofit problem.

- If it is to deliver against current targets the housing sector, including repair and maintenance, must undergo a radical sectoral and organisational transformation. New products, supply chains, processes and business models will change, appear and disappear during this time. We need to fully understand the current situation and anticipate what an integrated value and use supply chain might look like in order to effectively deliver the "green sector" policy makers are looking to develop.

- People and communities are a core part of the system. Understanding how individuals behave and interact in relation to energy use and the built environment is important if we are to create effective responses to the issues of domestic energy use. SCRI has long recognised the role of people as a key element of value creation in the built environment through its Value in Use Theme. In addition, supporting work has been undertaken with the Environment Agency to look at the role of communities in changing the perceptions and behaviours of individuals. People remain at the centre of the question of domestic energy use and SCRI is looking to engage with this area.

- Technology is important. Well-designed solutions are an essential part of solving the problem. SCRI is forming partnerships with the engineering disciplines to investigate this area; most importantly with the Salford Energy House. Working with engineers, SCRI brings a wider understanding of the context in terms of innovation and people. SCRI is looking to work in trans-disciplinary teams with technology providers to help them consider the wider implications of product innovation to support effective delivery.

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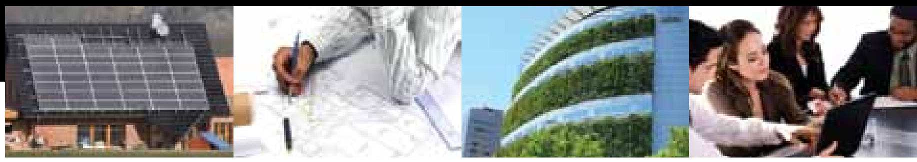

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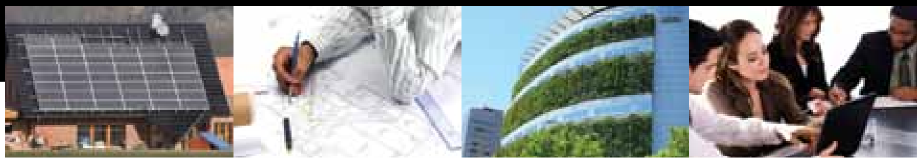

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