
House
UNIVERSITY OF OXFORD

Funded by:

The 40% House project has been a collaboration between the Environmental Change Institute, University of Oxford (who co-ordinated the work), the Manchester Centre for Civil and Construction Engineering at the University of Manchester Institute of Science and Technology (now part of the University of Manchester), and the School of Engineering and Physical Sciences at Heriot-Watt University, Edinburgh.

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FUTURE WORK

The 40% House project will be followed up by *Building Market Transformation* (BMT), a consortium led by the ECI under *Carbon Vision – Buildings*, funded by the Engineering and Physical Sciences Research Council and the Carbon Trust. BMT will focus on scenarios that cover all energy use in the entire UK building stock, except for industrial processes. There are two other consortia in *Carbon Vision – Buildings*. One is led by Heriot-Watt University, Edinburgh; and the other by University College, London and De Montfort University.

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40% house

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Executive summary

The UK residential sector can deliver a 60% reduction in carbon dioxide emissions by 2050, in line with the targets outlined in UK Government's 2003 Energy White Paper. Such a reduction is essential in light of the growing impact of climate change. This represents a significant challenge that requires some hard, but necessary, decisions if these savings are to be achieved. Urgent problems require radical solutions – current policy is not taking us to where we need to be.

Many of the constituents of the 40% House scenario for 2050 are challenging, but that demonstrates the scale of change needed. Whilst this represents just one solution to the issues faced, it is clear that the overall target is non-negotiable – if less is done in one area or sector, more will need to be achieved in another.

- The focus is on the role of households in securing emissions reductions, covering the building fabric, lighting and appliances, and building-integrated technologies.
- The aim is market transformation of the total housing stock to the average of a 40% house, with the emphasis on strong regulation and product policy. A proactive, rather than reactive approach is taken.
- All four principles in the Energy White Paper are addressed in achieving the 40% House: the 60% target, fuel poverty, security of supply and competitive markets.
- These savings are achievable even with the constraining assumptions made, including a 33% increase in household numbers between 1996 and 2050, a smaller average household size (from 2.4 to 2.1 people per household), stable emissions factors from 2030 and no reliance on unknown technological advances.

Over a span of 50 years, substantial changes will occur – technologies, appliances, housing styles not even thought of today could form part of everyday life. In five decades from now, most central heating systems and appliances would have been replaced at least three times, the majority of power stations replaced twice and almost the whole of the electrical and gas distribution network renewed. As well as illustrating the level of change that will occur over this timeframe, this also highlights the considerable opportunities for intervention that exist, fitting in with the natural cycles of replacement. Prompt action will ensure that the appropriate technologies are available to match these cycles. The improvements set in motion now to reach the 60% reductions target will continue to provide benefits to 2050 and beyond.

Housing

The efficiency of the UK housing stock is improved substantially by 2050. This occurs through altering the standard of the existing stock, the quality of new-build and the relative proportions of each.

Current stock

- Two-thirds of the dwellings standing in 2050 are already in existence. A substantial programme to upgrade these existing houses results in an average space heating demand of 6,800 kWh per annum.
- This requires insulation of 100% of all cavity walls, 15% of all solid walls, 100% loft insulation (to a depth of 300 mm) and 100% high performance windows.
- The aim is to achieve as much as possible through retrofit measures before resorting to demolition, which is more disruptive and expensive.
- The worst houses, around 14% of the current stock, are removed through a targeted demolition strategy – care must be taken not to invest money in upgrading those homes that will ultimately be demolished.
- This requires demolition rates to be increased to four times current levels, rising to 80,000 dwellings per annum by 2016.

New-build

- Construction rates are increased to replace the demolished homes and to meet the rise in demand for housing due to the growing population.

- New build is a third of the stock in 2050.
- This requires an average construction rate of 220,000 per annum.
- These new homes are built to a high energy-efficiency standard, with an average net heating demand of 2,000 kWh pa in all new dwellings from 2020.
- Appropriate design and siting limits the requirement for air conditioning. Cooling is achieved through passive measures.

Housing stock in 2050

- By 2050, the number of households will have increased to 31.8 million, housing a population of 66.8 million, with an average of 2.1 people per household.
- The average efficiency of dwellings is a SAP rating of 80, with a SAP of 51 (the current average) as the minimum standard.
- Fuel poverty has been eliminated, with affordable warmth and cooling for all households.
- The needs of single people are recognised through the provision of smaller housing in appropriate locations.

Policy

- The various aims would be best incorporated into a long-term, over-arching UK energy and housing strategy that covers both the rate of turnover in the housing stock and the resultant energy use and carbon emissions.
- The strategy would have a full remit to consider the implications of location, tenure, size and density of housing developments over the next 50-100 years.
- The energy and housing strategy clearly defines the role of grants in improving the stock of dwellings and the extent to which these should be primarily focused on eliminating fuel poverty, as at the moment, and whether additional resources should be available for encouraging best practice.
- Responsibility for implementing the energy and housing strategy is largely devolved to local and regional authorities.
- The Building Regulations set the minimum standard for new build and renovation. A clear strategy for standards (and their enforcement) over the next 40-50 years is required to identify the necessary technologies and appropriate timescales to ensure transformation of the housing stock.
- Providing information to consumers and local authorities on the energy performance of a dwelling is essential to guide policy and push the market towards more efficient homes. A universal, address-specific database of the energy efficiency of individual homes (on an established scale), collated at the level of each housing authority, would provide this detail.

Lights and appliances

All households, new and existing, are installed with energy efficient appliances and lighting throughout, representing the best technology currently available. Further savings are possible through new and unforeseen technologies that may emerge over the next 50 years, but do not form part of the quantified scenario.

- Household electricity demand for domestic lights and appliances (excluding space and water heating) is reduced to 1680 kWh per annum – almost half current levels.
- The key technologies installed include vacuum insulated panels (VIPs) for refrigeration and LED (light emitting diode) lighting in all households.
- Peak electricity demand is reduced through appropriate appliance design.
- The rapid turnover of the stock of lights and appliances means that savings can be achieved quickly, once appropriate policies are in place. This would contribute additional savings to achieve the UK's Kyoto targets for 2008-12.

Policy

- Market transformation is already established as the main policy approach in this sector, but has not yet be used to full effect. The emphasis needs to be on stronger, more focused measures, such as minimum standards.

- Replacing policy on energy efficiency with policies on absolute energy demand would encourage downsizing and could reverse the present trend towards larger (more energy consuming) equipment.
- Manufacturers must be encouraged to view energy-efficiency as a vital component of product design to prevent energy-profligate equipment appearing on to the market. This could be achieved under the European Energy-using Products Directive.

Space and water heating

The way in which the space and water heating needs of the residential sector are met is revolutionised, with an average of nearly two low and zero carbon (LZC) technologies per household.

- LZCs cover community CHP (combined heat and power), micro-CHP (at the household level), heat pumps, biomass, photovoltaics (PV), solar hot water heating and wind turbines.
- In all new build, LZCs are installed as matter of course. Existing dwellings are retrofitted when and where appropriate.
- This would be sufficient to meet total residential electricity demand from low-carbon sources and turn the residential sector into a net exporter of electricity by 2045.

Policy

- A complete market transformation to LZC could be achieved over the course of 2005 to 2050, which could be considered as three heating system replacement cycles of 15 years each.
- Building regulations specify the minimum standard for LZC technologies in new build and renovations.
- The substantial capital investment in building-integrated LZC will only occur through novel policies, for instance, energy service companies or feed-in tariffs.

Consumers and society

Society has been transformed to become more community-minded and environmentally-aware, providing the necessary framework and support for successful implementation of the required policies.

- If UK society continues to develop along current trends, no carbon emissions reductions are expected by 2050.
- Only societies where environmental concern and awareness are much stronger than today will produce significantly reduced carbon emissions.
- Changing social priorities is an important Government action as part of meeting its carbon reduction target.

Policy

- Feedback and information are an essential part of raising awareness. The design of utility bills, electricity disclosure labels, the tariff structure and the existence of the standing charge all need to be considered in terms of discouraging consumption and improving the energy-literacy of society.
- As an example of an appropriate framework, personal carbon allowances (PCAs) offer an equitable solution to achieving greater carbon awareness amongst consumers, by placing a cap on individual consumption.

Conclusions

Securing a 60% reduction in carbon emissions from UK households is a considerable challenge that requires a radical shift in perspective in the housing, appliance and electricity supply industries and policy co-ordination across a number of Government departments. Current policies, programmes and trends are not sufficient to put the UK on a trajectory that will lead to this level of emissions reductions by 2050. A clear over-arching strategy that deals with both the energy and housing needs of UK dwellings, with an emphasis on carbon mitigation, is necessary.

Introduction

The 40% House project has investigated how the UK Government's commitment to a 60% cut in carbon emissions from 1997 levels by 2050 can be realised in the residential sector, so that the typical home becomes a '40% House'.

This report summarises the main findings and recommendations of the 40% House project towards achieving this target, setting out, as explicitly as possible, the decisions that face policy-makers. It explores the technical and social possibilities for reducing energy demand and integration of renewable energy technologies within the building fabric, in order to propose a policy agenda for transforming the housing stock over the coming half-century. The policy pathway chosen is market transformation – the substitution of products, systems and services that have lower environmental impact than those used at present. The elements of the '40% House scenario', developed over the course of this project, are discussed, demonstrating how a combination of technological advances and policies can cut carbon emissions radically without compromising comfort and service levels.

Glossary
This report is intended for a non-specialist reader, so technical jargon and acronyms have been kept to a minimum. Specialist language is explained in a glossary at the back of the report.

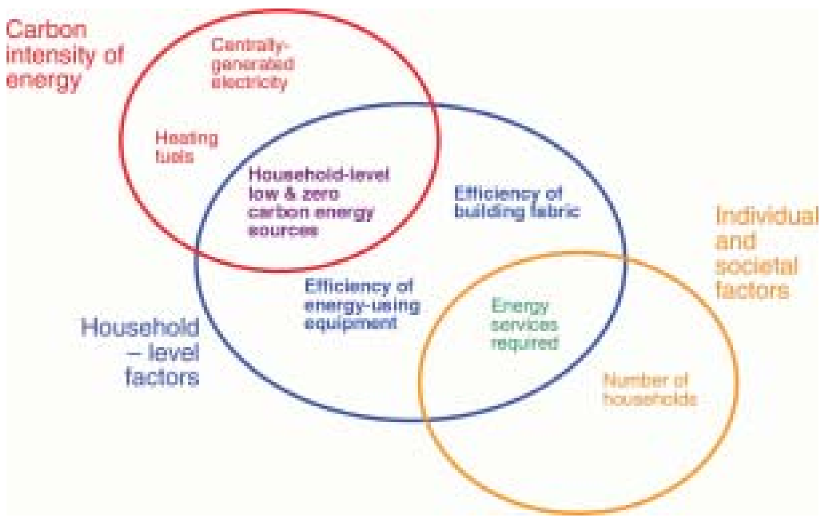


Figure 1.1: Key factors determining UK residential sector carbon emissions

1.1 Project scope

The 40% House project has focused primarily on demand-side influences on residential carbon emissions which can be changed through government policy. Figure 1.1 provides a simplified representation of the key factors influencing carbon dioxide emissions from the UK residential sector. These can be divided into three overlapping spheres: carbon intensity of energy, household-level factors and individual and societal factors. Fuel prices and economic factors influence all three spheres. This project has focused on policy approaches which provide savings by influencing the factors shown in bold type, ie household-level low and zero carbon energy sources (LZC), including solar hot water heating, solar photovoltaics (PV) and micro-combined heat and power (CHP); the efficiency of the building fabric and the efficiency of energy-using equipment.

Although the other factors identified in the diagram, as well as cost issues, are also of great importance in determining carbon emissions, they are not the main focus of the report for the following reasons:

- **Household numbers**. Household numbers are discussed thoroughly in Chapter 3, but policies will not be suggested to influence them. A central projection of household numbers will be used to inform analysis on how to achieve the 40% House.
- **Energy services**. These are the services that people gain from using energy and include warm rooms, hot water, a well-lit home and refrigerated food. The general approach in this project has been to broadly accept today's standards of energy services as a given – policies to influence this component of energy demand are not developed. The key exception is that home temperatures are expected to be higher in future (Chapter 4). Social change could result in higher or lower demand for energy services (Chapter 2). A reduction in demand could come about as a response to the

The serious consequences of climate change can be averted by reducing carbon dioxide emissions. One quarter of all emissions come from the residential sector

repeated impact of extreme weather events, at home and abroad, or from the imposition of tougher post-Kyoto international agreements. One route to influencing energy service demand would be to introduce personal carbon allowances (Section 1.5.1).

- **Carbon intensity of centrally-supplied fuels**. A future 'fuel world' that is largely similar to the present has been assumed, with no constraints on the use of natural gas. Emissions factors from electricity generation in power stations have been addressed in Chapter 8. By not including the possibility of very significant contributions from lower carbon options on the supply side, the target set for the project of a 40% House was made all the more challenging.
- **Cost of fuels**. The impacts of future residential fuel prices were not included in the analysis because of the huge uncertainties in energy prices over 45 years, depending on future availability. For example, if over-use in the next 30 years creates scarcity in 2050, energy prices in 2050 will be much higher than if efficiency and low carbon energy supply measures were introduced early.

1.2 Climate change

There can be little doubt that climate change is the most important environmental problem facing the world community. Indeed, it is seen by many as the most important problem of any sort, with the UK government's chief scientist, Sir David King, declaring: "*climate change is the most severe problem that we are facing today – more serious even than the threat of terrorism*" (King 2004).

Climate change is caused by the emission of additional 'greenhouse gases' (GHGs) into the atmosphere. The single most important GHG is carbon dioxide, which is generated primarily from fossil fuel burning. Additional carbon dioxide stays in the atmosphere for up to 200 years, and there is no quick way of reducing atmospheric concentrations (Jardine et al 2004). The best that can be done is to reduce emissions in order to stabilise concentrations at the earliest opportunity.

The evidence for climate change both in the UK and globally is extremely clear. Global surface temperatures have risen by 0.6°C, with those over central England rising by 1°C over the last century (IPCC 2001, Hulme et al 2002). In the summer of 2003, a new temperature record of 38.5°C was set in the UK (Met Office 2004). These higher temperatures are already having serious impacts: during summer 2003, a heat wave throughout Europe caused an estimated 35,000 deaths (EEA 2004). Rising temperatures have not been the only consequence. There is strong UK evidence for changing rainfall patterns and extremes of climate. Because of accelerated climate change, it has been suggested that: '*Many regions and populations are already beyond acceptable thresholds of exposure to climatic risk*' (RS 2002).

The degree of climate change expected in future depends on emissions of greenhouse gases, with higher emissions totals leading to greater climate change. The UK can expect warmer and wetter winters along with warmer and drier summers, with the average annual temperature rising by between 2°C and 3.5°C by 2080 (Hulme et al 2002). Globally, temperatures could rise by up to 6°C by 2100 (IPCC 2001). The likely effects on humans and the natural environment of high emissions scenarios range from the extinction of species to the creation of millions of environmental refugees (Thomas et al 2004, Conisbee and Simms 2003). Many countries will be under threat from rising sea levels, droughts, storms, heat waves and extreme economic and social disruptions. Sea level is predicted to rise by up to a metre over this century which could, for example, lead to a loss of over 20% of Bangladesh's land area, where an eighth of the country's population live (IPCC 2001). The consequences of allowing the higher emissions scenarios to become reality are global, highly damaging and almost unthinkable.

1.2.1 UK and international response to climate change

The world community has responded collectively to climate change by adopting the United Nations Framework Convention on Climate Change in 1992, followed by the Kyoto Protocol, which came into force in February 2005. Under Kyoto, the UK has a greenhouse gas reduction target of 12.5% of 1990 levels by 2010, as part of a European Union collective target of an 8% reduction. Several EU countries, including the UK, have gone beyond the Kyoto target to suggest future greenhouse gas and carbon dioxide emissions targets, and these are summarised in Table 1.1. These targets are far more ambitious than the short-term Kyoto goal and may offer a starting point for future international negotiations.

Table 1.1: Examples of long-term climate change targets set by European countries

Country	*Maximum allowable atmospheric concentrations of GHGs*	*Carbon dioxide emissions reductions commitments*
France	Stabilise CO_2 concentrations at 450ppm or less	Limit per capita emissions to 0.5 tonnes carbon (tC) by 2050
Germany	Limit surface temperature rise to 2°C or less compared with pre-industrial levels, and to 0.2°C or less per decade. Limit CO_2 concentrations to below 450ppm	Reduce energy-related CO_2 emissions by 45-60% compared with 1990 levels by 2050; will commit to 40% reduction by 2020 if EU commits to a 35% reduction over that period
Sweden	Stabilise atmospheric concentrations of all GHGs at 550ppm, with CO_2 concentrations at 500ppm or less	Reduce per capita emissions of CO_2 and other GHGs of developed countries from 2.3 tC to below 1.2 tC by 2050, and further reduce thereafter
UK	Stabilise CO_2 concentrations at 550ppm or less	Reduce national CO_2 emissions by 60% compared with 1997 levels by 2050

Sources: French Interministerial Task Force on Climate Change (2004); German Advisory Council on Global Change (2003); Swedish Environmental Protection Agency (2002); DTI (2003c)

The UK's target of a 60% reduction by 2050 was originally suggested by the Royal Commission on Environmental Pollution (RCEP) as a means to limit the rise in atmospheric concentrations of carbon dioxide to 550 parts per million (ppm) (RCEP 2000) and was adopted by the Government in the 2003 Energy White Paper (DTI 2003c). The RCEP target was based on the assumption that all nations would be contributing to a global reduction in carbon emissions via a framework called 'contraction and convergence'. This ensures that over time, firstly global carbon emissions would contract and secondly, there would be global convergence to equal per capita shares of this contraction (GCI 2001). The UK Government has not yet adopted contraction and convergence as its international negotiating position for the period after the Kyoto agreement, despite RCEP's advice. Setting a national target is only part of what is needed to stabilise global atmospheric concentrations of carbon dioxide and other greenhouse gases – it has little value unless it eventually forms part of a strong global agreement, which the UK must work towards achieving.

There are increasing fears, based on new scientific data, that 550ppm may far exceed a 'safe' level of carbon dioxide in the atmosphere. For example, the recent report of the International Climate Change Taskforce claims that 400ppm is likely to represent a point of no return, beyond which climate change could spiral out of control (ICCT 2005). The current level is 378ppm, rising at around 2ppm per year – only 20 years away from what could be a critical level. If this proves to be the case then a greater reduction in UK carbon emissions will be required, well before 2050.

1.3 UK carbon emissions

Contrary to experience in most countries, UK carbon emissions have fallen in recent years, being around a fifth lower in 2003 than in 1970. Over the same period, energy use has increased by 8.2%, with the upward trend still continuing (DTI 2004a). The fall in emissions is largely because of a switch to lower carbon intensity fuels (ie fuels which produce lower carbon emissions per unit of energy provided). The key changes have been an increase in nuclear energy and a switch away from coal and oil towards natural gas, both at the power station level and for heating homes and businesses. In addition, the efficiency with which electricity is generated has increased considerably.

The UK is expected to meet its Kyoto target of a 12.5% reduction of 1990 levels in all GHG emissions by 2010. Until recently, it also boasted a national target of reducing carbon dioxide emissions by 20% by 2010. Unfortunately, the Government announced in 2004 that this target would not be met (DEFRA 2004d).

1.3.1 Residential energy use and carbon emissions

The residential sector accounts for 30% of total UK energy demand. In some respects, this sector appears to offer potential reductions in energy use and carbon emissions that are relatively easy to achieve: many energy-efficient and low-carbon technologies are available or being developed and there is huge scope for improvements to the energy efficiency of homes in the UK. On the other hand, achieving these improvements is not straightforward, because it is not simply a matter of applying a few new technologies in a uniform way. The future of household energy supply and use lies in the hands and minds of some 25 million householders, over 400 local authorities and the many elements of the construction, building services, appliance and fuel supply industries, as well as with central government. Levels of knowledge are often low, many people have limited access to capital for home improvements, not all new developments lead to energy conservation and a sense of urgency about reducing carbon emissions from housing is still lacking.

Energy use in the residential sector is rising more quickly than in the UK economy as a whole. Total UK energy demand has grown by 7.3% between 1990 and 2003, but residential energy consumption grew by an astounding 17.5% over the same period (DTI 2004a). Looking at development of household energy trends over the longer term (Figure 1.2), the major influences on energy consumption can be illustrated.

Since 1970, energy use per household has changed very little, but due to increasing household numbers, overall energy use in the residential sector has increased by 32%. At a household level, the energy saving effect of much reduced heat losses has been offset by increases in demand (eg for electricity use in lights and appliances). Energy use for heating still dominates demand, being responsible for 60% of the total, with around 20% used to provide hot water and the remaining 20% supplying all other needs.

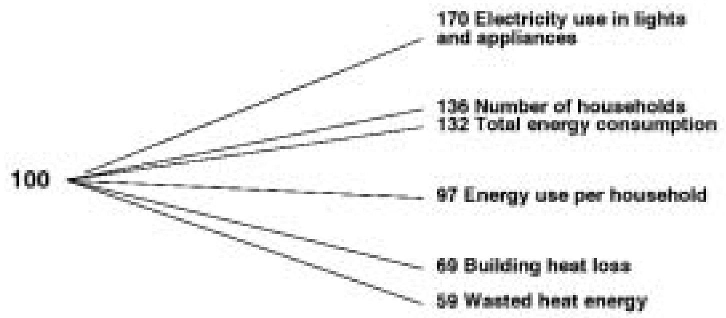


Figure 1.2: Residential energy indices, Great Britain, 1970-2001

Source: Based on Shorrock and Utley (2003)

1.4 UK energy policy

The Energy White Paper brings together all existing policies for achieving carbon reductions and provides a framework for energy policy with four key goals (DTI 2003c):

- reduce UK carbon dioxide emissions by 60% by 2050, with real progress by 2020;

- ensure that every home is adequately and affordably heated;
- maintain the reliability of energy supplies; and
- promote competitive markets in the UK and beyond.

For the purposes of this report, it is assumed that carbon reductions will be shared equally across all sectors of the economy and therefore the residential sector reduction target will be 60%. Whilst the 60% target is the main focus of this project, the issue of equity and fuel poverty underpins the approach and policy recommendations made. The other two objectives have also been addressed, but to a lesser extent given that the focus is on the residential sector alone.

1.4.1 Fuel poverty

Fuel poverty is an important social problem, and concern to eradicate it has led to the aim, as part of energy policy, to ensure that every home is 'adequately and effectively heated'. A person is in fuel poverty if they need to spend more than 10% of their income to afford adequate energy services – a warm and well-lit home, for example. The key causes of fuel poverty are inefficient housing, low income, under-occupation of dwellings and fuel prices. The effects of fuel poverty include cold homes, illness, discomfort from cold and money budgeting problems. There is clear evidence that the winter death rate is higher for people living in cold homes than it is for those that are able to keep their homes warm (Wilkinson et al 2001). In the UK there are tens of thousands excess winter deaths every year. The Government has pledged to ensure that, by 2016 at the latest in England and Wales, 'as far as reasonably practicable persons do not live in fuel poverty' (UK Government 2000). There is comparable legislation for Scotland and Northern Ireland.

The number of households in fuel poverty is contested, but the most recent Government estimate for 2002 stands at around 2.25 million households in the UK (DEFRA 2004b). Downward trends in fuel poverty statistics in recent years have not reflected improvement in the energy efficiency of housing so much as the lowering of gas and electricity prices following liberalisation, relatively low levels of unemployment and increased benefits. The most recent residential fuel price rises in 2004 mean that several hundred thousand households have gone back into fuel poverty. Thus, to achieve permanent reductions in fuel poverty, definite improvements in energy efficiency are vital, rather than reliance on reductions in energy price, which cannot be guaranteed to last.

1.4.2 Security of supply and competitive markets

Anticipated peak demand for electricity is an important factor in national energy policy, as it determines the electricity generating capacity that will be planned. The design, use and ownership of lights and appliances, as well as the deployment of low and zero carbon technologies within the home can contribute to lowering peak residential demand and, therefore, improving the security of electricity supply in the UK (Chapter 8). The development of these new technologies also contributes to the promotion of competitive markets.

1.4.3 Routes to the 60% target

The 60% target relates to carbon dioxide emissions. In theory, if sufficient carbon-free energy sources (nuclear power and renewable energy) could be provided, energy use could continue at current levels, or even increase, while carbon emissions reduce. However, it is very far from certain that adequate carbon-free sources could be developed, or that all or most carbon emissions from fossil fuel could be captured and stored (carbon sequestration). Therefore, significant energy demand reduction is almost certain to be required. Table 1.2 shows four scenarios designed to reach the end-point of 60% reductions in UK carbon emissions for the whole economy, developed by the RCEP. These use

Supply-side fixes, such as optimistic use of centralised renewable energy are not considered in the 40% House scenario

different combinations of reduced carbon intensity of energy supply and reductions in the total energy demand to reach the 60% target. Only one scenario features no reduction in demand for energy and none allows for growth in energy demand, which would result if current trends continue.

Reducing demand for energy poses a major challenge to our ways of thinking and acting – but so does a failure to reduce it. For example, if demand were to remain the same as in 1997 (Scenario 1), the nation would have to accept changes such as an increase in nuclear power to provide one quarter of all *energy* (presently it supplies around one quarter of electricity). There would also need to be a huge increase in the use of renewable energy sources.

The approach taken in the 40% House project was to focus primarily on reduction in energy demand and an increase in low and zero carbon energy supply methods at a household level, rather than changes to the carbon intensity of the energy supplied nationally. For this reason much of the analysis focuses on reducing energy consumption as the key means of reducing carbon emissions.

Table 1.2: The RCEP energy demand and supply scenarios for 2050

	Scenario 1	*Scenario 2*	*Scenario 3*	*Scenario 4*
Change in energy demand compared with 1997 (%)	0	−36%	−36%	−47%
Total energy supply (TWh)	1848	1323	1314	1104
Fossil fuels (TWh/% of total)	929 (50%)	929 (70%)	929 (71%)	929 (84%)
Renewables (TWh/% of total)	464 (25%)	394 (30%)	219 (17%)	175 (16%)
Nuclear/carbon sequestration (TWh/% of total)	456 (25%)	0	166 (13%)	0

Source: RCEP (2000)

1.4.4 Residential sector

Whilst Government policy has contributed to increasing the efficiency of the housing stock, particularly in regard to heating, overall energy demand is still increasing. Before considering current policies and their likely impact, the political and organisational complexity of housing and energy policy is outlined.

There are four major Government departments

Table 1.3: Departmental responsibility: housing and energy

Department	*Policy*
ODPM	Sustainable communities; neighbourhood renewal; planning; Housing Corporation; housing funding; building regulations; urban policy; devolution; regions
DEFRA	Climate Change Programme; air quality; energy efficiency; sustainable energy; fuel poverty; pollution prevention and control; consumer products; Market Transformation Programme; Carbon Trust; Energy Saving Trust
DTI	Sustainable construction; conventional and renewable energy; Foresight programme; Energy Saving Trust; fuel poverty; neighbourhood renewal implementation strategy
Treasury	House prices; fiscal incentives
Devolved administrations	Housing and energy efficiency are devolved matters

involved in Whitehall alone (Table 1.3), not including the parallel responsibilities in the devolved administrations. Several departments fund additional, external groups, such as the Energy Saving Trust and Carbon Trust, and some initiatives have joint oversight, such as the Climate Change Project Office, which was set up by the DTI and DEFRA to advise business on Kyoto obligations. Below Whitehall, there are various levels of regional and local government. This complexity and fragmentation is a barrier to the 'joined-up governance' needed to achieve significant energy and carbon reductions from the housing stock.

An illustration of the variety of policies affecting the residential section is shown in Table 1.4, which lists a number of important policies and describes what is known about their impacts.

The government expects existing policies to deliver a total cut in residential sector carbon emissions by 2010 of 4.2 MtC (DEFRA 2004a). These savings would amount to a 10% cut in emissions since 1990, when residential sector emissions stood at 41.7 MtC (DEFRA 2004e). Emissions in 2002 were just 3% lower than in 1990, so there is a considerable way to go before even this modest target is achieved.

Despite the wide range of policies in place, and some very good individual initiatives, it is doubtful whether current policies will meet the savings target. As mentioned earlier, the Government has already admitted that it will not meet its economy-wide target of a 20% cut in carbon emissions by 2010. Beyond 2020, there is little policy thinking in place and certainly no detailed long term strategy to deliver the 2050 target. This report will build on existing policies to show how 60% carbon reductions could be achieved by 2050 in the residential sector and why it is vital that action begins now to meet this target.

1.5 Policy approach

The philosophy underlying the suggested policy approach to achieve the 40% House is described here, prior to outlining individual policies in the following chapters.

1.5.1 Options

There are currently two major potential approaches to achieving lower energy use and lower carbon emissions in the residential sector: product-based market transformation, focusing on the equipment/capital stock used, and increasing fuel prices, eg via carbon taxation. This report is based on a market transformation (MT)

Table 1.4: Examples of UK policies and programmes affecting the residential sector

Policy/ Programme	*Summary*	*Achievement*
Building Regulations Part L	2002, 2005, 2008 – continual revision. Amendments under consideration should increase efficiency of new build and home extensions by 25%	2002 regulations estimated to have reduced heating energy needed by 50% on 1990 regulation levels (DTI 2003c). Not confirmed by evidence
Energy Efficiency Commitment (previously EESoP)	All suppliers with >15,000 residential customers to install efficiency measures. Aim for 0.4 MtC (million tonnes of carbon) pa saving over lifetime of measures by 2005; 0.7 MtC pa by 2010. EEC renewed every 3 yrs. Current spend is £150m pa, mostly on cavity wall and loft insulation + low-energy lighting. Half the benefit to go to vulnerable households	Estimated annual savings of 0.1 MtC from EESoP 3, 2000-2002 (Ofgem/EST 2003)
Home Energy Conservation Act 1995	Obligation on all housing authorities to submit plans to improve energy efficiency of housing stock by 30% by 2010 over 1996 level	Claimed mean improvement of 13.4% by 2003 (DEFRA 2003), but thought to be based on overestimates
Market Transformation Programme	Continued promotion of 'resource efficiency' for products, systems and services, leading to removal of least efficient products and appliances; encouragement of most efficient	Operates a consultative review process to develop policy strategies with business, consumers and other bodies.
Energy efficiency advice	Through national network of Energy Efficiency Advice Centres (EEACs) and other sources	EEACs advised 2 million + householders by 2004.

approach, which uses a variety of policy instruments to deliver higher levels of efficiency by directly targeting individual products. By contrast, carbon taxation would work by promoting more efficient, lower carbon solutions through raising the price of carbon-based fuels. Carbon taxation would not necessarily conflict with an MT approach and the two could be used together. However, carbon taxation would seriously disadvantage the poor in society. Recent research shows the practical impossibility of financially compensating the poor for carbon taxation, so that it would inevitably add to the burden of fuel poverty (Ekins and Dresner 2004). Given the aims of this study, this rules out carbon taxation as a policy approach.

A new approach, which is just beginning to be discussed, is that of personal carbon allowances (PCAs), also known as personal carbon rations or domestic tradable quotas (DTQs) (Hillman and Fawcett 2004, Anderson and Starkey 2004). With PCAs, each adult has an equal carbon allocation to cover purchases of gas, electricity, petrol and aviation. The PCA brings home to the individual, in a forceful way, the amount of carbon being released through daily activities. It reflects the principles of contraction and convergence, and is strongly rooted in the need for equity. PCAs could form the umbrella of an overall emissions reduction policy, within which many specific product and systems policies would still be required. This policy could work well with market transformation to deliver carbon savings. However, the main focus of this report remains market transformation.

1.5.2 Market transformation

Market transformation is already the established policy approach when dealing with much energy-using equipment (eg fridges, light bulbs, boilers). It combines individual policies into a strategic framework, moving the distribution of sales towards greater energy efficiency over several years. The typical suite of policies includes labelling – to distinguish the good from the bad –

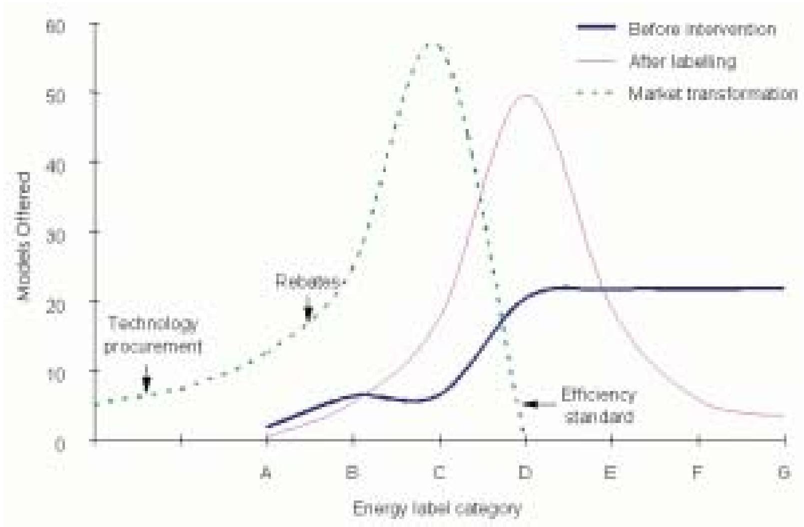


Figure 1.3: Market transformation strategy

followed by combinations of procurement, rebates, minimum standards and education (Figure 1.3). The objective is to introduce new, super-efficient equipment onto the market through procurement and then support it with rebates, until it can be produced by several manufacturers and competition exists (about 20% of the market). In parallel, there is a clear strategy to ensure that the least efficient items are no longer manufactured or sold, through mandatory minimum standards or voluntary agreements with industry. As a result, the sales profile of new equipment and the stock in people's homes is gradually transformed towards greater energy efficiency.

The 40% House scenario proposes a radical agenda for the transformation of the entire housing stock

The cycle can be undertaken several times, for instance by introducing a new procurement activity today in preparation for a second, tighter, minimum standard at a stated point in the future. The market transformation strategy works well with products that have a natural turnover in the stock as they break down and need replacement (Boardman 2004a, b). The detailed design and timetable of a market transformation strategy depends upon the relative importance given to factors such as the cost to government, the certainty of the savings and the inclusion of all social groups (Boardman et al 1995).

1.5.3 Market transformation and housing

The market transformation approach is such a powerful analytical tool that it is used here to structure the debate on policy options for housing as a whole. This is notwithstanding the major differences that exist between houses and white goods. For instance there is no clear end-of-life to a dwelling; it is not a traded good that can be moved around but a social necessity with powerful emotional associations, and the way in which people chose their home is influenced mainly by location and price rather than the quality of the building. Where housing is concerned, present policies support the status quo rather than encouraging transformation. However, it is possible to upgrade and improve a house, and thus make it more energy efficient, and in this way the housing stock is open to market transformation. The case for market transformation of housing will be made in greater detail in the following chapters.

1.6 Conclusions

The key conclusions from this chapter are:

- Climate change is a deeply serious problem and action both in the UK and internationally is currently insufficient to address it.

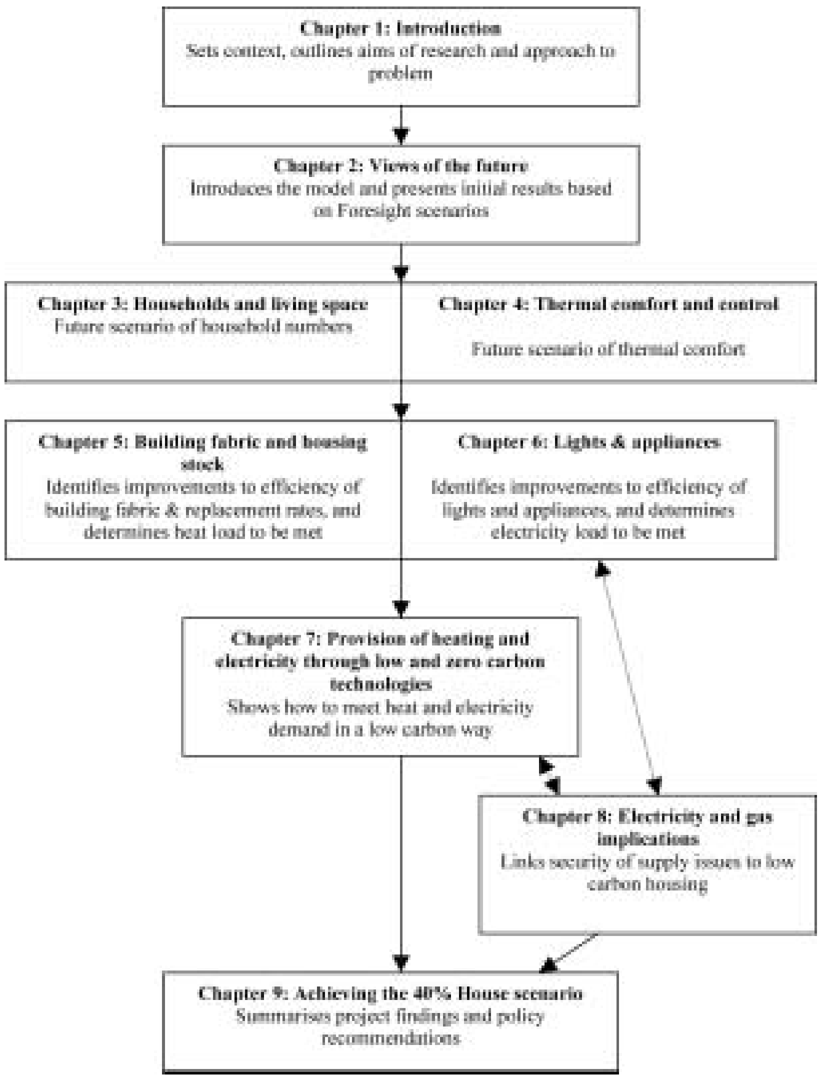
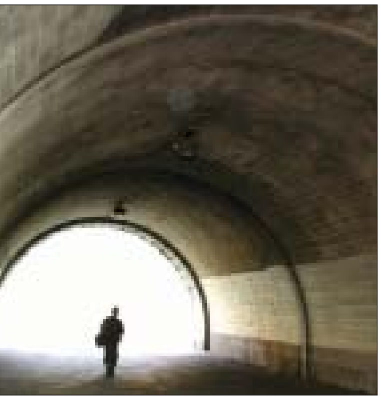


Figure 1.4: Schematic structure of 40% House report

- Energy use in the residential sector is a significant component of the UK's contribution to climate change. Energy use in this sector is rising much faster than in the economy as a whole and carbon emissions have fallen very little.
- In order to achieve a total reduction in residential carbon emissions of 60% by 2050, emissions will have to drop around 2% per annum – this compares starkly with the 3% reduction in total during the twelve years since 1990.
- Fuel poverty is an important social problem linked with energy use, and must be resolved in parallel with reducing carbon emissions. This, along with other considerations, leads to the adoption of market transformation as the policy strategy for achieving change.
- A clear strategy is needed to reverse the current trend of increasing energy consumption, with continuing cuts in emissions between now and 2050, and beyond. The 40% House project proposes an agenda for the future of the whole housing stock of the UK, with a 60% cut in household carbon emissions as the target for 2050 throughout.

Views of the future



This chapter concerns future energy use and carbon emissions from the UK residential sector and how these were modelled through the UK domestic carbon model (UKDCM), developed as part of the 40% House project. This model underpins the energy and carbon savings calculations throughout the report. The structure of the model is briefly described, then the broader context of modelling energy futures is examined, with the introduction of the UK Foresight scenarios. These are combined with the UKDCM to provide four varied future scenarios to 2050, showing how carbon emissions could change in the residential sector if different pathways were followed. The Foresight scenario expected to deliver the highest carbon savings is identified so that it can be investigated further and developed into a more robust and realistic '40% House' scenario.

2.1 Modelling an uncertain future

How well insulated will buildings be by the middle of the century? How efficient will appliances be in design and use? What will the uptake rate of new technologies be and what will be the design priorities? What types of home will people be choosing? How many individuals will live in the average dwelling and for how much of the year? It is impossible to predict such variables with any accuracy when looking as far ahead as 2050 and many depend crucially on political commitment. For example, the technology to insulate new buildings so that they require virtually no artificial heating already exists: the question is how far Government is prepared to go in setting such insulation standards and how quickly the construction industry can build quality homes to meet the standards on a large scale.

To give an idea of how significant the changes could be, it is useful to look back 50 years and to consider the changes in energy use, social organisation and technological possibilities since then. For example, in 1950, almost 90% of the UK's total primary energy was supplied by coal and it was the dominant fuel used for household heating, primarily in very inefficient open fires (PIU 2002). By 2003, less than one fifth of UK primary energy came from coal (DTI 2004a) and natural gas had become the heating fuel used in fourth-fifths of homes (DTI 2004c). A choice of basic parameters can be overtaken rapidly by events: for example, energy projections for the UK made only a short time ago were based on energy price scenarios that now seem highly unlikely, such as oil prices in 2005-10 ranging from $10 to $20 per barrel (DTI 2001a). In 2004, oil reached $55 a barrel.

Long-term scenario building therefore needs to provide decision makers with information on the potential impacts of different directions in which society might develop. For example, household size will be tied in with incomes, land availability, house prices and social provision for the elderly and the young – all of which will be affected by the prevailing political consensus. Similarly, the choice of high- or low-technology pathways is affected by availability of materials, scientists and engineers, and by public attitudes towards different technologies. Scenarios can demonstrate how one or two fundamental shifts in society in the near future could radically alter a wide range of aspects of life by 2050. They are a way of handling complexity and uncertainty by generating possible futures, not by making accurate predictions. These can then be translated into detailed estimates for use in modelling to help assess the likely effects of specific medium and long-term government policies.

2.2 The UK Domestic Carbon Model

In order to investigate how 60% savings could be achieved in the UK residential sector, a detailed bottom-up model, the UK domestic carbon model (UKDCM), was developed. Bottom-up modelling is a long-established technique for modelling possible futures based on highly disaggregated, physically-based data and relationships. A considerable amount of data are required for this type of model, including annual values for population, levels of insulation, efficiency of

In 1950, almost all houses were heated by coal. What, if anything, will be used in 2050?

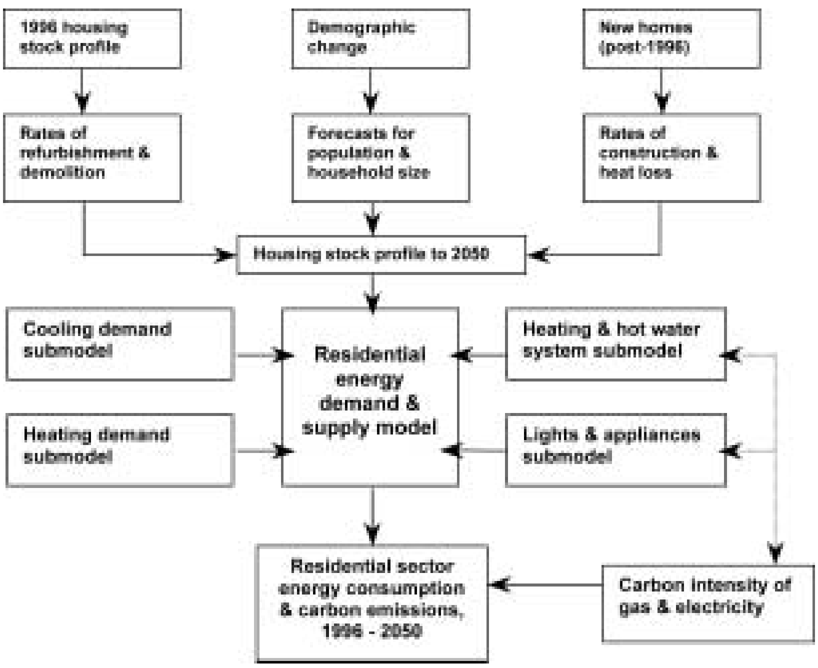


Figure 2.1: UK Domestic Carbon Model structure

heating equipment, ownership of appliances and many other energy related characteristics of the UK housing stock. The most well-known prior model of this type is BREHOMES (Shorrock and Dunster 1997), with more recent work having been carried out by Johnston (2003). However, the BREHOMES model is not publicly available and Johnston's model included just two dwelling types: a typical pre-1996 dwelling and a typical post-1996 dwelling. In order to understand more of the detail of how homes and house-building might change over 45 years, a decision was made to create a new bottom-up residential sector model for the 40% House project.

2.2.1 Data inputs

The UKDCM uses detailed housing data from the English Housing Condition Survey (EHCS) and the corresponding surveys of housing in Northern Ireland and Scotland to form the basis of a stock model of UK housing (Figure 2.1). In the absence of survey data for Wales, data from the West

Midlands were used, as the closest geographical fit.

The resulting UK housing stock profile is highly disaggregated, with data sets for nine geographical areas, seven age classes and ten types of construction (mid-terraced houses, semi-detached houses, etc). Different combinations of these data sets are further divided by tenure, number of floors and method of construction. In all, over 12,000 dwelling types are modelled in the UKDCM for 1996. The period 2005 to 2050 is divided into decadal age classes for future dwellings, so that different building standards can be modelled over time. With the addition of these future age classes, the UKDCM models over 20,000 dwelling types for 2050.

In addition to the housing stock profile, the following trends and projections are incorporated:

- Historic demolition and future regional dwelling forecasts (National Statistics/ODPM).
- Scenarios for future population growth and dwelling numbers (DEFRA, Foresight/SPRU 2002).
- Scenarios for future average monthly temperatures. The UKCIP high scenario has been used and this shows a 2°C from 1996 annual average temperatures (UKCIP).

This information was combined into a database model and predictions regarding house types, numbers and their energy use and carbon emissions were made. Four sub-models were also developed to feed in information on space and water heating, cooling and lights and appliances. The energy performance of existing dwellings and domestic equipment was used as a baseline to estimate the rates of change and as a starting point for the sub-models.

The number of new dwellings that will be constructed between now and 2050 is strongly dependent on demolition rates. While predictions can be made regarding the thermal performance of future dwellings, based on assumptions about future Building Regulations, the shape and size of these dwellings is unknown. The size and shape of new buildings are based on the most recent age class data, with some variation from this starting point as the model progresses (for example, average size of dwellings is expected to decrease slightly and this is reflected in the model).

2.2.2 Costs

The key aim of the modelling was to demonstrate a plausible technological route, backed by policy, which can achieve 60% savings by 2050. The financial costs and benefits of particular technology adoptions in future scenarios are difficult to estimate, both in principle and in practice, for a number of reasons:

- The cost of any given technical improvement is not a given, but strongly dependent on policy (Hinnells and McMahon 1997).
- The cost of any given technical improvement is dependent on the timescales for implementation. If changes can be made to fit with natural product improvement cycles, changes can be met at much lower, zero or even negative costs.
- The cost of future technical options is not fully known and will depend on a wide range of factors which determine economies of scale.
- Cost, both initial and life-cycle cost, is not the only criterion on which consumers base their decisions. A number of other factors, including the level of service, style preferences and availability, all come into play.
- The cost/benefit of external effects is unclear, ie the societal value of a tonne of carbon saved varies with projections of climate change and timescale. The value in 2050 may be very different to current expectations.

Although costs and financial benefits are of importance, particularly on shorter timescales, they were considered to be a second order effect in terms of the modelling, particularly given the inherent uncertainties that exist over a timeframe of 50 years. The main drivers of policy over this time will be factors such as population, household numbers and household size, building and demolition rates. Costs were therefore not modelled – it was considered more important to

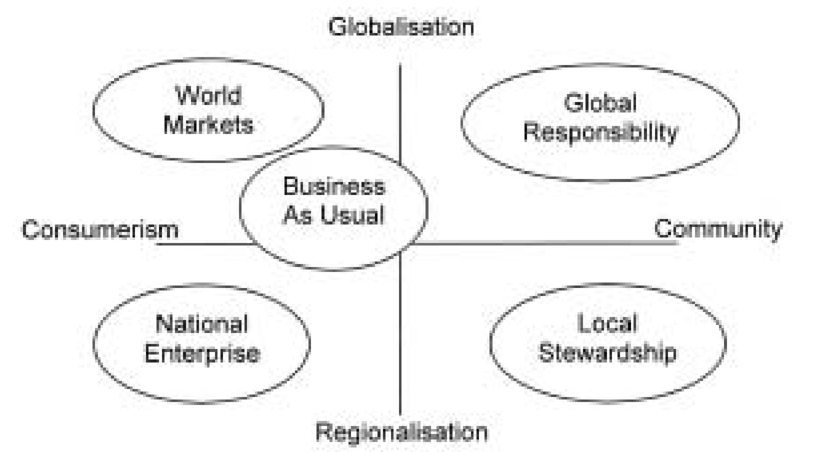


Figure 2.2: Foresight scenarios on a grid of governance and social values

Source: PIU (2001)

identify a route to the necessary carbon savings, whilst keeping an awareness of the cost and feasibility issues that would need to be addressed along the way.

2.3 The Foresight scenarios

Having developed the UKDCM and calibrated it against current energy use, the aim was to develop a scenario that would achieve 60% carbon savings by 2050. In order to quantify the details of possible futures in terms of energy use and carbon emissions, it was first necessary to look at some alternative futures in broad terms – the Foresight scenarios were used as the basis for this.

The UK 'Foresight' programme was set up in 1994 as a 'national capacity to think ahead'. One of the research outputs has been the creation of four future scenarios, which have been widely used in a variety of research. The Foresight scenarios are framed in the context of two basic dimensions of change: social values and governance systems (Figure 2.2), which are taken as axes to define the four scenarios. For example, the World Markets scenario has values of consumerism and globalisation, whereas Local Stewardship is the society that develops under strong regionalisation and community values.

Although none of the scenarios was intended to represent business-as-usual, it is generally considered that World Markets best describes the trajectory we are on at present.

The Foresight scenarios do not offer probabilities of a given outcome but supply a useful way of thinking about possible futures associated with different worldviews and mindsets. They give a snapshot of how life might be in 2050, to aid more detailed assessment of possible energy futures. Using the Foresight scenarios as a basis for the detailed modelling has two main advantages:

- Compatibility: the broad world-views underlying the scenarios are consistent with previous work done under the Foresight programme and other modelling work that has used the Foresight scenarios.
- Consistency: the scenarios provide a framework to ensure that developments in the residential sector are consistent with developments in other sectors of the UK economy, including consumer patterns, investment, regulation, market and environmental factors.

Table 2.1 summarises the key aspects of the four Foresight scenarios that are particularly relevant to this project. The energy aspects of the Foresight scenarios are given in general terms and show very different fuel mixes, variation in total energy use and strongly divergent aims for energy policy. These overall statements were translated into carbon emissions projections to 2050 for the residential sector, using the UKDCM. It should be noted that UK population projections have been revised since the Foresight scenarios were developed, with an increase of several million additional people by 2050 under 'business as usual'. Therefore, population figures are likely to have been underestimated in all the Foresight scenarios.

2.4 Modelling carbon emissions

In order to calculate carbon emissions under each of the Foresight scenarios using the UKDCM, detailed assumptions were created for each type

Table 2.1: Socio-economic and energy trends of the Foresight scenarios

	World markets	*Global responsibility*	*National enterprise*	*Local stewardship*
Core value	Consumerism	Sustainable development	Individualism	Conservation
Environmental concern	Limited, health-linked	Strong	Limited	Strong
Annual rate of GDP growth	3.5%	2.75%	2%	1.25%
Population, 2050 (000s)	59,000	57,000	57,000	55,000
Household size, 2050*	2.0	2.2	2.4	2.6
Households, 2050 (000s)*	29,500	25,900	23,800	21,200
Energy policy priorities	Low prices	Efficiency and development of renewables	Security of supply	Efficiency and local fuel sourcing
Primary energy consumption average annual change	+1.7%	+0.1%	+1.5%	+0.1%
Energy prices	Low	High	High	High
Energy efficiency	Limited adoption of improvements	Strong international agreements	Limited – low capital availability & environmental concern	High priority
Security of supply	More interconnection, decentralised generation, liberalisation	Wide range of sources used. Increase in distributed power generation	Nuclear and coal stations replaced, to avoid imports. Quota system for coal, nuclear and gas	'Think global, act local' policy reduces imports
Renewables	Renewables are 10% of electricity, from wind and waste	Renewable generation expands to 30% of electricity supply	Renewables are 10% of electricity	Renewable generation expands to 20% of electricity supply

Sources: PIU (2001), SPRU (2002), DTI (2000), UKCIP (2000)
* Assumes 2050 household size values equal those published for 2020

of energy using equipment, each element of the building fabric and the carbon intensity of energy used. The following guiding principles were used in developing the scenario parameters:

- **Energy efficiency**: improvements in energy efficiency will be greater in the WM and GR than in the LS or NE scenarios.
- **Adoption rates for technology and efficiency measures**: higher adoption rates for energy efficiency measures will occur in the more regulated scenarios, GR and LS, with lower rates in WM and NE. High adoption rates of electronics-based and labour-saving technologies occur in the WM scenario.
- **Behaviour and energy services**: the highest demand for most energy services (eg hours of lighting, uses of washing machines, etc) is found in WM, followed by GR and NE, with LS experiencing the lowest demand.

2.4.1 Model results

Once all the parameters for each scenario were established, carbon emissions from the UK housing stock were modelled to 2050. The results are shown in Figure 2.3, illustrating the very different levels of carbon emissions projected under the four scenarios.

Household numbers – ranging from 21.2 million under LS to 29.5 million under WM – based on assumptions of household size, have a significant effect on carbon emissions under each scenario. However, this is not the only important factor –

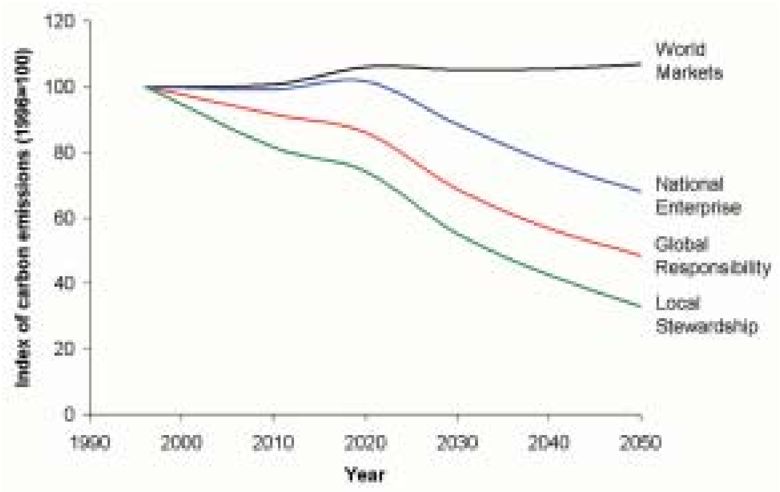


Figure 2.3: UK residential carbon emissions under the Foresight scenarios, 1996-2050

Source: UKDCM

GR has higher household numbers than NE but achieves considerably lower emissions.

These runs of the Foresight scenarios provide valuable clues as to which policy orientations are most likely to succeed in reducing carbon emissions (although not necessarily in eliminating fuel poverty). It is clear that WM – the scenario that comes closest to present policies – does not achieve any reduction in carbon emissions. NE, which is relatively isolationist, non-innovative and reliant on coal, gives some reductions. The two scenarios which achieve the lowest carbon emissions, GR and LS, involve some radical changes. Both assume societies that set a high value on environmental quality and educate people accordingly. The technological possibilities open to them are a product of this basic orientation. Global Responsibility comes close to the 40% target, due to strong environmental concern, an international framework of environmental legislation and plenty of innovative technology. But only Local Stewardship takes the UK below the 40% threshold; it achieved 33% of 1996 emissions levels by 2050. Hence, LS was taken as the starting point for developing the 40% House scenario.

Our current world market economy will not bring about the carbon savings needed. A new approach is required.

2.4.2 Local Stewardship Scenario

Local Stewardship is the scenario with the lowest carbon emissions. It combines low household numbers with lower levels of energy demand within the home as a result of the integration of some low and zero carbon technologies into the building fabric. This scenario also involves major changes in the way in which individual and social priorities develop. The key changes by 2050 under LS, as assumed in the UKDCM and shown in Table 2.2, are:

- relatively low population growth combined with increased household size, leading to three million fewer households than in 1996;
- demolition rates increased considerably, leading to more rapid replacement of the old, inefficient housing stock as well as removal of excess housing;
- improved efficiency of the building fabric of new and old houses, but new houses will still be considerably more efficient than retro-fitted old ones with lower heat demand;
- heating energy supplied far more efficiently, primarily through gas condensing boilers, but also increasingly by micro-CHP; and
- a wide uptake of renewable energy for electricity generation (25% of households) and hot water (75% of households).

Table 2.2: Main variables in Local Stewardship scenario

Variable	*1996*	*2050*
People and dwellings		
Population (000s)	59,000	55,000
Household size (people per household)	2.47	2.6
UK household numbers (000s)	23,900	21,150
UK rate of new construction (dwellings per year)	162,000	91,000
UK demolition (dwellings per year)	8,000	227,000 (note: artificially high due to falling household numbers)
Building fabric		
Fabric values for retrofit to existing stock U values in w/m² K	Cavity wall insulation U=0.4 Solid wall insulation U=0.5 Double glazing U= 2.5 Loft insulation U=0.35	U=0.3 (90% ownership) U=0.3 (30% ownership) U=0.8 (90% ownership) U=0.14 (100% ownership)
New building fabric values U values in w/m² K	Walls U=0.45 Windows U=2.1 Loft insulation U=0.24 Floors U=0.6 Doors U=2.5	U=0.1 (all 100% ownership) U=0.8 U=0.1 U=0.09 U=2.0
Ventilation rate (air changes per hour) for new buildings	3.5	0.6
Energy uses		
Internal temperatures (°C) – zone 1 zone 2	 18.3 17.3	 21 18
Relative electricity consumption in lights and appliances (including cooking) per household	100	83
Supplying energy demand		
Gas boilers ownership efficiency	 69% 68%	 54% 95%
Electric space heating ownership efficiency	 9% 100%	 9% 100%
Micro-CHP ownership	 0%	 26.5%
Photovoltaics (electricity production) ownership	 0%	 25%
Solar Thermal water heating ownership	 0%	 75%
Emissions factors electricity (kgC/kWh) gas (kgC/kWh)	 0.136 0.052	 0.095 0.052

Source: UKDCM

Whilst the Local Stewardship scenario was found to deliver in excess of 60% carbon savings for the residential sector, the factors behind this cannot all be delivered via energy policy (or perhaps any policy). A key feature which leads to the low emissions under this scenario is the considerable decrease in household numbers, resulting from an increase in household size and a reduction in UK population. However, household size has been decreasing for 150 years, so to assume an increase to 2050 is problematic. These issues are discussed further in Chapter 3. Given the doubt around the low LS household numbers (and other factors) and the lack of policy mechanisms to achieve them, a more robust and realistic scenario was developed – the '40% House' scenario.

2.4.3 The 40% House scenario

The 40% House scenario took the Local Stewardship scenario as a starting point, drawing on some of the technical analysis which underpins LS and assuming similar societal attitudes, but with some significant changes. The 40% House scenario does not rely on decreasing number of households and yet can still deliver 60% carbon savings. The various assumptions made under this scenario will be described and discussed in greater detail in the following chapters.

Inevitably, modelling possible future housing scenarios has many dimensions. Radical improvements in one factor or collection of factors may be traded off against less challenging ones in others. As the remainder of the report will show, the proposed carbon savings in the residential sector are made up of a wide range of actions from increased demolition rates (so that old inefficient homes are replaced by new low energy ones), to greatly improved insulation standards, to a huge increase in adoption of household-level renewable technologies for hot water and electricity. The balance of these different measures illustrated in the 40% House scenario is not the only mix that could have achieved the same saving. However, it is presented as one possible solution, offering a good insight into the considerable changes which have to be made to all factors affecting carbon emissions from the residential sector.

2.5 Conclusions

The key conclusions from this chapter are:

- A new modelling tool for the UK residential sector – the UK domestic carbon model (UKDCM) – has been developed and tested.
- In combination with detailed data assumptions, the UKDCM illustrated the wide range of carbon emissions futures that are possible, based on the Foresight scenarios. These range from a slight increase in emissions by 2050 to a 67% decrease.
- UK society is on track at present to develop in a World Markets manner. If this continues, no carbon emissions reductions are expected by 2050.
- Only societies where environmental concern and awareness are much stronger than today (ie LS and GR) produced significantly reduced carbon emissions. Therefore, changing social priorities must become an important Government action as part of meeting its carbon reduction target.
- The future scenario that resulted in lowest carbon emissions, LS, did this in considerable part due to assumptions about low numbers of households in 2050.
- Household numbers cannot be reduced through energy policy or guaranteed in any way. Thus a risk-averse future scenario should not rely on these and must be able to deliver 60% savings even with increasing numbers of households.
- The '40% House' scenario can deliver savings purely due to improvements delivered by housing and energy policy, which is within Government control. This will be developed and described in the remainder of the report.

Households and living space

Demographics have a major impact on the prospects for reducing residential emissions – not only how many people will be living in the UK by 2050, but how many live in each household, what ages they are, how much space they occupy and where the households are located. The number of households is one of the driving forces behind the growth in residential energy consumption. Whilst not easily amenable to policy, it is important to understand the population trends and projections in order to develop a reliable estimate of future energy demand and consequent carbon emissions. Assumptions about household numbers and amount of living space have implications for space heating and cooling, water heating and the number, size and usage of appliances, which raise important policy considerations. Likely trends in population, household numbers and household size (both in terms of number of people and living space) to 2050 are summarised here, along with the assumptions made under the 40% House scenario.

3.1 Population

Population projections are based on census figures, extrapolated to the present and then projected into the future on the basis of three factors: fertility, life expectancy and net migration.

3.1.1 Net migration

Net migration is the most difficult factor to predict and accounts for around 60% of projected increases. A net migration gain of 130,000 each year between 2004 and 2031 is assumed by the Office of National Statistics (NS 2004e) – this is somewhat lower than estimates for the past five years of between 151,000 and 172,000 (NS 2004g) and any changes to these figures could have a significant impact on current projections.

3.1.2 Fertility

Post-war fertility peaked in 1964 with a total fertility rate of 2.95 children per woman, falling to 1.71 in 2003. While actual births each year will continue to fluctuate, the overall trend since the baby boom has been downward (NS 2004f). The birth rate is unlikely to rise significantly in the foreseeable future and it is assumed that the number of children born to women born after 1985 will level off at 1.74, close to the current level (NS 2004e).

3.1.3 Population age structure

Life expectancy at birth is projected to rise from 76.2 years in 2003 to 81.0 in 2031 for men and from 80.6 to 84.9 for women (NS 2004e). The latest projections for the UK show that the total population of pensionable age (over 65 years) will increase from 10.9 million in 2002 to 12.7 million by 2021 and 15 million by 2031, peaking at over 17 million in the 2060s (Shaw 2004). This represents almost a quarter of all residents and an increase in the potentially vulnerable population. Homes will be needed that allow for as much self-sufficiency as possible in old age. In March 2004, the ODPM committed itself to reviewing Part M of the Building Regulations (access and facilities for disabled people) in order to incorporate Lifetime Home Standards, so that homes can easily be adapted to different stages of life and to chronic illness or disability.

3.1.4 Population assumptions

The current UK population is approximately 60 million. Projections of population size, and also the size and year of the 'peak' population, have risen considerably over the last decade. The range of predicted figures widens as the time horizon lengthens into the future and it is extremely difficult to give an accurate projection of the population in 2050 – the Government Actuary's Department figures range from 62.5 million to 72 million (Shaw 2004). A mid-range projection of 66.8 million for 2050 has been adopted for use in the 40% House scenario (Table 3.1) since this is thought likely to be the period of peak population. This figure was felt to be more realistic than the 2050 population figure of 55 million assumed under the Local Stewardship scenario.

By 2050, a quarter of the population will be over 65

3.2 Household size and numbers

The number of households, each with its own lighting and set of appliances, will be a key factor in future energy consumption. Communal space and water heating are unlikely to spread beyond 20% of dwellings – a large majority of households will still have their own systems. The actual number of households is dependent on the total population and the average number of people per dwelling (household size).

3.2.1 Trends in household size

There has been a downward progression in household size for some time to the current figure of 2.3 people per dwelling. Only 7% of households in Great Britain contained more than four people in 2002 – half the figure for 1971 – whilst the proportion of one-person households rose from 18% to 29% over the same period (NS 2004b). Traditional families make up a decreasing proportion of the population: for example, Scottish projections are for a drop in households with two or more adults with children from 21% of the total in 2002 to only 15% in 2016 (Scottish Executive 2004).

Table 3.1: UK population projections used in the 40% House scenario (thousands)

Year end	*2003*	*2011*	*2021*	*2031*	*2051*
England	49,856	51,595	53,954	55,885	
Wales	2,938	3,020	3,106	3,153	
Scotland	5,057	5,034	4,963	4,825	
Northern Ireland	1,703	1,753	1,811	1,840	
United Kingdom	**59,554**	**61,401**	**63,835**	**65,700**	**66,800**

Source: Shaw (2004)

Almost 70% of the expected rise in household numbers in England between 1996-2016 is attributed to single-person households (Holmans 2001), nearly half of which currently contain pensioners (NS 2004d). The Treasury report on future housing needs anticipates a continuation of this trend, with approximately 9 million single-person households by 2021 (Barker 2004). However, it is possible that this is actually coming to an end: *'over the last five years there have been no statistically significant changes in the overall proportion of adults living in one-person households, and among people aged 65 and over, the proportion living alone has remained relatively stable since the mid-1980s'* (NS 2002).

Household size in the future will depend on a number of socioeconomic factors that shape people's preferences. For example, the downward trend in extended families living together could change given house price trends, increased life expectancy, pension under-funding and increased costs of residential care. It was recently estimated that the number of three-generation families could rise from 75,000 to 200,000 over the next 20 years (Skipton Building Society 2004).

3.2.2 Regional issues

Government projections show increases in household numbers for all four countries of the UK, although some population decline is expected in Scotland and in North-East and North-West England (ODPM live tables). Projected household growth in the English regions is highest in the South East, South West, East and the East Midlands and lowest in the North East, North West and the West Midlands. These figures mirror existing and expected trends in employment – there is momentum towards growth in the parts of the country that are most economically active and current policy is to adapt to this: 'predict and provide'. The East of England Regional Assembly is likely to ratify plans for 500,000 new homes in the region – an increase of 20% in the number of households, in a region that is already experiencing water shortages. The planned

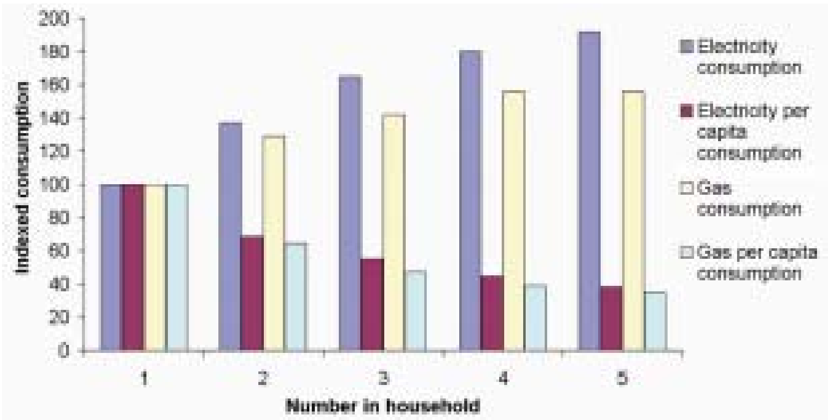


Figure 3.1: Effects of household size on energy use

Note: One-person household = 100

Source: Fawcett et al (2000), based on analysis of EHCS 1996 data

Thames Gateway development is the biggest co-ordinated building programme for more than 50 years, with 120,000 new homes planned (ODPM 2004f). The House Builders Federation claim that 47% of projected growth in England between 2001 and 2021 is likely to be in London and the South East, with three quarters of the total in these two regions plus the East and South West (HBF 2003). Hence the highest growth in household numbers is expected in the warmest regions of the country.

3.2.3 Household size and energy demand

Per capita consumption plummets when people live in larger households, with a particularly marked difference between one- and two-person households. Figure 3.1 illustrates how, in theory, 60% energy savings could be achieved for all one-person households simply by moving them into five-person households, although this is unlikely in reality.

3.2.4 Household size assumptions

Household size is not easily amenable to policy intervention as it results from a complex mixture of factors such as income, house prices and availability, employment opportunities, social provision for children and the elderly, and the age at which young people move into their own homes. It was therefore important not to base the modelling on household size assumptions that might be over-optimistic in terms of the impact on carbon emissions.

The lowest European figure for household size is for Sweden, with 1.9 persons per household in 2002 (Eurostat 2004). If household size in the UK were to drop to this level, there would be a 47% increase in the number of households by the middle of the century, assuming a population of 66.8 million. If household size were to hold steady

Table 3.2: Projected UK household numbers, 2050

Year	*Household size (people)*	*Population (000)*	*Household numbers (000)*	*% Change in household numbers, 1996-2050*
1996	2.43	58,139	23,926	–
2002	2.31	59,232	25,641	–
2050 (household size falls to current Swedish level)	1.9	66,800	35,158	46.9
2050 (household size stabilises at current level)	2.31	66,800	28,918	20.1
2050 (40% House scenario)	2.1	66,800	31,810	33.0
2050 (Local Stewardship scenario)	2.6	55,000	21,154	-11.6

Sources: population figures – NS (2004a); household size estimates – NS (2004b); LS scenario - UKCIP (2000)

Table 3.3: Average floor space by household size and category, England, 2001 (m^2/person)

	1 person	*2 people*	*3 people*	*4 people*	*5+people*	*All*
Owner-occupied	77	48	33	27	21	46
RSL*	54	31	24	19	15	36
Couple + dependent child(ren)	–	–	31	26	20	26
Couple aged 60 +	–	48	34	27	20	46
1 person under 60	65	–	–	–	–	65
1 person aged 60+	71	–	–	–	–	71
All	**69**	**44**	**31**	**25**	**20**	**44**

* Registered Social Landlord
Source: ODPM (2003a)

at its current level of around 2.3, this would represent a 20% rise in household numbers by 2050 (Table 3.2). The Local Stewardship scenario assumes an average household size that stabilises at 2.6 by the 2020s (UKCIP 2000), giving 21.2 million households by 2050. Although this was the average household size in the UK as recently as 1985 (GHS 2002), it was thought unlikely that there will be a return to this level. A conservative approach was adopted for the 40% House scenario, stabilising household size at 2.1 by 2020. This allows for some continuation of the downward trend but stops short of the Swedish figure.

Under the 40% House scenario there is a substantial increase of 33% in the number of dwellings needed, over and above the number in 1996, which would give rise to a 33% increase in carbon emissions, all other things being equal. The table also demonstrates the huge difference in projected housing demands between the Local Stewardship and 40% House scenarios: the latter has an additional 10.7m homes, accommodating 11.8m more people, living in households with 0.5 fewer inhabitants on average.

The relationship between new households, replacements, new construction and house prices is complex, particularly when regional issues are included. Currently, most new housing is for new household formation; very little replaces old stock. The recent Treasury review of housing proposes 242,000 new starts per year in England in order to reduce annual house price inflation from 2.4% to 1.8%, whilst building extra social housing and meeting the backlog of need, although no time horizon is given (Barker 2004). Building on this scale has occurred before – the peak was in 1968, when over 425,000 new homes were built in the UK (ODPM live table 241). This is considerably higher than the figures proposed under the 40% House scenario.

3.3 Living space

The amount of living space has implications for the energy required to heat (or cool) the space and the number and size of appliances that can fit into the dwelling. On average, personal living space has risen primarily because of dwindling numbers of people per household – from 38 m^2 per person in 1991 to 43 m^2 in 1996 and 44 m^2 in 2001 (ODPM 2003a). Table 3.3 indicates the range of personal living space, from single retired people to those in large households.

When they can afford to, people tend to buy themselves more living space: among single people in the private sector who moved house between 1996 and 2001, the highest earners bought or rented accommodation that was 17 m^2 larger on average than that for the lowest earners. For households of four or more, the difference was still 11 m² per person (ODPM 2003a).This supports the contention that *'demand for small dwellings will generally be restricted to those on low incomes, including many first-time buyers ... and the elderly trading down from a family home'* (HBF 2003).

3.3.1 Under-occupancy and fuel poverty

Much of the current housing stock is able to accommodate larger households (ie more people) than it does at present, because of under-occupation. It is estimated that 36% of all English households (45% of owner-occupiers) have two or more rooms above the 'bedroom standard' (ODPM 2004d). Under-occupancy is of course not necessarily a problem for individuals, although it does drive up the demand for space and space heating per person. However, it is a factor in causing and compounding fuel poverty. Approximately 29% of fuel poor households in England surveyed for the 1996 EHCS were under-occupying by two or more bedrooms above the standard, while 65% (4.5m) were under-occupying by one or more bedrooms above standard. They consisted predominantly of single householders over 60, couples over 60 and single adults under 60 (Houghton and Bown 2003). There would seem to be a clear case for building more attractive, efficient and relatively small-scale housing, to provide a range of alternatives for those who are in fuel poverty living in large properties (often a family home that they are reluctant to leave).

The median floor area of those in severe fuel poverty was 102 m² in 1998, whereas the majority of the population spending 10% or less of their income on fuel – those free from fuel poverty – had the use of 82 m² per household (DTI 2002b). Households in the lowest income quintile can normally only stay out of fuel poverty if they live in the smallest and most energy-efficient housing – under 63 m² with a SAP of 60+ (DETR 2000). Larger homes need a higher SAP in order to provide affordable warmth.

Where should standards be set, in order to be spacious enough to appeal to elderly people and small enough to heat effectively on a pension? The Housing Corporation gives 40-45m² as 'typical' for a new 1-bedroom dwelling and 72.5 m² for a '2.5-bedroom' dwelling (HC 2002). The former may be too small to appeal to most elderly people (Appleton 2002). An average living space of 74m² (35.2 m² per person) is assumed for the 40% House scenario for all dwellings built between now and 2050.

3.3.2 Overcrowding

The ODPM estimate that 2.4% of the English housing stock is overcrowded (ODPM, 2004d) – around 492,000 dwellings – with the highest percentage in London (6.1%). As with homelessness (Section 3.4.1), the problem relates to social and economic factors such as high rents and employment opportunities.

3.3.3 Teleworking and home-working

Home-working could potentially increase the demand for space, with a requirement for a home office, as well as resulting in higher use and ownership of home office and other equipment. The number of teleworkers has been rising rapidly in recent years, being estimated in 2001 at 2.2 million, of whom approximately one-third work part-time (Hotopp 2002). However, the estimated extra consumption was not thought significant enough to include in the model.

3.4 Number of dwellings

The number of dwellings in the UK exceeds the number of households by around 3% because of the existence of second homes and long-term vacant dwellings. This is balanced out to some extent by the fact that around 1.5% of the population live in communal establishments.

3.4.1 Homelessness and vacant dwellings

Homelessness is a social, economic and location issue, rather than one of actual housing space. In 2004 there were approximately 300,000 homes

Of the 31.8 million households in 2050, 10 million of them will be new

in England that had been vacant for six months or more – roughly 1.5% of the housing stock – and around three times as many as the (rising) number of homeless households being accommodated temporarily by local authorities (ODPM 2004e).

The Housing Act of 2004 allows councils to apply to make Empty Homes Management Orders on long-term empty properties. The owner retains legal ownership and will be entitled to rental income generated by letting the property, after deduction of relevant costs such as renovation (UK Government 2004). This provides an opportunity to reduce homelessness and improve energy efficiency, in a housing stock where between a quarter and a third of homes are estimated to be 'non-decent' – that is, they are not wind and weather-tight, warm and with modern facilities (ODPM 2004b).

3.4.2 Second homes

UK household statistics – and references to household data used in this report – relate to *occupied* dwellings unless otherwise stated. The figure for English households with a second home in Great Britain (not counting those held as an investment and rented out) has risen by 37,000 since 1993-94 to 228,000 (ODPM 2004d). The figure for the UK is therefore around 1% of the total housing stock, giving a total for vacant and second homes of 2.5%. This has implications in terms of duplication of appliances and heating systems, and how much they are in use when a dwelling is unoccupied. The impact of second homes in the UK on residential energy use is not great at present – and is not modelled – but the trend needs watching.

3.5 Conclusions

Population and household size are important factors in determining residential energy demand. Other important policy considerations relate to an ageing population, under-occupancy and regional planning. By exploring the current and projected trends, the following assumptions have been made for the 40% House scenario:

- A population projection of 66.8 million by 2050. This represents a mid-range estimate.
- An average household size of 2.1, giving 31.8 million households by 2050. This assumes a slight trend downward, but does not go as low as the lowest figures for some European countries today.
- An average living space of $74m^2$ per dwelling in these new homes by 2050.
- Almost 70% of the expected rise in household numbers in England between 1996-2016 is attributed to single-person households, half of whom are likely to be pensioners.
- By 2060, Government projections give a figure of 17 million pensioners, making up 25% of the population and potentially a much higher proportion of households.

Thermal comfort and control

Overall demand for space heating as a service has grown over the past three decades. Improved efficiency compensated for higher internal temperatures, higher levels of central heating and the heating of a larger part of the home, so that energy consumption per household remained more or less stable; but growth in household numbers meant that total energy demand for space heating rose by 36% between 1970 and 2001 (DTI 2004c). This chapter sets out some key considerations related to comfort and energy, in the present and for the future, setting the context for the discussion of the building fabric and low carbon heating options in later chapters.

4.1 Comfort, health and climate

In physiological terms, thermal comfort is what we experience when the body functions well, with a core temperature of around 37°C and skin temperature of 32-33°C. There are many ways of maintaining these body temperatures in a wide range of climates and this has been the case for centuries. If it were not so, large parts of the globe would be uninhabited. In the UK climate, comfort is a major consideration when considering the future demand for space heating and cooling, and the ways in which this can be met. There are interactions between climate, behaviour, building design and heating, cooling and insulation technologies.

The immediate challenge is to raise the level of energy efficiency in housing so that indoor warmth is sufficient for health and well-being in winter – ensuring that all households are adequately and affordably heated is a priority of current UK energy policy. As well as raising comfort levels, improving the energy efficiency of the housing stock provides cost, health and environmental benefits, both for individuals and society at large. The significant improvements required in the UK housing stock represent an opportunity to maximise these benefits for all. Once a safe level of thermal comfort for health has been reached, personal preferences will affect the extent to which improvements in residential energy efficiency are realised as energy savings, or lost because people live in larger homes, heat a larger proportion of their homes, and/or turn up their thermostats. Personal comfort preferences, and the technologies available for meeting them, will also determine how much the demand for artificial cooling is likely to grow between now and 2050, particularly given rising temperatures due to climate change.

4.1.1 Climate change

The United Kingdom Climate Impacts Programme has modelled four scenarios for future climate change (UKCIP 2002). A study of the potential impacts of climate change on human health notes the trend towards higher temperatures in all four scenarios and calculates that, without adaptation, there could be a rise to 2,800 heat-related deaths per year by the 2050s under a medium-high climate change scenario (Donaldson et al 2001). These would be accompanied by a fall in cold-related deaths in milder winters (assuming no disruption of the Gulf Stream), but are clearly a cause for concern. During the 2003 heat wave, it is estimated that approximately 2,000 excess deaths were caused in the UK (NS 2003b). Deaths peaked on the day after the highest temperatures were recorded. The elderly are most at risk from overheating, as from cold; and the highest risk is for those who live on their own (DEFRA 2004b, Rau 2004).

4.1.2 Policy approaches to comfort

Comfort is a complex issue which raises a number of policy considerations. Comfort conditions in general are socially influenced and may change with time as design, activity, technology and clothing fashions change (Shove 2003). However, the main question addressed here is the extent to which thermal comfort should be addressed by engineered solutions to the problem of maintaining a defined optimum temperature range in winter and summer (Fanger 1970, CIBSE 1999). This is a common approach in office buildings and could spread to homes.

The 2003 heatwave was good for some – but caused 2,000 excess deaths in the UK

The main alternative to this approach is to concentrate on getting the materials, design, location and shading of the building as suitable as possible for likely future climate conditions, while leaving it possible for residents to make themselves comfortable by adaptation that does not involve energy-intensive engineered solutions: shedding or adding clothes, altering thermostats, opening or closing doors and windows and being more or less active (Nicol and Humphreys 2002).

Decisions on the best course of action will depend on a number of factors, not least whether a building is being designed from scratch or adapted. Design of new buildings offers far more options for the use of natural ventilation, high quality insulation, high thermal mass and shading in order to avoid thermal discomfort.

4.2 Heating

People are normally sedentary for around two-thirds of their time at home (provided they are not immobile through disability), regardless of their age, or how much of each day they spend in the home (Boardman 1985). The World Health Organisation (WHO) recommends temperatures of 21°C for the main living area and 18°C for the rest of the home. The values recorded for living areas in the UK have so far been lower than this, although they are increasing. Winter conditions in 1986 and 1996 were comparable, and recorded temperatures in England show that living rooms were on average 0.9°C warmer in 1996, whilst hallways were 1.6°C warmer (DETR 2000).

4.2.1 Underheating

The 1996 English House Condition Survey (EHCS), using spot temperatures, found that 6.9 million homes (28%) had living rooms at or below 16°C, and 10.9 million (44%) had cold hallways (Table 4.1). Although around 80% of those interviewed claimed that they were satisfied with their home temperatures, the data show that many were

Table 4.1: Temperatures in homes and health effects, England. 1996

Indoor temperature (°C)	*Assumptions of physiological effect*	*Living rooms at these temperatures (million)*	*Halls/stairs at these temperatures (million)*
24+	Risk of strokes and heart attacks	0.4	0.3
21-24	Increasing discomfort	3.5	2.1
18-21	Comfortable temperatures	8.8	6.3
16-18	Discomfort, small health risk	4.1	4.6
12-16	Risk of respiratory diseases	2.5	4.7
9-12	Risk of strokes, heart attacks	0.2	0.9
< 9	Risk of hypothermia	0.1	0.7
Unhealthily cold (<12°C)		2.8	6.3
Total cold homes (<16°C)		6.9	10.9

Source: Richard Moore, pers. comm. Note: Outside temperature 5°C or below living at temperatures that are associated with physiological discomfort and danger to health (DETR 2000). The national temperature survey has since been dropped from the EHCS, but it is important that this is reinstated if progress towards warmer, healthy homes is to be monitored and confirmed.

Mortality in the UK rises on either side of an outdoor temperature of approximately 16-19°C (Donaldson et al 2001). Low temperatures are the most hazardous to health, with England and Wales having excess mortality of 23,500 during the winter of December 2003 – March 2004 (NS 2004c). This was a relatively low figure: the average for the previous eight years was 35,220. The UK has one of the highest levels of excess winter mortality in northern Europe and housing conditions are a contributory factor (Boardman 1991, Wilkinson et al 2001). Elderly people spend a higher proportion of their lives at home, so they need to be able to afford to heat it for longer hours. They are more likely to suffer from 'cold strain' than the young, so that even short periods of cold stress may damage their cardiovascular and respiratory systems (Healy and Clinch 2002).

An evaluation of the Warm Front/HEES programme, the main initiative to lessen fuel poverty in vulnerable households for owner-occupied and privately rented housing, shows that temperatures in the homes of the fuel poor are now rising, although those in extreme fuel poverty are not gaining much as yet (Sefton 2004). There is therefore still a large hidden demand for heating and many people are still at risk of death or disease, as well as enduring discomfort and distress from cold homes in winter.

4.2.2 Comfort factors

The percentage of potential energy savings that are taken as improved comfort is known as the 'comfort factor'. This has to be taken into account when estimating the effect of improvements to the housing stock. 'Warm Front' allows for up to 75% of theoretical savings to be taken as comfort. The comfort factor in the Energy Efficiency Standards of Performance (EESoP) programme of efficiency improvements was found to be 55% for 'disadvantaged' customers (Henderson et al 2003). The best general estimate available is that 80% of potential energy savings from efficiency improvements in housing will be taken as savings, once the average temperature has risen above 19°C, with only 20% of the potential savings taken in the form of further energy consumption or 'takeback' (Milne and Boardman 2000).

4.2.3 Model assumptions – heating

Under the 40% House scenario it is assumed that there will be adequate, affordable heating for all in line with the Government's legal obligation to eliminate fuel poverty by 2016. In the short term, there may be a further increase in emissions if the fuel poor become able to achieve higher indoor temperatures through higher incomes or benefits. This will be more easily achieved, with less of an energy penalty, as homes become more efficient and better at retaining heat.

Whilst the requirement to meet basic physiological needs and to do away with fuel poverty can be addressed in a relatively straightforward way, it remains difficult to describe, evaluate and prescribe for thermal comfort, or to predict the temperature beyond which all efficiency gains will be taken as energy savings. The 40% House scenario assumes 24-hour averages of 21°C for the living room and 18°C for the rest of the dwelling in line with WHO recommendations. These are on the high side for all-day averages, but allow for higher living room temperatures than 21°C for the elderly during the daytime, along with factors such as the use of bedrooms for homework.

4.3 Cooling

Adequate heating is the main issue in the short term, but cooling is likely to become an increasingly important issue over the coming years with rising global temperatures. Therefore, at the same time as improving the energy

Shading over windows could reduce the need for energy intensive air-conditioning units

efficiency of the housing stock, it is essential that cooling needs are taken into account in design, construction and refurbishment to avoid intensive energy demand for cooling in the future. Some of the solutions will overlap – for example, improved insulation is also important for keeping homes cooler in summer, especially in attic rooms.

It is estimated that 70-90% of energy decisions are made at the 'concept' stage of a building, which will go on to affect the behaviour of the people who use it (Chappells and Shove 2004). The commercial pressure to design for air-conditioning can be powerful, bringing more energy-intensive behavioural change in its wake: during the 1950s, the USA summer 'comfort zone' became cooler than the winter comfort zone of 20.5-26.7°C, as people became able to control indoor temperatures and wanted to achieve a contrast with the weather outside (Ackermann 2002). Eighty-three percent of US homes are now air-conditioned (Ackermann 2002) and sales of air conditioning are rising in the UK, especially during heat waves. Cooling existing buildings during heat waves, especially in dense urban developments, is likely to pose a challenge without air-conditioning, although there is scope for retrofitting with shading and shutters. This could be grant-aided, just as heating efficiency measures are now.

Although the use of air-conditioning in the UK is modest at present, ownership could rise steeply if temperatures were a few degrees higher and if people were to be in a position to switch on air-conditioning rather than using other methods to keep cool. Outdoor summer temperatures in the south of the UK are now occasionally close to the American threshold for air-conditioning (Levermore et al 2004), although European householders show less inclination to purchase air-conditioning at a given outdoor temperature than those in the USA. This is partly because of the higher average thermal mass of dwellings and differences in humidity. Southern European housing designs are therefore likely to provide better models for housing in a warmer UK than those from America.

There is a danger that climate change will contribute to continued growth of a market for air-conditioning, resulting in a destructive positive-feedback cycle of hot summers that increase a demand for fossil-fuel-based cooling systems. The cooling demand sub-model of the UKDCM looked at the possible effects of climate change on demand for air-cooling. Even under a low carbon emissions scenario, it showed a substantial rise in the number of 'cooling degree days' (CDD, that is, equivalent days above a base mean temperature of 18.3°C), rising to 193 CDDs for Heathrow in 2050, with comparable figures for Edinburgh and Manchester at 29 and 66. Such an increase in temperatures in the south of England could lead to 29% of homes there having some air-conditioning by 2050 – and as many as 42% under a high-emissions scenario – if other factors such as fuel prices, affluence, building construction type and sunlight intensity were comparable with the USA, and if policy operated on a World Markets-type scenario.

4.3.1 Model assumptions – cooling

The 40% House scenario does not include any air-conditioning but allows for some cooling, for example in hard-to-cool dwellings (mostly high-density, highly-glazed flats). This might be through absorption cooling from a district chilling network (using the heat from CHP), or heat pumps circulating cold water (or cold air) during the summer.

4.4 Water heating

Hot water demand has not been dealt with in detail in the UKDCM, but some basic assumptions have been made for modelling purposes. Although demand for hot water per household has risen in recent years, it is assumed to stabilise at the current level under the 40% House scenario. This is mainly due to a decrease in the use of water from the home's central water-heating system as more people adopt dishwashers and cold-fill washing machines, with the trend towards colder washes. This, along with the replacement of bathing by showering, is estimated to compensate for increased use of hot water for additional, or more high-powered, showers. Figures for water heating energy consumption are given in Chapter 5, while the energy required is covered in Chapter 7.

4.5 Other policy considerations

Other factors which influence energy demand for heating and cooling need to be taken into account when developing a policy approach to ensure that maximum savings are achieved.

4.5.1 Controls and consumption feedback

Predictions of energy use tend to suffer from over-reliance on an assumption that the public use control devices in the way that the designers intended. Eighty-eight percent of UK households had some form of programmed heating by the time of the 1996 EHCS, yet many householders still do not fully understand how to operate their controls, with many preferring to use them as on-off switches whether or not they are designed to be used in that way (Pett and Guertler 2004). There is a clear need for simpler, more user-friendly controls if householders are to be able to use timers and thermostats to best effect. Digital wall thermometers, which warn the householder when the temperature is too hot or cold for health, would also be useful as standard installations.

More accessible metering and informative bills can both help with user understanding and control of their heating: better direct feedback through meter-reading or direct displays can give savings of the order of 10%, while informative bills can produce savings of 5-10% or more, especially if feedback is incorporated into advice programmes (Darby 2001).

4.5.2 Training and infrastructure for comfort

Tightly controlled comfort conditions are more common in offices and public buildings than in homes, but conditions in the workplace are likely to affect what people do when they return home – for example, altering the thermostat in order to stay comfortable in the same clothes as they wear at work. It is going to be important to train designers, engineers, architects and building users in low-energy methods of controlling temperature in order to achieve comfort, whether in public or residential buildings.

Shading and thermal mass are going to become increasingly important considerations in building design and refurbishment, whilst air-conditioning and electrical fans are likely to become significant energy end-uses under 'business as usual' assumptions. Convergence on a high-energy controlled indoor environment is not inevitable, though. There is still plenty of scope to extend traditional, low-energy forms of cooling and to educate for an approach that concentrates on imaginative use of building design and low and zero carbon technologies to minimise heat gain during the summer and natural ventilation, along with the use of blinds, shutters and other forms of shading. Some of this expertise would then be usable in providing cool buildings through environmentally-sympathetic systems (Chappells and Shove 2004). Grants from schemes such as the Energy Efficiency Commitment could be used to provide summer shading and two-way heat pumps.

The 40% House scenario assumes adequate warmth for all, with an average living room temperature of 21°C

4.6 Conclusions

Comfort is a concept that goes beyond health needs to personal preferences. There is still considerable unmet need for warmth for the fuel poor in winter, while a warming climate poses the question of how best to achieve cooling in summer. Policy needs to be geared towards design for high thermal mass, high insulation values and the use of shading and natural ventilation wherever possible, rather than energy-intensive solutions; and better controls and use of feedback are advocated as a way of improving householders' control over their own comfort levels while reducing consumption. There is an urgent need for training in the use of techniques to minimise energy use for cooling during hot spells, which are likely to become increasingly important in the future. The approach and technologies for achieving improved comfort levels are discussed in detail in the following chapters.

In terms of the 40% House scenario, the following assumptions were made:

- There will be adequate, affordable heating for all in line with the Government's legal obligation to achieve affordable warmth by 2016.
- Beyond 2020, there will be average all-day temperatures of 21°C in the main living area and 18°C in the rest of the dwelling.
- Cooling demand is met by design for natural ventilation and shading and/or low and zero carbon technologies.
- The quantity of hot water per household remains stable.

Building fabric and housing stock

This chapter considers the state of the existing UK housing stock and the options for improving the energy efficiency of dwellings to provide appropriate levels of comfort whilst minimising energy consumption. The role of the building fabric in achieving the 60% target is discussed, along with a consideration of the levels of refurbishment, construction and demolition that are required, whilst ensuring social and political acceptability. Policy options forming part of a market transformation strategy for the housing stock are introduced.

Results from the UKDCM show that the 60% reduction target can only be met if there is a step-change in the quality of the fabric of the housing stock. Demolition and construction rates both need to rise; the average energy consumption of the existing stock needs to be brought up to a SAP (Standard Assessment Procedure) rating of 80, and all new homes need to achieve close to zero space heating demand from 2020 at the latest.

5.1 Context

There were 25 million homes in the UK in 2003, making up one of the oldest and least efficient housing stocks in Europe. The poor quality of the building fabric across the whole stock means that space heating accounts for roughly 60% of total delivered residential energy demand (Shorrock and Utley 2003). Some 2 million homes in England are rated with a SAP score of below 30 (ODPM 2003a), representing a very low efficiency standard. In contrast, a handful of pioneering housing developments have been designed and built to achieve zero space heating demand.

Improvements through a range of cost-effective energy efficiency measures are currently promoted in a variety of Government programmes, and heat loss standards for new homes have become progressively tighter in the regular cycle of revisions to the Building Regulations. The net effect on the UK housing stock has been a 1% annual drop in fabric heat loss from UK homes between 1970 and 2001 (Figure 1.2).

However, current policies are inadequate to the scale and urgency of the task. Existing grants and advice programmes promoting cost-effective energy efficiency measures are planned to achieve 2020 targets (DEFRA 2004a) but the same set of measures cannot deliver enough additional savings beyond 2020. The Building Regulations set standards for new construction which, though they get tighter with each five-yearly revision, fall a long way short of the low or zero space heating energy demand of the best current practice using existing technology. There is a poor record of compliance with the design standards and a dearth of data on real-life performance of new homes.

5.2 Heat losses and gains in buildings

Heat is lost from buildings through the fabric of the building itself (roof, walls, floor, windows and doors) and through infiltration of cold air via any holes and gaps. Fabric heat loss can be slowed down with insulation materials, the performance of which is a function of the material used, its thickness and a number of other factors to do with how well the insulation is installed: gaps in insulation quickly compromise performance, for example. Ventilation heat loss can only be reduced by minimising infiltration of cold air: construction needs to be airtight, with controlled ventilation supplying adequate fresh air, possibly with a heat recovery system to reduce the heat loss even further. Airtight construction requires good design and close attention to detail during construction. As insulation standards have improved in the UK for new construction, the issue of ventilation heat loss has become relatively more significant (ODPM 2004h).

Buildings also gain heat – from sunshine coming through windows, from body warmth, from hot water in pipes and storage tanks, and from the heat given off by lights and appliances. In a building where the total heat loss is kept to a minimum, these incidental gains contribute more of the heating.

15% of solid walls will be insulated by 2050

5.3 Current picture

The main challenge in working towards a 60% reduction in carbon emissions from the residential sector is the poor state of the existing housing stock.

5.3.1 Stock profile

National statistics on energy in housing use the Standard Assessment Procedure (SAP), which gives a score of up to 120 – the higher the number, the better the rating (recalibration under SAP 2005 will give a top score of 100). SAP is based on the thermal performance of a building, its heating appliances and the energy prices for different heating fuels used. SAP 2005 will take more account of carbon emissions.

The average SAP rating in England in 2001 was 51 (Figure 5.1). Almost 2 million homes have a SAP rating below 30 (ODPM 2003a). A transformation of the housing stock to a target SAP rating of 70 would reduce CO_2 emissions by 34.5% (DETR 2000). Such a transformation of the stock would be an enormous challenge but would still not provide enough savings in space heating demand to make the overall 60% carbon reduction achievable.

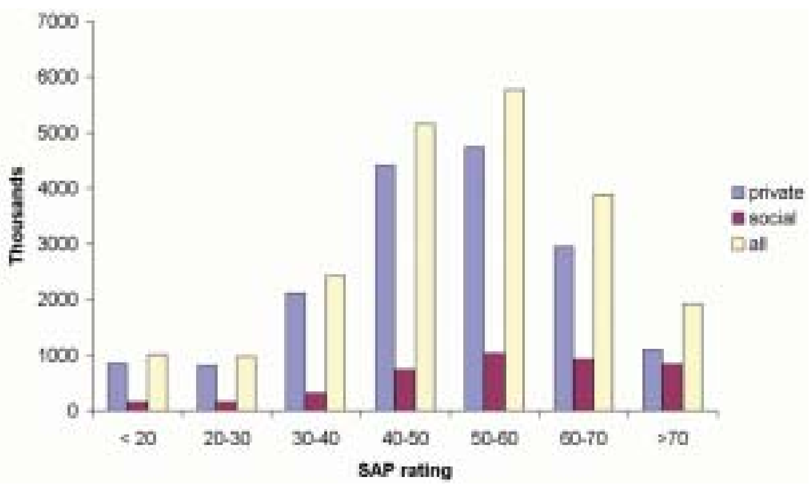


Figure 5.1: English housing tenure by SAP rating, 2001

Source: ODPM (2003a)

5.3.2 Refurbishment opportunities

The distinction between old and new housing is crucial to the overall performance of the stock, as there are practical limits to what can be done to improve a building. Energy efficiency is much easier to achieve when it is incorporated at the design stage in new build, rather than as a refurbishment. However, since many of the existing dwellings will still be standing in 2050, refurbishment will be a necessary part of improving the energy efficiency of the stock.

Options for refurbishment range from easy, cost-effective measures to more expensive and disruptive solutions. Although a certain number of measures have already been installed in the existing stock, there is still substantial opportunity for further improvement.

In 2003 there were an estimated 17 million homes with cavity walls, of which 11 million were uninsulated (DEFRA 2004a). Cavity wall insulation is one of several cost-effective measures supported by the Energy Efficiency Commitment (EEC) and Warm Front grant schemes. Another 7 million dwellings have solid walls, almost all of which are uninsulated, as solid wall insulation is a costly, disruptive measure resulting in slightly reduced room sizes (if the wall is insulated on the inside) or a changed façade (if the insulation is clad on the outside). A future technical breakthrough may lead to the development of a new insulation product without these drawbacks, but has not been assumed here.

Most homes with a loft have some loft insulation, although the commonest thickness of 100mm is well below the current recommended level, and performance may frequently be compromised through compaction due to the storage of heavy items directly on top of the insulation material. Loft insulation is a cost-effective measure, causing minimal disruption, and is also supported by grants under EEC and Warm Front.

Solid ground floors can be insulated during construction, with the insulation under a slab of poured concrete. In refurbishment, the floor would need to be excavated and re-laid to achieve comparable performance. Suspended timber floors can be insulated more easily as a refurbishment measure, typically to the depth of the floor joists, although deeper insulation can be installed on hangers fixed to the joists where there is sufficient space below the floor. There are no data on floor insulation or the proportion of solid versus suspended timber floors in published housing statistics, and so the potential for uptake in older dwellings is unknown.

The performance of glazing has increased considerably in recent years with multiple panes (double-, triple- and quadruple-glazing), low emissivity coatings, inert gas fills between the panes, and improved seals and frame designs. Whole window replacements are regulated by the Building Regulations, although compliance is reported to be low (EAC 2005). Replacement glazing is a home improvement that improves security and sound-proofing, as well as energy efficiency, and the market is already mature.

5.3.3 Demolition and construction rates

Current levels of construction are relatively low, with around 167,000 housing starts in the UK in 2002-3. Demolition rates are also low – between 1996-2004, a total of nearly 160,000 dwellings were demolished, approaching 20,000 a year. Continuing at these rates means that the average house will last for over 1000 years – clearly an unrealistic scenario.

Historically, the highest level of demolition occurred between 1961-75, when the annual rate was just over 81,000 pa in GB, the majority being defined as unfit. Only 20% of those demolished between 1996-2004 were considered to be unfit (EHCS 2001), indicating a shift in the criteria used to decide which properties are removed from the stock.

5.3.4 Decent homes

A third of dwellings in England are acknowledged to be 'non-decent' – unhealthy, in disrepair, in need of modernisation or providing insufficient thermal comfort, with 80% of these failing the comfort criterion (ODPM, 2003a). Current policy on decent homes sets a basic standard and a timetable for implementation. Homes should be free from serious disrepair, structurally stable, free from damp, have adequate light, heat and ventilation. All social housing should be up to standard by 2010; for vulnerable private-sector households, 65% are to reach the standard by 2006 and 70% by 2010.

There are useful policies and programmes to address fuel poverty and market transformation, such as the Energy Efficiency Commitment, Warm Front and Decent Homes, but these are inadequate, not linked to each other and their effect is limited in relation to the scale and urgency of the challenge.

The policies needed to achieve 60% reductions in residential carbon emissions can also deliver decent homes to the most vulnerable in society.

5.4 40% House scenario

By 2050, 31.8 million dwellings will be needed to meet the growth in population (Chapter 3). This represents a net increase of 7.9 million homes (33%) from 1996. The stock increased by 1.1 million between 1996 and 2004, leaving 6.8 million to build between 2005 and 2050. Under the 40% House scenario this has been achieved through the construction of 10 million new homes and demolition of 3.2 million existing homes (Table 5.1). In other words, over two-thirds of the 2050 housing stock has already been built, highlighting the importance of refurbishment of these dwellings. The total space heating energy

Table 5.1: Housing stock assumptions, 40% House scenario, 1996 and 2050

	Base year 1996	*40% House scenario 2050*
Total number of dwellings	23,900,000	31,800,000
New build 1996 – 2004		1,280,000
Demolition 1996 – 2004		160,000
Homes already built and remaining in 2050		21,800,000
Homes demolished 2005 to 2050		3,200,000
New homes built from 2005 to 2050		10,000,000
Heat demand for space heating per dwelling built pre-1996 (kWh delivered energy)	14,600	9,000
Heat demand for space heating per dwelling built post-1996 (kWh delivered energy)		2,000
Total space heating demand (TWh delivered energy)	348	216
Energy saving from fabric measures (TWh delivered energy)		148
Average heat demand for hot water per dwelling (kWh delivered energy)	5,000	3,400*
Total water heating demand (TWh delivered energy)	120	108*
Total space and water heating demand (TWh delivered energy)	468	324*
Energy saving from all space and water measures (TWh delivered energy)		144*

Source: UKCDM
* net of solar hot water

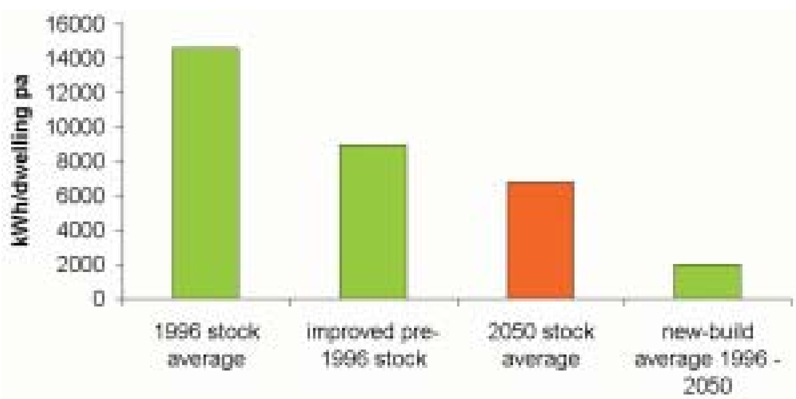


Figure 5.2: Net space heating energy demand, existing stock and new-build to 2050

Source: UKDCM

demand in 2050 is reduced by 38% compared to 1996 levels, despite a 33% increase in the number of households.

The demolition rate is assumed to rise from current levels until it reaches 80,000 per annum in 2016, after which time it remains constant. This represents an increase from 0.1% of the stock now to 0.25% of the housing stock in 2050. Continuing at this rate means that it will take 400 years to replace the 2050 stock of houses. The average annual construction rate is assumed to be 220,000 completions per annum between 2005 and 2050.

5.4.1 Space heating demand

The energy efficiency of the fabric of the housing stock in 2050 is a function of the energy efficiency improvements made to existing homes, the number of existing homes demolished and the quality of the new homes built. In the 40% House scenario, the average net space heating demand across the whole stock in 2050 is 6,800 kWh/year. For homes built before 1996, the average net space heat demand in 2050 is 9,000 kWh/year (after energy efficiency improvements and incidental heat gains) – a 38% reduction compared to 1996 levels. For homes built after 1996, the average net space heating demand is 2,000 kWh pa (Figure 5.2).

5.4.2 Refurbishment of existing stock

To achieve a 38% reduction in the average space heating demand of the existing stock, a high level of refurbishment has been assumed. This was considered a preferable option (even where expensive and disruptive) compared to higher levels of demolition (potentially more expensive and disruptive) in order to realise the necessary levels of energy efficiency.

Under the 40% House scenario, energy efficiency improvements to the existing stock are modelled, with average uptake rates and insulation levels for each decade. Values for 1996 and 2050 are given in Table 5.2. It is assumed that there is a considerable market in replacement double-glazing, so that all windows in 2050 have

Table 5.2: Refurbishment measures, 40% House scenario, 1996 and 2050

Efficiency measure	*U value 1996 W/m²K*	*U value 2050 W/m²K*	*Uptake by 2050*
Cavity wall insulation	0.4	0.25	100%
Solid wall insulation	0.5	0.25	15%
Loft insulation	0.6	0.15	100%
Floor insulation	Varies with dwelling age	Varies with dwelling age	0%
Glazing	3.3	0.8	100%
Doors	3.5	2.0	100%
	Air changes per hour, 1996	Air changes per hour, 2050	
Ventilation	3.5	0.6	

Source: UKDCM

a U value of 0.8 W/m²K. Solid wall insulation is assumed to reach 15% uptake by 2050, with a U value of 0.25 W/m²K for work done between 2030 and 2050. From 2030 onwards, many cavity-walled dwellings will have external cladding in addition to filled cavities, so that 35% of this dwelling type has a wall U value of 0.25 W/m²K by 2050. All lofts are assumed to be insulated by 2050 with a U value in 2050 of 0.15 W/m²K, equivalent to about 300 mm of insulation (dwellings with no roof above or a flat roof are not insulated). Although technically feasible, no retro-fit floor insulation is modelled, erring on the side of extreme caution in the absence of reliable data. The U value for floors varies with the age of the dwelling.

The 40% House scenario assumes no loss of architectural heritage in conservation areas (1.2 million dwellings) or listed buildings (300,000 dwellings). Internal measures that do not alter the appearance of valuable interiors are permitted (eg loft insulation), but solid walls, doors and windows are assumed to remain untouched by energy efficiency improvements in these dwellings.

5.4.3 Performance of new homes

All new homes built to 2050 are assumed to be of a high efficiency standard, based on demonstrated design and technology already in existence (Table 5.3). The average net space heating demand of 2,000 kWh pa across all new homes built since 1996 incorporates a range of efficiencies, gradually improving to 2020 when the standard for space heating energy demand in new housing is assumed to be close to zero, depending on the availability of solar gains. Site conditions (eg shading of sunlight) may mean that zero is not always achieved but demand for space heating will still be low.

Table 5.3: Performance standard of new housing, 40% House scenario

	Rate of heat loss (U value, W/m²K)					
Source of fabric heat loss	*1997-2004*	*2005-2009*	*2010-2019*	*2020-2029*	*2030-2039*	*2040-2050*
walls	0.35	0.3	0.2	0.1	0.1	0.1
roof	0.24	0.15	0.1	0.1	0.1	0.1
floor	0.35	0.2	0.15	0.1	0.1	0.1
glazing	2.2	2.0	1.5	0.8	0.8	0.8
doors	2.5	2.0	2.0	2.0	2.0	2.0
Ventilation heat loss (air changes per hour)	2.0	1.5	0.6	0.6	0.6	0.6

Source: UKDCM

5.5 Housing renewal

Aside from improving the efficiency of the housing stock, the building of 10 million houses and demolition of 3.2 million by 2050 raises a number of other issues around design, location and the amount of energy and waste involved in this level of housing renewal.

5.5.1 Energy in construction and demolition processes

Construction and demolition processes all use energy, but the amount is relatively small compared to the energy consumption in the use of buildings. When an old, inefficient building is replaced with a new, efficient one, the embodied energy in the construction process will be offset within a few years by the lower energy consumption of the more efficient building in occupation: thereafter, the more efficient building will represent savings throughout its lifetime (Matsumoto 1999, XCO2 2002).

While the priority is clearly to reduce energy in use, there are significant secondary concerns to do with the carbon balance of building materials and processes. When local plant-derived materials are used, they may act as net carbon sinks, helping to offset carbon emissions (Reid et al 2004).

5.5.2 Waste minimisation

The construction and demolition industry produces some 70 million tonnes of waste, of which 13 million tonnes (19%) are materials that are ordered but never used (EAC 2005). An accelerated programme of housing stock replacement would exacerbate the problem unless waste management is also improved. Where practically possible, old buildings need to be dismantled brick by brick and re-used, rather than demolished into rubble. The re-use of building materials needs to be considered at the design stage of new construction, so that a maximum quantity of materials can be

Demolition at current rates means the average house will last over 1,000 years. Demolition will have to increase to turn over an inefficient housing stock by 2050

dismantled intact, rather than being 'down-cycled' at the end of the building's useful life (OECD 2003). However, it is beyond the scope of this report to analyse waste issues in detail.

5.5.3 Modern Methods of Construction

There is renewed interest in making modular, prefabricated building elements as a solution to the dual problems of a housing shortage and a persistent low level of quality in construction. Modern Methods of Construction (a new term for high-quality prefabrication) has inherent advantages: quality control is easier in a factory environment than on a building site and fewer days are lost due to inclement weather. However, pre-fabrication using mainly lightweight building materials may lead to an increase in summer over-heating and an energy penalty from residential air-conditioning demand. Pre-fabricated panels may also be harder to re-use than conventional building materials, adding to future waste problems.

5.5.4 The built environment in a changing climate

Building design and planning policy in the twenty-first century need to take account of the likely impacts of climate change, including greater extremes of summer heat and increased flood risks. One estimate is that over 2 million properties in the UK already are at risk of flooding (OST 2004). Avoiding flood-risk areas in future is a planning issue, and will put additional development pressure on other areas.

As highlighted in Chapter 4, the take-up of air-conditioning in UK homes is at negligible levels now, but a warming climate may well increase demand, potentially adding significantly to electricity consumption and carbon emissions. Optimising the adaptive potential of buildings and minimising demand for air-conditioning will be increasingly important across the whole housing sector. New and existing homes can be fitted with shutters or other shading devices to help prevent over-heating in summer. A key design strategy for new buildings is to make use of materials with high thermal mass, which moderate extreme temperature changes and provide comfort without mechanical cooling.

5.5.5 Spatial development

In the 40% House scenario, the housing stock increases by a net 7.9 million homes from 1996 to 2050, risking increased pressure on green-field sites.

Raising the demolition rate not only creates the opportunity to remove some of the worst housing from the stock, but it also creates new development sites in urban areas. Local planning authorities will need to ensure that replacement housing increases in density, as well as energy efficiency, across the local area, particularly since increased density is also well suited to carbon-efficient heating and cooling systems (Chapter 7).

5.6 Policies

A market transformation approach to the housing stock requires an overall coherent strategy if it is to be effective. Improvement of the energy efficiency of the housing stock is a vital part of this strategy and there are a number of measures that need to be put in place in order to achieve this and meet the 60% target.

5.6.1 Information

Clear, reliable information about the energy performance of a dwelling is a crucial first step in market transformation. By 2006, all EU member states are required to have a methodology in place for providing information on the energy performance of all buildings when they are built, sold or rented, as set out in the Energy Performance of Buildings Directive (EPBD). The current revisions to SAP are intended to fulfil the requirement for a building rating methodology under this Directive. The SAP rating of a dwelling, together with other information about energy use and potential for efficiency improvements, will be included in the proposed Home Information Pack (HIP), which puts the onus on the vendor of a property to gather all relevant information about the property prior to sale. Both SAP and HIP cover space and water heating only. An equivalent information service is needed for the rented sector.

5.6.2 Regulation at point of sale or rental

Sales and rentals of residential properties totalled 1.3 million transactions in 2002, far exceeding the number of newly built homes (ODPM 2003e). The point of sale or rental is therefore of critical importance to the transformation of the housing stock. Tenants in rented housing move, on average, every five years, while owner occupiers move less often – about once every fifteen years (Robinson et al 2004). By 2050, each rented dwelling therefore needs to be transformed through the process of nine property transactions. Owner-occupied homes need to achieve the same transformation in only three transactions.

Energy consumption is typically not a deciding factor in the purchase of somewhere to live, especially when there is a shortage of choice in the sought-after areas. Therefore, information on energy efficiency – necessary though it is – is unlikely to be enough on its own to transform the housing stock. A system of rebates on stamp duty is proposed as a means of motivating energy efficiency improvements in the time just following a property sale, when major works are often undertaken or considered. In the rental sector, where the efficiency cost savings and comfort improvement are enjoyed by the tenant rather than the landlord, there is far less scope for incentivising improvement. Regulation of the rented sector could provide an obligation to improve the property to a minimum standard before a new rental contract can be agreed.

5.6.3 Regulation of refurbishment

Recent revisions to the Building Regulations have included controls on replacement heating boilers and replacement windows, extending the coverage of the legal standard to include refurbishment works, as well as new construction. For the 2005 revision, consideration is being given to a new requirement aimed at major renovations: for works costing over a threshold amount, an additional percentage of the total budget would have to be spent on cost-effective energy efficiency measures. By extending the scope of the Building Regulations to cover renovation in this way, energy efficiency will have to be considered at a time when major disruption and cost are already being contemplated.

The proposed extension of the Building Regulations to cover major refurbishments is a welcome first step, but its impact will be insufficient if it only covers those measures which are cost effective today. The 40% House scenario represents a massive level of improvement to the existing housing stock, as well as an accelerated programme of stock replacement. Increases in insulation and measures to reduce ventilation heat loss are all needed if the 60% target is to be met. As cost effective measures are taken up, the onus needs to shift towards new measures.

5.6.4 Ensuring compliance

Compliance with Building Regulations needs to be improved if claimed carbon savings from homes are to have any basis in fact. Very few studies are conducted on the performance of buildings in use, but these few suggest that standards are frequently not being met (eg Olivier 2001, EST 2004c). The current shortage of building control inspectors has led to trials of self-certification schemes, for example with replacement double-glazed windows. Widespread non-compliance has been reported (EAC 2005).

A policy which relies on un-policed standards or self-assessed compliance is unlikely to deliver all the expected benefits. The 2005 revision to the Building Regulations is likely to include a new requirement for pressure-testing a percentage of new dwellings as a proxy for overall quality in construction. It remains to be seen whether this will bring about improved performance.

For refurbishments, there will be a need for

All insulation measures, including costly and disruptive measures like underfloor insulation, need to be taken up at higher rates than at present

more qualified surveyors to carry out energy audits. The requirements of the EPBD allow EU member states until 2009 to put in place the systems for energy audits to take place.

5.7 Priorities for action

Translating these policy measures into practical steps identifies the following priorities for action:

- Initiate a system of incentives using rebates on stamp duty to encourage greater energy efficiency;
- Instigate a system of regulation for the rented sector to compel landlords to meet minimum energy efficiency standards;
- Extend the scope of the Building Regulations' coverage of major refurbishments;
- Broaden the coverage of the Building Regulations beyond 'cost effective' measures;
- Invest in research to create a database of real-life energy performance from a representative sample of UK homes;
- Develop a strategy to ensure compliance based on performance rather than design standards;
- Recruit and train enough surveyors to carry out clear and reliable residential energy audits.

5.8 Conclusions

Reducing space heating demand across the whole housing stock is made difficult by the poor standard of so many existing homes. A dual strategy of refurbishment and replacement is needed in order to make the necessary carbon savings, and compliance with design standards needs to be much better enforced.

Information on the energy performance of a dwelling at the point of sale or rental has the potential to increase the rate of improvement through refurbishment, but the impact of information alone is likely to be low. Regulation and financial incentives could help translate information on the quality of homes into lasting energy efficiency improvements, using a market transformation approach. Preparation for the implementation of the EPBD is already providing some of the groundwork for a market transformation system to be in place from 2009.

The quality of the audits will be key to the success of the EPBD. Financial incentives and, in time, the setting of minimum standards will also be needed.

The list of measures needs to be extended to include solid wall insulation, ground floor insulation (where feasible) and works to reduce ventilation heat loss from existing dwellings (eg blocking up chimneys, sealing skirting boards and service pipe penetrations). All measures – those that are currently promoted, as well as the more costly and disruptive ones – need to be taken up at higher rates than are currently achieved if the 60% carbon reduction target is to be met by 2050. Stamp duty rebates would be one way of increasing uptake in the private sector.

The major findings from the 40% House scenario for space and water heating are summarised below:

- The 21.8 million pre-1996 homes that are still standing in 2050 are much more energy efficient and only need 62% of the delivered energy for space heating.
- From 2020, all new homes have a space heat demand of near zero to achieve an acceptable stock average in 2050.
- The demand for hot water per home is assumed to stay at 1996 levels until 2050 though an increasing proportion is met by solar water heating.
- The quantity of energy for space heating, for the whole stock, has been reduced by 38% in 2050, despite the 33% increase in the number of homes and a nearly 2°C rise in internal temperatures.
- The rate of demolition in the UK rises to 80,000 per year by 2016, and stays at the same level to 2050: a total of 3.2 million demolitions from 2005-2050.
- The rate of new construction in the UK is an average of 220,000 dwellings per year for the next 45 years.

Lights and appliances

This chapter considers the potential for reducing energy consumption and carbon emissions from residential lights and appliances. An overview of the current situation is provided, along with an outline of existing trends and policies, followed by a discussion of the barriers to achieving a 60% reduction in this sector. The key technologies that underpin the lights and appliances in the '40% House' are discussed, with proposals for future policy, building on the market transformation approach already established in this area.

6.1 The low carbon house

Under the 40% House scenario, by 2050, electricity consumption in residential lights and appliances (RLA) in the low carbon house is almost half current levels (excluding space and water heating). This represents savings that could be achieved mainly through improvements in technology alone and does not take into account many possible behavioural shifts, beyond adopting the technologies. These necessary technologies are available now, with some at early stages of development, hence the challenge is to bring these products onto the market and into people's homes.

One of the advantages of reducing energy consumption in RLA is that savings can be realised relatively quickly due to the turnover of appliances in the stock. A cold appliance lasts, on average, 14-18 years, compared to 60+ years for the house itself. By 2050, all appliances in the house will have been replaced at least twice, if not three or four times, providing ample opportunity for the introduction of more efficient technologies. Conversely, a new technology that is inadvertently inefficient can be rapidly taken up into the stock, with negative impacts lasting for years, as in the case of large-screen plasma TVs which consume 350 W in the on-mode, compared to 75 W for the average cathode ray tube (CRT) TV.

6.2 Current picture

Lights and appliances represent the area of greatest growth in residential energy use (Figure 1.2). This increase is mainly in electricity, which is currently the most-polluting energy source, emitting at least twice as much carbon dioxide per unit of delivered energy as gas in the UK. At present, RLA account for 23% of residential delivered energy consumption (electricity and gas), the other 77% being used for space and water heating. In 1998, electricity consumption in lights and appliances was 73 TWh or 3000 kWh per household, equating to emissions of 330 kgC per household (Table 6.1).

Over the last 31 years, RLA consumption has been steadily increasing at around 2% per annum and is set to continue along this path given current trends. A 60% reduction will only be achievable if these trends are reversed. This will be possible through a combination of improved appliance efficiency along with a reduced growth in ownership levels (ie ownership levels still increase to a certain extent, but at a slower rate), as illustrated in the 40% House scenario (Table 6.1). Energy conservation, not just energy efficiency, is the crucial issue here (Chapter 9).

The assumptions in the 40% House scenario are based on current knowledge relating to the range of appliances available at present. It is certain that new appliance types and unforeseen innovations will emerge over the next 50 years or so. Some of these may well come and go quite rapidly – either becoming obsolete or combined with other technologies, as has already been seen, for instance, with mobile phones becoming mini-computers. Given the difficulties in predicting what these changes might be, such novel devices have not been incorporated into the UKDCM.

Despite the problems inherent in making forecasts of what might happen over half a century, it is possible to identify where technological improvements should be focused, whatever the appliance. The majority of energy used in household appliances is related to heat

Table 6.1: Electricity consumption and ownership, residential lights and appliances, 1998 & 2050

	Current – 1998			*40% House – 2050*		
	TWh	*ownership per household*	*kWh per appliance per year*	*TWh*	*ownership per household*	*kWh per appliance per year*
Cold	**17.5**			**3.5**		
Refrigerator	3.1	0.43	300	0.8	0.43	58
Fridge-freezer	9.5	0.60	650	1.8	0.6	94
Upright freezer	2.9	0.24	500	0.7	0.32	64
Chest freezer	2.0	0.18	460	0.2	0.12	54
Consumer electronics	**10.4**			**21.0**		
TV – CRT	5.3	1.7	128	4.4	0.5	277
TV – Plasma	–	–	–	6.6	0.3	693
TV – LCD	–	–	–	4.2	1.2	111
VCR	1.9	0.94	84	–	–	–
DVD	–	–	15	0.6	1.3	15
IRD (digital box)	0.6	0.28	95	0.8	2	13
Computer	0.5	0.3	75	1.1	1	36
Games console	–	–	–	3.3	1	105
Miscellaneous	2.1	–	–	–	–	–
Cooking	**11.9**			**11.5**		
Hob – electric	3.0	0.46	270	2.8	0.43	203
Oven – electric	3.4	0.57	245	1.8	0.69	80
Kettle	3.9	0.95	170	4.5	1	140
Microwave	1.6	0.77	85	2.4	0.85	90
Lighting	**17.4**			**4.1**		
Indoor	17.4	1	715	3.9	1	122
Security	–	–	–	0.2	1	5
Miscellaneous	**4.0**			**4.0**		
Wet	**11.8**			**9.3**		
Dishwasher	2.2	0.22	410	1.6	0.60	83
Tumble dryer	3.1	0.35	365	1.0	0.25	128
Washing machine	5.1	0.77	270	1.1	0.50	72
Washer dryer	1.4	0.15	380	5.6	0.50	352
TOTAL	**73.0**			**53.4**		
Total kWh per hhold	3000			1680		

Sources: 1998 data: Fawcett et al 2000; 2050 data: UKDCM (or the removal of heat). Less than 10% is used in motor control and another 10% goes into the electronics (eg display, controls). Therefore the most significant savings can be achieved through concentrating on reductions in the heat requirement (eg through improved insulation, lower temperature washes).

Unrelegated growth in the use of plasma TVs has wiped out efficiency savings achieved by improved stand-by consumption

6.2.1 Trends

The population is increasing and the rise in household numbers is a strong driver towards higher levels of total consumption, but is a trend that is virtually impossible to alter. This makes it all the more important to secure reductions in energy consumption per household to compensate.

Energy consumption at the household level is determined by a combination of ownership, technology and usage patterns, each of which varies between the different appliance sectors. There has been a general trend over the last 20 years towards increased ownership across all sectors – whilst it was once uncommon to own a TV or refrigerator, practically all households now have at least one cold appliance and TV, if not two or more. Multiple appliance ownership has increased with the trend towards more fragmented households, with additional TVs in bedrooms, for example. Ownership levels have now reached saturation in some areas, such as the cold appliances, but are still growing in others, particularly the consumer electronics sector. The overall trend is still towards more appliances in each house.

Technological improvements are seen as the key to decreasing energy consumption in lights and appliances. There have been some major improvements in energy efficiency over the last 10 years, mainly as a result of European policy. The most significant advances have been made with cold appliances, through the combination of the European energy label and minimum standards – the energy consumption of an average 140-litre refrigerator in a UK home has dropped by 29% between 1990 and 2001 (Boardman 2004b). Progress has also been made in wet and cooking appliances. However, such advances are not expected to be sufficient to completely offset the increase in overall consumption due to population and appliance ownership trends. The average size of cold appliances on the market increased by 15% between 1995 and 2001, reducing the impact of the efficiency improvements. The efficiency gains have also been negated to a certain extent by unregulated growth in the consumer electronics sector, where the trend appears to be towards higher rather than lower energy use (eg plasma TVs and the digital revolution).

Behavioural trends are more difficult to quantify. There have been some changes in usage patterns, for example, a shift towards lower washing temperatures and an increase in microwave meals, but such changes are the least certain and most difficult to predict or alter.

Household size has a significant impact on energy consumption, with average energy consumption per person increasing as household size decreases. One-person households in particular have a much higher energy consumption per person than larger households (Fawcett et al 2000) since they have many of the same basic appliances which would normally be shared. The actual size of the dwelling is more likely to have an impact on reducing consumption. One-person households will, in general, occupy smaller dwellings, which will limit the size and number of appliances installed – a policy trend that needs to be encouraged. With the growing number of single people living alone, appliances specifically designed for smaller houses are needed. These are more likely to be multi-functional devices, such as washer-dryers and fridge-freezers, where careful design is required to make sure that efficiency and service are not compromised. It is essential that these factors are optimised in the appliance design to ensure that reductions in the number of appliances do not result in higher consumption.

6.2.2 Current policy

For the past 10 years, technological improvements in energy efficiency have been the main focus of product policy at the European level, using a market transformation approach (Boardman et al 1997, Fawcett et al 2000). Essentially, this employs a synergistic package of policies that work together to bring about a shift on the market towards more efficient appliances. Whilst not the only factor behind reducing energy consumption, technological improvements have the advantage that savings are guaranteed and irreversible, unlike behavioural changes.

One of the key elements of a market transformation approach, consumer information, is in place for many appliances in the form of the EU energy label. Although the label has been successful in increasing sales of more efficient appliances, weak minimum standards have limited the effectiveness of this tool, but the opportunity is still there to bring about a more powerful shift on the market. Due to the common market, policies such as labelling, minimum standards and voluntary agreements must be implemented at the European level (although voluntary agreements can be country specific) (Table 6.2). Procurement, rebates, subsidies and education are more suited to national policy.

Achievement of the 60% target, as outlined in the UK Energy White Paper, depends on strong European policy. This expectation appears to be misplaced given the EU is moving away from minimum standards towards weaker and slower voluntary agreements proposed by the industry, eg the fleet average target of 1W standby consumption for all audio equipment by 2007. If significant savings are to be achieved, then a stronger approach is essential – the market is unlikely to get there alone since energy efficiency is not (yet) a priority for manufacturers.

Policy can deliver a significant shift in the market, as demonstrated in the cold appliance sector. The effect of the 1999 minimum standards for cold appliances in the UK was a 15% improvement in energy efficiency of the average appliance sold over 15 months (January 1999 - March 2000), accompanied by a 14% drop in average purchase price. For those appliances bought in the year 2000, this translates into lifetime savings of 2.9 TWh of electricity, £285m in reduced costs to consumers and a third of a million tonnes of carbon (Boardman 2004b, Schiellerup 2002). This benefit to the environment and consumers was achieved at no cost to government or manufacturers. Similar shifts are necessary over the next 20-30 years if the 40% House is to be realised.

Table 6.2: Summary of current European policy instruments, residential lights and appliances

Sector	*Sub-sector*	*Instrument*	*Directive*	*Minimum efficiency/ maximum power*	*In force/ target date*
Multiple		Framework legislation for energy labels	92/75		1.1.94
		Eco-design requirements for Energy-using products	amending 92/42		1.7.06*
Cold		Label	03/66	Introduced A+ and A++ classes	1.1.05
		Minimum standard	96/57	C (E for chest freezers)	3.9.99
		Industry agreement		Fleet average of EEI of 52	2006
Cooking	Electric ovens	Label	02/40		1.7.03
	Gas ovens	Label*	–		2006
Consumer electronics	TV with inbuilt IRD (integrated receiver decoder)	Code of conduct		Passive standby: 3W Active standby: 7-9W	1.1.05 – 31.12.07
	Stand-alone STB (set-top box)	Code of conduct		Passive standby: 3W Active standby: 6-8W	1.1.06 – 31.12.07
	Digital TV converters	Code of conduct		Passive standby: 2W On: 11-14W On: 7-10W	1.1.05 1.1.06
	Audio	Industry agreement		Standby: 1W	1.1.07
	External power supplies	Industry agreement		No-load: 0.3-1W No-load: 0.3-0.5W Active load	1.1.05 1.1.07
Lighting	Lamps	Label	98/11		1.1.01
	Fluorescent ballasts	Minimum standard	00/55	C B2	1.4.02 1.10.05
Wet	Washing machines	Label	95/12		1.10.96
		Industry agreement		C Fleet average of 0.2 kWh/kg	31.12.03 2008
	Tumble dryers	Label	95/13		1.10.96
	Washer dryers	Label	96/60		1.2.98
	Dishwashers	Label	97/17		1.8.99

Note: 'In force' indicates the date on which the provisions should be in force in the Member States eg the date from which energy labels should be on all appliances in the shops

* under negotiation or development

6.3 Barriers to the low carbon house

Although the low carbon house is achievable, it is by no means a given. Reaching a 60% reduction in RLA energy consumption requires some significant barriers to be overcome.

6.3.1 Weak policy

Despite some advances in reducing energy consumption in RLA, far greater savings could have been achieved through stronger, more focused policy. This is particularly evident in the cold appliance sector where the energy label has not been used to full effect. Originally, two rounds of minimum standards were proposed – one in 1999 and a second in 2003, requiring an additional 20% reduction over the 1992 baseline. However, only the first standard was implemented which required just a 15% reduction in consumption – far lower than the 46% reduction identified as the minimum life-cycle cost in an EU-wide study in 1992 (GEA 1993). The ease with which this standard was met implies that a more ambitious standard could have been achieved (Schiellerup 2002).

A second opportunity to increase the impact of the label was missed when the categories were revised to reflect the 1999 minimum standard, after which the models were concentrated in the top categories. Instead of re-calibrating the categories, two additional groups, A+ and A++, were added and the redundant D-G categories left in place. Not only does this weaken the effect of the label, since there now appear to be three ‘good’ categories, it is also confusing for consumers.

Label categories A-G should reflect what is available on the market. New A+ and A++ categories are confusing for the consumer

In the lighting sector, the main approach in the UK has been subsidies for the energy-efficient compact fluorescent lamps (CFLs) through the electricity industry. Almost 17 million CFLs were distributed between 1994-2002 under the Energy Efficiency Standards of Performance (Ofgem/EST 2003), with the delivery of a further 26.7 million CFLs expected through the 2002-5 Energy Efficiency Commitment (Ofgem 2004b). This may actually have had a detrimental effect on the retail market for CFLs and resulted in continuing dependence on such subsidies, rather than building a mature market (Boardman 2004a, Schiellerup and Fawcett 2001). Grants and subsidies are appropriate at the early stages of market building, but grant-dependency is something to be avoided. This illustrates a need for a coherent approach, with a mix of subsidies, minimum standards and other policy tools, rather than relying on only one of these measures.

6.3.2 Over-emphasis on energy efficiency

Whilst an emphasis on energy efficiency is important, without a parallel focus on energy conservation this will not necessarily lead to reduced energy consumption, as demonstrated by the appliance energy label. Because the label is based on relative values, such as kWh/litre, it actually encourages manufacturers to produce larger models since this makes it easier to attain an A-rating. A smaller appliance consuming the same amount of energy overall would have a higher kWh/litre value and would therefore receive a lower rating. If the aim is to reduce consumption, then smaller, not larger, appliances are needed, particularly given the trend towards smaller household and dwelling size, as assumed in the 40% House scenario. Using absolute consumption as the basis for the energy label would help to encourage energy conservation.

6.3.3 Manufacturer priorities

Energy efficiency is not seen as a priority by the majority of manufacturers, partly because they do not perceive it as being demanded by consumers. More often than not it is a beneficial side effect as a result of other design requirements eg long battery life for laptop computers. Energy efficiency needs to become a systematic requirement of product development – it is estimated that over 80% of all product-related environmental impacts are determined during the product design phase. Shifting these priorities may only be possible through regulation, given the urgent need for reduction in consumption. It will happen too slowly, if it all, if left to voluntary agreements or the market alone.

This is particularly evident in the consumer electronics sector. One of the difficulties with this sector is that a traditional market transformation approach is not possible since technical change is too fast for a test procedure and energy label to be developed and implemented. A different policy approach is required. There has been some success in the use of voluntary agreements – the standby consumption in colour televisions and video recorders was reduced by around 50% over five years (1996-2000). However, rapid, unregulated growth in other areas, such as plasma TVs, has completely wiped out these savings and more, indicating a lack of concern for the environment amongst manufacturers (Boardman 2004b). Clear policy is needed to prevent manufacturers taking such an approach in the first place – pro-active rather than reactive policy. The draft European Energy-using Products (EuP) Directive, which aims to provide eco-design requirements for energy using products, represents a move in this direction. It is expected to become law in Member States by December 2005, with manufacturer compliance required from 1 July 2006.

6.3.4 Lack of consumer awareness

Demand from consumers can create a strong market pull towards more efficient technologies. However, this is dependent on consumers being aware of the technologies available and, to a certain extent, making the links between their energy use and the impact of the resultant carbon dioxide emissions. There is evidence that people do understand these associations, but this does not necessarily translate into actions to improve the energy efficiency of their homes and appliances (Boardman 2004a). When householders were made aware of the high levels of standby consumption in their homes, this resulted in 'substantial behavioural induced reductions in standby levels' (Vowles 2000). This implies that with the right information, householders will take action to reduce their electricity consumption, demonstrating the value of feedback.

The increasing focus on carbon in energy policy requires a greater awareness amongst consumers of the importance of carbon (Fawcett et al 2002). The introduction of the disclosure rule under the revised European Liberalisation Directive (2003/53/CE) is a step in this direction. Under this legislation, from October 2005, UK consumers will receive information about how their electricity has been generated, provided on an annual basis with their electricity bills. Details on the consequent environmental impact in terms of carbon dioxide emissions and radioactive waste

Phasing out of analogue radio and TV and going digital offers an opportunity to incorporate more energy efficient technologies. This has not yet been recognised by industry

will also be provided on a website (Ofgem 2004a). Such information could help raise carbon awareness, enabling householders to choose their electricity supply on the basis of environmental information and not price alone (Boardman and Palmer 2003).

6.3.5 Increasing appliances

In this age of labour-saving devices, there is an ever-increasing number of appliances available to perform all manner of tasks. Appliance ownership has been on the rise throughout the 20th Century and this appears set to continue into the future. The 'digital revolution' that started in the 90s, and still continues, has resulted in an explosion of new appliances onto the market – something that would have been hard to predict 30 or 40 years ago. Analogue services are likely to be fully phased out by 2012 (Digital Television Project 2004). How many more such 'revolutions' are likely to occur between now and 2050? Will there be a shift towards multi-functional 'hybrid' appliances? And how would these be labelled? Whilst it is difficult to predict what will happen, it is clear that if consumption in appliances is to decrease, then the general ethos has to move away from accumulating more and more appliances. This would require a significant shift in peoples' attitudes and the way in which manufacturers and retailers drive such trends.

6.4 Key technologies for 40% house scenario

The three main areas where significant savings are possible are:
- vacuum insulated panels in cold appliances;
- light emitting diode (LED) lighting;
- consumer electronics.

There are, of course, savings to be made in other appliance groups. However, the focus here is on those sectors that offer the greatest reductions.

6.4.1 Vacuum insulated panels

Vacuum insulated panels (VIPs) improve the insulation of the cold appliance, refrigerator or freezer, thus reducing the energy needed to maintain the required temperature. VIPs can reduce the consumption of a cold appliance to around a fifth of the average appliance in the stock and half the consumption of the best model currently available to between 58-94 KWh (depending on the type of appliance).

This technology has been available for the last 10-15 years, but uptake in the residential sector has been limited due to price constraints and concerns about its durability. Weak efficiency standards have also hindered its introduction since the current standards can be met through the cheaper options of better compressors and improving evaporator surface area. Hence there has been no incentive for manufacturers to incorporate this technology.

The 40% House scenario assumes 100% adoption of VIPs in the total stock of cold appliances by 2050. This would require stricter minimum standards to bring these appliances onto the market. Procurement programmes would also be helpful in pulling the market in the right direction. This could follow the format of the 'Energy+' co-operative procurement scheme, which proved successful in building the market for A+ appliances prior to the revision of the EU energy label in January 2004 (Boardman and Attali 2003).

If VIP cold appliances are to be installed in every home by 2050, allowance must be made for the turnover of appliances in the stock. The average life of a cold appliance is 14-18 years, therefore it will take this long before the full impact of the energy efficiency improvement is seen. In order to achieve the savings, minimum standards would be necessary, along with the appropriate notice period, to allow manufacturers the time to adjust their product range. In the case of the 1999 minimum standards, the official notice period was three years (with an additional three years in negotiation) for a 15% improvement in energy efficiency. Given that VIPs are an already established technology, a minimum standard requiring the 50% reduction in consumption could be brought in by 2015. Hence, the market would be fully transformed, with only VIP products available, by 2035.

6.4.2 LED lighting

To date, the main focus for energy efficiency improvements in this sector has been the compact fluorescent lamp (CFL), which consumes around 25% of the energy of an equivalent incandescent lamp. Despite numerous subsidy programmes and the introduction of an energy label, the rise in CFL ownership has been slow, estimated to be around 0.9 CFLs per household in 2000.

In the longer term, LED (light emitting diode) lighting may offer a more effective solution. LEDs are already in use in the automotive, advertising and retail industries and in some traffic lights. This technology is advancing rapidly, with LEDs now being produced that replicate the light from an incandescent bulb (LumiLeds 2003), although, as yet, they are not used in residential applications. Large-scale replacement of bulbs is not expected for 5 to 10 years (Mills 2003). The introduction of LEDs has the potential to reduce lighting electricity consumption by over 80%, from 720 to 122 kWh per household pa (the best prototypes currently available are around an efficiency of 75 lumens/Watt). No take-back has been included since this is assumed to be minimised by the use of occupancy sensors. The 40% House scenario assumes full achievement of this ‘technical potential’.

To change the type of lighting used in all households is a major challenge since it is not just a case of switching bulbs, but altering the light fixtures as well (in existing dwellings). Whilst turnover of light bulbs is rapid (in the case of ordinary incandescent bulbs), turnover of fixtures is much slower, particularly since many are installed when the house is built. A large-scale replacement of the lighting technology would require a significant shift in consumer perceptions about how a house is lit. It would also involve a major retrofit of existing homes and complete transformation of products available in retail outlets. Lighting design trends, such as the current move towards more focused task lighting, are difficult to predict over such long periods. However, the rapid uptake and popularity of halogens in recent years has resulted in a revolution in residential lighting. Given the similarity of LEDs and halogens – both in terms of light quality and being directional light sources – a major step-change in the type of lighting in peoples’ homes is by no means inconceivable, particularly over the time-scale of 50 years.

Assuming an average of 24 lighting fixtures per household and that each house buys one new fixture each year, the lighting market will take around 25 years to be fully transformed to only LED lights and fittings. Alongside this, the Building Regulations will need to be revised to require the installation of LED fixtures. Since LEDs for residential applications are unlikely to be available before 2015, any revisions to the regulations will need to start from this point. One possibility is to require all fixed lighting fixtures in new build to be for LEDs from 2020. This will help build the market for LED lights and fixtures, but design competitions and active procurement programmes will also be needed for both fixed and portable fixtures. This could include the development of versatile fixtures that can be altered to take CFLs, halogens or LEDs.

Incandescent light bulbs will have to be banned – whilst a drastic measure, this is the only way to ensure that the savings are guaranteed. The shift towards more efficient lighting sources could be achieved through a Corporate Average Bulb Efficiency (CABE) (Palmer and Boardman 1998, Hinnells 1997).

6.4.3 Consumer electronics

This sector covers everything from home entertainment equipment (TVs, VCRs, music systems) to home office appliances (computers, faxes). This is the fastest growing appliance sector, with rapid advances being made in technology, although not necessarily in energy efficiency. As such, it is difficult to predict future trends for this sector – many of the current issues now faced were unforeseen a few years ago.

Under the 40% House scenario, the full technical potential has been assumed. For TVs this requires almost static ownership levels, with a shift away from conventional and plasma TVs to LCD screens. VCRs are phased out with the switch over to digital services and replaced with DVDs, but with a slight increase in overall ownership levels. This is mainly due to the increased dominance of computers in the household to perform these functions, which shows a rise in ownership to one in every household, also supported by the likely increase in teleworking. Technologies for these appliances are assumed to reach the best that is currently available on the market – a conservative assumption for 2050 and easily achieved provided energy-profligate appliances are discouraged.

One of the key areas of growth in the last few years has been in Integrated Receiver Decoders (IRDs), which accompanied the introduction of digital TV. People tend to leave these on 24 hours a day and IRDs therefore represent a significant area of consumption, particularly given the rapid growth in ownership to two per household in 2050 (one for each TV). This is the key area in terms of the technical potential, with a 95% reduction in consumption for the on-mode and a 1W standby consumption. The sooner these more efficient technologies are introduced the better, to ensure that the total stock will be fully transformed by 2050 and preferably earlier. Whilst minimum standards would guarantee the savings, strong voluntary agreements may be more appropriate due to the fast rate of change in this sector. One possibility is a series of four rounds of agreements over 15 years, with a 50% reduction in consumption at each stage. This would result in a transformed market by 2020, allowing ample time for the efficient technologies to be adopted by all households.

The major risk with this sector is that the range and number of appliances will continue to increase at the cost of energy efficiency and conservation. The 40% House scenario assumes that this trend has been curbed, with more circumspect research and development by manufacturers. Given the current attitudes of the majority of manufacturers, it is quite likely that this will require some form of legislation (Section 6.5.2). There are also significant opportunities within this sector – the phasing out of analogue and switch over to digital services represents an opportunity for energy-efficient technologies to be incorporated into this new era of appliances. It is possible that by 2050, computers (or some other multi-functional device) have completely replaced many of the traditional appliances in this sector – yet another chance to incorporate energy-efficiency into the home. Hence, the figures used in the scenarios may well be conservative given that no such combination-appliances have been assumed.

6.4.4 Other appliances

In the cooking sector, the main savings are expected through a combination of behavioural and technical changes. Low emissivity electric oven design could reduce consumption by 35% (Kasanen 2000). Energy display meters have been shown to result in a 15% reduction in the energy used in cooking (Wood and Newborough 2003). Together, these give a 50% reduction, resulting in consumption of 80kWh per year when applied to the best model currently available. Savings in electric hob consumption have been attributed to behavioural changes only. For the 40% House scenario, the full technical potential is implemented, with usage staying constant and a continuation of the trend in ownership towards electric, rather than gas, ovens. In addition to the energy savings available, there is a fuel-switching opportunity in this sector (from electric to gas) that could contribute towards carbon reductions, particularly given that cooking is one of the main contributors to peak demand.

For wet appliances, technological changes are the key factor, such as increased insulation, higher spin speeds and heat pump tumble dryers. A trend towards cooler temperature, longer washes has also been assumed. These represent improvements of between 20-55% in relation to the best models currently available on the market. Fuel-switching is also an option to reduce carbon emissions in this sector through gas tumble dryers.

6.5 Future policy

In order to achieve the 40% House scenario, the full technical potential in all lights and appliances must be reached for all households. Many of the current trends are in the wrong direction, leading to increased consumption – some way must be found to reverse these trends wherever possible. This is a considerable challenge and one that requires strong and clear policies at both the national and European level. Although much policy has to be EU-wide, since appliances are traded goods, there are opportunities for individual countries to speed up the process, through, for example, procurement, to demonstrate that new technologies are feasible. The EU may well be supportive of UK efforts to meet the 60% carbon reductions target since the likely failure of many Member States to achieve their Kyoto targets means that the EU needs to take urgent action to address the shortfall (EEA 2004). Market transformation is the key policy approach for this area and requires careful design and timetabling for maximum effect. Where there has been a coherent approach in the past (eg wet and cold appliances), the result has been an overall drop in energy consumption despite rising household numbers and ownership (Lane and Boardman 2001). Whilst some elements of a market transformation strategy are already in place, a number of improvements could be made to strengthen their impact.

6.5.1 Revisions to the energy label

There are three key revisions to the energy label that would be beneficial:

1. Use absolute consumption as the basis of the label to discourage trends towards larger (and thus more consuming) appliances.
2. Reconfigure the label categories to A-G to provide a more realistic reflection of what is available on the market, in conjunction with minimum standards.
3. For cold appliances, remove the compensation factor for frost-free appliances in the energy efficiency index calculation.

In addition to this, the full potential of the label as an awareness raising tool has not been realised – it represents a missed opportunity in terms of educating the public about the links between energy use and the environment and the savings that can be made. Used effectively, the energy label could become an even more powerful tool.

6.5.2 Minimum standards

Minimum standards are the cheapest and most effective approach for achieving guaranteed savings. They also treat imports and the products produced within a country equally. If substantial reductions in consumption are to be made, strict minimum standards are essential. Voluntary agreements are not an option because they do not deliver large enough savings over the required time-frame. In Australia, regulation is the main focus of energy policy: a situation which industry is content with (provided they are given sufficient notice) and has resulted in manufacturers taking a leading role in actually

Washing machines have improved significantly in efficiency – but larger machines still consume more. Downsizing would occur if labels emphasised total energy consumption

creating national efficiency standards (Holt and Harrington 2003).

Most policy acts retrospectively, allowing manufacturers to develop and produce appliances that consume unnecessarily high levels of energy. Manufacturers need to be encouraged to take responsibility for incorporating energy efficiency as a vital component of design, as could happen under the draft EuP Directive. This does not necessarily have to limit advances in technology and product design, but would ensure that energy efficiency is at the core of any such developments.

6.5.3 Building Regulations

Building Regulations can be an effective tool for certain appliance groups, most notably lighting with the specification of LED lights and fittings.

With the trend towards incorporating appliances, such as fridges and washing machines, into new homes at the building stage, specification of efficient technologies in the building regulations would guarantee substantial savings. With the 10 million new homes assumed in the 40% House scenario, this also represents a significant procurement opportunity through bulk purchasing.

6.5.4 Introducing new technologies to market via procurement

Introducing new technologies to market via procurement is a vital component in building the market for energy-efficient products and will be essential if the technical potential for all lights and appliances is to be achieved. The UK Government, with the Energy Saving Trust and Carbon Trust, needs to develop a clear strategy that identifies the new, upcoming and promising techniques and technologies and provide support for their introduction to market. Key technologies include LED lighting and VIPs in cold appliances. These technologies will see application in both high value commercial applications and mass market residential applications, therefore a cross-sectoral approach is appropriate. Government purchasing can also play a role in building the market, as demonstrated by the US Government's 1W initiative which required federal governments to purchase products with low-standby from July 2001 (IEA 2002).

Co-operative procurement is a relatively new approach which has proved extremely successful in the cold appliance market under the Energy+ programme. Energy+ has brought together manufacturers, retailers, buyers and consumers with the aim of promoting very efficient cold appliances through design competitions and information exchange; the number of super-efficient models (a minimum energy efficiency index of 42 – equivalent to the A+ category) has increased from two in 1999 to nearly 900 in 2004 (Energy+ website). Hence, when the new label was introduced in 2004, there were already a significant number of models in the A+ category (Boardman and Attali 2003).

6.5.5 Feedback

Whilst not part of a market transformation package, feedback has been shown to be effective in reducing household energy consumption – a review of 38 feedback studies which took place over 25 years showed that savings ranged from 5-20% (Boardman and Darby 2000). Feedback can

A 1 Watt Initiative is required to improve standby electricity consumption of new appliances

take a number of different forms ranging from direct, immediate feedback, as with the cooking energy display meters and interactive electricity meters, to information provided on the electricity bill, such as bar charts comparing consumption to the previous quarter. The latter has been shown to reduce consumption by 10% (Boardman 2004a).

A further step would be to introduce a system of personal carbon allowances which cover all fuel directly consumed by an individual (eg gas, electricity and petrol) (Fawcett 2003), creating an umbrella policy under which the individual product policies would sit. This would represent a move towards increasing consumer awareness of carbon and help them make the links between their personal actions and climate change (Chapter 9).

6.6 Priorities for action

Residential lights and appliances is one of the easiest and quickest sectors in which to realise potential savings. Most household appliances will be replaced two to five times over the next 45 years – the aim is to bring the efficient technologies onto the market without delay in order to access these savings as soon as possible. Action needs to be taken now, building on the market transformation tools already established so far. The necessary technologies have been identified – the challenge is how to bring them to the market. The following steps represent the key priorities for action:

- Active procurement programmes to start immediately for all appliance groups, with the Energy Saving Trust and Carbon Trust working internationally. This will help set future minimum efficiency standards.
- Minimum standards introduced for cold and wet appliances by 2015 and by 2020 for lighting, so that all lighting is LED. Negotiations need to be started now for a decision by 2010 (2015 for lighting), allowing 5 years to take effect.
- Revision of the energy labels to absolute consumption and reconfiguration of the scale in preparation for the minimum standards in 2015.
- EU level collaboration with consumer electronics manufacturers to incorporate energy efficiency as a central feature of product design.
- Negotiation of strong voluntary agreements with manufacturers on 1W standby consumption for IRDs and other consumer electronics. If ineffective, minimum standards will be needed.
- Revision of the Building Regulations to specify the installation of energy efficient appliances by 2015 and LED lighting by 2020 (to tie in with minimum standards).

6.7 Conclusions

Significant and essential savings are available in residential lights and appliances, but this requires some radical shifts in attitudes and perceptions amongst manufacturers and consumers and a strengthening of the market transformation approach taken in this sector. For the 40% House scenario:

- By 2050, electricity consumption in residential lights and appliances is reduced by 44% to 1680 kWh per annum per household.
- This is equivalent to a 27% reduction overall (due to the increase in household numbers) to 53.4 TWh, equivalent to a saving of 1.96 MtC. Therefore, greater savings need to be made through space and water heating if the 40% House is to be realised.
- These savings are based on technologies which are already proven and available.
- Energy service through RLA increases, with more households having a clothes dryer and dishwasher.
- With the move towards smaller households (both in terms of size and people), appliance design needs to be optimised for reduced space and single person households to ensure that down-sizing does not result in higher consumption.
- The success of market transformation policy in this area to date has been limited by weak policy, an over-emphasis on energy efficiency rather than energy reduction, energy consumption being a low priority amongst manufacturers, lack of consumer awareness and the trend towards increasing numbers of appliances.
- A clear market transformation strategy, with a focus on strong regulation, is necessary if these savings are to be achieved.
- Action must be taken now to realise the available savings as soon as possible and to ensure that low energy lights and appliances are in all homes by 2050.

Provision of heating and electricity through low and zero carbon technologies

Low and zero carbon technologies (LZCs) provide space and water heating and electricity through renewable technologies or combined heat and power (CHP), which are retrofitted or integral to the building or community. This chapter explores what those technologies could be, how they could come about and the major issues (technical and regulatory) that would need to be addressed along the way. It synthesises what is known about each of these emergent technologies and then brings them together to show what could be achieved under the 40% House scenario. The policy implications to deliver this change are then discussed.

7.1 The low carbon house scenario in 2050

Under the 40% House scenario, by 2050, space and water heating requirements (ie useful heat provided) have been substantially reduced from 375 TWh in 1996 to 318 TWh in 2050, through improvements to the building fabric in both existing dwellings and highly efficient new build (Chapter 5). Electricity consumption in residential lights and appliances (RLA) has decreased from 73 to 53.4 TWh through the use of more efficient technologies (Chapter 6). Households have, on average, almost two LZCs, equivalent to a total installed capacity of 55.6 GW. This is sufficient by 2050 to generate 82% of total space and water heating demand and meet total residential electricity demand, with around 15 TWh exported back to the grid. By 2050, more than 20% of homes will have very low space heating demand (1,500 kWh pa useful energy) with no need for central heating. All homes are expected to need around 4,000 kWh useful energy for water heating. Around 75% of homes have either community heating (with CHP or biomass), micro combined heat and power (micro-CHP), biomass or heat pumps, as the basis for their heating system. Around two-thirds of homes will have solar hot water heating and around 30% will have photovoltaics (PV).

Whereas it is relatively easy to foresee some of the improvements in fabric construction, or improvements in lights and appliances, the revolution which could be LZC (Table 7.1) has hardly started. In 1950 central heating was virtually unknown. Within five decades, 90% of homes have central heating. In five decades from now most central heating systems will have been replaced three times, most power stations twice, and probably the majority of the electrical and gas distribution network. Whilst no new technology is envisaged, significant development of existing technologies (eg PV and fuel cells) is expected to drive down costs. Investment decisions on the infrastructure for the provision of heating, cooling and electricity over this timeframe will be hugely affected by climate change, political change and regulatory change.

7.2 Current picture

The majority of UK homes (69%) have gas central heating and 9% electricity. Average space heating demand is 14,600 kWh pa, with an additional 5,000 kWh pa for hot water delivered energy. Installation of LZC technologies is low, for example, only around 1% of UK homes are connected to a community heating scheme. Continued high penetration of boilers and central power-only generation (however high efficiency) will not deliver a 60% reduction in carbon.

Proposals for amending part L of the Building Regulations (ODPM 2004a) stated that "*if we are to achieve a 60% reduction in carbon emissions by 2050, we are likely to need renewables by then to be contributing 30% to 40% of our electricity generation and possibly more... We have therefore included in the proposals measures that will encourage greater uptake of low or zero carbon (LZC) energy generation systems. This is also in line with Article 5 of the Energy Performance of*

Table 7.1: Types of LZC considered, 40% House scenario

	Heat only	*Heat and electricity*	*Electricity only*
Low carbon	Heat pumps	Gas fired CHP in community heating Gas fired micro-CHP (Stirling engine) Gas fired micro-CHP (fuel cells)	–
Zero net carbon	Solar hot water Biomass Geothermal	Energy from Waste or biomass CHP in community heating Biomass in micro-CHP (eg Stirling engines)	Photovoltaics Wind

Buildings Directive." The consultation document therefore proposed that, in addition to "*what might be achieved by a typical package of conventional energy efficiency measures, there should be an additional reduction in carbon emissions of 10%. This 10% can be seen as a 'notional' LZC contribution, but leaves the developer to decide how best to achieve the improvement*.".

If implemented as proposed, the 2005 regulations are expected to deliver a 27% carbon saving in new build housing, of which more than a third, 10% carbon savings, will come from LZC technologies (Ted King pers. comm.) The question is, therefore, given an expected revision to the regulations perhaps every 5 years, what might be the opportunity for LZC technologies to generate heat as well as electricity by 2050? And what might be the effect if Building Regulations were to apply to refurbishments as well as new build?

7.2.1 Current support for LZCs

The main mechanisms for supporting uptake of household renewables at present are Clear Skies (England and Wales), and the Scottish Community and Household Renewables Initiative. Community energy and PV are supported through the Energy Saving Trust (EST).

The Clear Skies programme provides grants as well as lists of manufacturers and installers. Data from the first 20 months of the Clear Skies grant programme shows that 92% of projects funded are solar thermal. At present only about 100 grants for heat pumps are awarded per year. To date, the EST solar grant programme has installed around 600 residential systems. In terms of community energy, the EST has £60 million to invest in refurbishing or extending community heating, which is expected to deliver around £240 million in total investment (EST website). PowerGen is the first of several manufacturers and suppliers to offer micro CHP on a commercial basis (micro-CHP website) but whilst field trials of a range of designs are ongoing, programme support is yet to be developed. PowerGen also has a programme to install 1000 heat pump systems over several years, principally in social housing as part of their Energy Efficiency Commitment (EEC) programme.

Whilst these measures are important and beneficial, there is insufficient cross-programme and cross-sectoral learning in terms of programme design. These programmes are at a small scale compared to what is needed and are not adequate to enable the uptake of technologies required to achieve the 60% reduction target.

7.3 LZC technologies

Table 7.1 summarises the LZC technologies considered, from simple, heat based renewables, to technologies that supply both electricity and heat, to those that supply electricity only. These are discussed in more detail below. LZC technologies that supply cooling (eg Riffat and Zhu 2004) are additional and not discussed further here.

Solar thermal systems will provide hot water heating in 60% of homes by 2050

7.3.1 Heat pumps

Heat pumps can provide space heating, cooling, water heating and in some cases recover heat from exhaust air. Heat pumps can be designed for individual dwellings or as a heat source for a heat network, often in conjunction with CHP (Section 7.3.4). There are currently only a few hundred installations in the UK, although the market is mature in Scandinavia and the US (IEA Heat Pumps website).

Heat pumps work like a refrigerator, moving heat from one place to another. To move heat takes energy, either electrical (vapour compression heat pumps) or thermal energy (absorption heat pumps). Up to five units of heat can be provided for one unit of electrical energy used. The efficiency of a heat pump depends on the relationship between the energy used to move the heat and the amount of heat recovered from the heat source, eg the ground. Air to air heat pumps are expected to find the coldest UK days difficult to provide for. Heat pump efficiency shows significant seasonal variation. A heat pump operates most effectively when the temperature difference between the heat source and distribution system is small (EEBPP 2000). Thus heat distribution systems need to be low temperature and therefore large surface area (eg underfloor heating systems). Consequently, the highest efficiency units (and therefore the largest carbon reductions) are limited to new build since installing such units in existing buildings would require major internal disruption. Refurbishment with lower efficiency units is possible, although with lower carbon savings. It is unlikely that this technology could provide all UK homes with heat.

Consumer barriers to this technology include unfamiliarity, uncertainty about continuing maintenance and service availability, and noise, although these have been tackled successfully elsewhere.

Heat pumps are only appropriate under certain conditions:

- The large surface area required for the heat distribution system and the disruption to land external to the dwelling during installation means that many existing properties with mature gardens or insufficient land would not be suitable.
- With a low distribution temperature and highly efficient heat pump, a long on-time is required to ensure an adequate indoor temperature. This would not be well suited to poorly insulated properties or intermittently occupied dwellings.

7.3.2 Solar water heating

Solar water heaters are simple, reliable, well known and widespread (Greenbuilder undated). They are probably the LZC technology closest to being commercially viable. The most efficient designs concentrate solar radiation onto a small diameter tube to maximise heating efficiency. Usually an installation of around 4 m^2 is needed for solar hot water, producing sufficient to keep a 200 litre tank topped up. Water heaters can provide all of summer demand and around 50% of current year round demand in an average house, but this could increase to over 60%. It is conceivable that in the most efficient dwellings, a wood burning stove and a solar water heater could provide all space and water heating requirements.

7.3.3 Biomass

Biomass can be used to generate heat in individual dwellings or as part of a community heating scheme. At the household level, a biomass boiler can provide space heating for the whole house as well as water heating on a timed daily basis, with automated fuel feeding from a hopper. This technology relies on a ready supply of fuel, such as woodchip, pellets or logs. The main potential is in rural dwellings (around 10% of households) and some suburban areas.

Biomass in heat networks can be more diverse and complex, serving both local rural and urban schemes. In addition to crop-based products, use of biomass in heat networks may also include tree wastes from council services; energy from waste; anaerobic digestion of food wastes or farm wastes to produce gases for combustion; landfill gas; or methane from pyrolysis.

7.3.4 Community heating using LZC technologies

A community heating scheme provides heat from a central source to more than one building or dwelling via a network of heat mains. Significant carbon savings are available if heat is supplied from biomass, geothermal heat, or the waste heat from power generation (known as combined heat and power or CHP). A community heating scheme may also provide cooling via an absorption chilling plant. A network is 'future proofed', in that the introduction of a single installation can switch a whole portion of a city over to a new lower carbon fuel, such as biomass, combined cycle gas turbines or fuel cells. Indeed the first fuel cell in operation in the UK was in a community heating scheme in Woking (DTI 2004d).

In the UK, less than 1% of homes are served by community heating, but in Scandinavia around half of homes are heated in this way (Euroheat undated). Community heating schemes can vary in size, from a small block of say half a dozen flats to individual tower blocks or whole portions of a city with tens of thousands of homes connected, as is the case in Southampton, Sheffield, or Nottingham. Schemes can start with a single tower block with additional buildings connected over time.

Community heating is most appropriate in the following circumstances:

- Dense housing: there are around 4 million dwellings in low and high-rise housing.
- Off-gas communities, where oil, solid fuel heating, or electricity is displaced (EST 2004a and b).
- In new and dense build, typically over 50 dwellings per hectare (Wiltshire pers. comm.), where electrical and gas network infrastructure is not already installed.
- Where there is decision making on behalf of a group, eg a strong residents association or new build developer.

7.3.5 Micro-CHP

Micro-combined heat and power (micro-CHP) units provide sufficient heat for a single dwelling, similar to a conventional boiler. Indeed, units are physically similar to boilers and are designed as drop-in replacements. However, the heat is provided as the by-product of the generation of electricity in the home – this is more efficient than the generation of heat in a boiler and import of electricity via the electrical network.

The power generation unit can be a Stirling engine, reciprocating engine, or fuel cell, each with different power and heat efficiencies: around 20% for larger Stirling engines (with up to 70% provided as heat) and up to around 35% for fuel cells (net of reformer and DC to AC conversion losses, with up to 55% of fuel converted to heat) Micro-CHP is capable of operating in condensing mode and thus at a high overall efficiency. In the longer term, fuel cells offer the greatest carbon saving potential, but there are a number of significant issues that need to be addressed first. For example, major cost reductions would be needed for large scale uptake, but the underpinning materials are themselves very expensive. DTI is investing significantly in fuel cell research (DTI 2001, 2002a, 2003a and 2004b).

The carbon savings from micro-CHP are strongly dependent on electrical efficiency as well as the operating strategy. As with conventional boilers, micro-CHP units operate to match heat demand, but it is also possible to turn them on at other times, for instance, to generate electricity when prices are high. The heat generated could then be stored in a high pressure water vessel contained within the unit for later supply to the dwelling.

Micro-CHP only generates a portion of household electricity demand, the balance being imported from the electrical network. At certain times, more electricity may be generated than is required by the home, allowing export back to the network. This represents a significantly different proposition for distribution companies and energy suppliers compared to the current situation, and there are a range of issues about connection, metering and the value of such electricity exports (FaberMaunsell et al 2002, Harrison and Redford 2002, Cogen Europe 1999 and 2004).

The most likely scenario for large-scale implementation is for units to be installed on an energy services basis (Section 7.5.2), in other words, financed, owned, operated and maintained by a supplier, with the household buying heat and electricity on a combined tariff (Harrison 2001, 2004).

The opportunities for community heating with CHP and micro-CHP are different and additional. Micro-CHP is best suited to:

- detached and semi-detached dwellings with a higher heat demand, where the micro-CHP unit will run for a sufficient length of time to generate enough electricity to make it cost effective;
- individual decision making, eg by owner-occupiers.

7.3.6 Photovoltaics (PV)

Photovoltaics (PV) convert light directly into electricity. Whereas the UK has around 600 installations, Germany has close to 100,000 because of support through electricity tariffs (Wustenhagen and Bilharz 2005). A typical current residential installation of 12m^2 could generate around 1,300 kWh pa with a peak of around 1.9 kW, though larger and more efficient installations are possible. Different materials can be used to give different efficiencies, with amorphous silicon efficiencies around 4-6% and crystalline efficiencies at around 15% and potentially up to 20%. The output from PV depends on the particular installation: shading can reduce output severely and orientation is also important (Jardine and Lane 2003). There may be an upper limit of PV on UK roofs (domestic and non-domestic) imposed by UK electricity summer peak demand (currently 20-25 GW) and network management issues if sufficient electrical storage is not available on the local distribution network.

7.3.7 Wind turbines

Wind in urban areas or around buildings is unpredictable with significant disturbance. A cleaner more concentrated flow can be achieved by channelling or ducting wind into a turbine, most suited to high rise blocks with stronger winds and higher load factors. However, these technologies are still in development and may have some associated noise management issues. In rural areas, only a small percentage of dwellings could support a wind turbine as a stand-alone device (without the need for ducting).

7.4 40% House scenario

Under the 40% House scenario, the aim is to reduce heat and electricity demands, and then to meet remaining heat demands from LZC to the maximum extent possible, and to meet or exceed the demand for electricity in households. This strategy is similar to the approach adopted when considering CHP for any given site.

Many of the available technologies may be perceived to be either in competition (eg PV and solar thermal competing for roof space) or

Producing electricity at the same time as providing heat is efficient either in the home or for a local community

complementary (eg PV and micro-CHP both need similar metering and remunerative arrangements for exported electricity). However, the savings are not dependent on the success or failure of any one technology – it is the achievement of the portfolio that is challenging and necessary. Each technology is appropriate to a different portion of the housing stock. In addition, each technology has a contribution to make at a different part of the load curve (Chapter 8), therefore a diverse portfolio of technologies will require fewer back-up fossil fuel plants.

The following assumptions were made under the 40% House scenario (Table 7.2):

- **Heat pumps** are best suited to large dwellings not on the gas network, or in new build. This is assumed to give 2.7 million installations by 2050, consistent with other estimates (Hitchen 2004).
- **Solar water heating** is assumed to be installed in around two thirds of homes by 2050. Installation occurs at the same time as roof replacement (to avoid the biggest installation cost which is scaffolding) or boiler replacement (to reduce plumbing costs). These assumptions, combined with volume, are expected to make it cost effective in most situations.
- **Biomass** boilers are assumed to remain a specialist product for rural areas.
- **Community heating** using a combination of CHP, biomass, and heat pumps is focused in dense urban areas in both new build and refurbishment. 4.1 million homes are refurbished with community heating by 2050,

Table 7.2: Uptake of LZC under the 40% House scenario, 2050

	Ownership
Gas boilers	10%
Electric heating	10%
Community heating (using CHP and biomass)	20%
Stirling micro-CHP	21%
Fuel cell micro-CHP	17%
Heat pumps	8%
Biomass (wood boiler rather than stove)	5%
PV	30%
Solar water heating	60%
Wind	5%
Total number of LZC installed	53.6 m
Electricity generated by LZC (TWh pa)	100.9 TWh
Heat generated by LZC (TWh pa)	260.9 TWh

which is within the cost effective potential (EST 2003). An additional 2.2 million new homes have community heating by 2050; a proportion of these will only provide hot water and a very small space heating load (like BedZED). By 2050, most schemes will be non-gas based (eg biomass CHP, energy from waste), or converted to higher electrical efficiency generation, such as combined cycle gas turbines or fuel cells, with biomass boilers for back-up and top-up heat.

- **Micro-CHP** is a suburban technology for semi-detached and detached owner-occupied homes. It is installed in some 12.4 million homes (around 40% of households) by 2050, similar to other estimates of the potential in this sector (Harrison 2001, 2004, EST 2002, FaberMaunsell et al 2002). Whilst the majority of CHP units will utilise gas, a proportion of Stirling engines could utilise biomass or bio-diesel. The electrical efficiency of the stock improves with time, and fuel cell micro-CHP emerges by 2020, with most uptake after 2040, resulting in 9.3 GW of fuel cell capacity installed by 2050. This compares with the 10 GW target Japan has set for fuel cells by 2020 (H2FC website).
- **Photovoltaics**. The period to 2020 replicates what has happened in Germany already, with hundreds of thousands, rather than millions, being installed. By 2050, 9.4 million units are installed, amounting to 28.3 GW in the residential sector, which is in excess of current summer daytime demand. Power storage on the local distribution network is therefore assumed. Around a quarter of homes will have the main roof facing between South East and South West, which retains output within 95% of maximum. West or East facing roofs still achieve 80% of peak output. South facing walls receive 70% of the maximum potential solar radiation, but are more subject to shading. The majority of the installations are assumed to occur after 2040, when costs are assumed to be well within product lifetime.

Table 7.3: Comparison of 40% House scenario with PIU and RCEP studies

	40% House	*PIU*	*RCEP (scenarios 1-4)*
Community heating with CHP or biomass	4.9 GW (25% are not gas fired)	Report states that “by 2050 all low temperature heat could be provided from CHP units of an appropriate size ... However, these are more likely to be micro units than community heating.” Therefore assume 114 TWh generated by an expected 28-57 GW of mchp	3-20 plants 8-60 MW fuelled by MSW (average of 0.4 GW) 42-2900 plants between 0.5 and 10 MW fuelled by biomass (energy crops and wastes) (average of 7.9 GW)
Stirling engine micro-CHP	12.8 GW		1.7-2.4 million at 2 kW (average of 4.1, max 4.8 GW)
Fuel cell	9.3 GW		
PV	28.3 GW	100 TWh from an estimated 133 GW across the UK economy	0.75 -15 million roofs at 4 kW (average of 31.5, max 60 GW)
Wind	0.2 GW		not building integrated
Total LZC capacity	55.6 GW in households	171 GW across the UK economy	44 GW average across several sectors

Source: PIU (2002, Table 6.1), RCEP (2000, Table E7)

Table 7.4: Installations of LZC by decade (thousands), 40% House scenario

	Installed currently	*2004 to 2010*	*2010 to 2020*	*2020 to 2030*	*2030 to 2040*	*2040 to 2050*
Total installed in the decade		650	6,972	11,974	16,064	17,966
Cumulative installations	37	688	7,660	19,634	35,698	53,665

- **Wind turbines** are assumed to be installed in 10% of dwellings, half being ducted turbines in tower blocks with good wind speeds and high load factors, and the other half being either freestanding or ducted devices in rural areas.

7.4.1 Comparison with other studies

Table 7.3 compares the 40% House scenario to work done by the Cabinet Office (PIU 2002) and the Royal Commission on Environmental Pollution (RCEP 2000). In summary, the 40% House scenario is considerably more challenging than the average of the RCEP scenarios, but equivalent in uptake to the future foreseen by the PIU for the residential sector alone.

7.4.2 Competitive markets

The 40% House scenario equates to an installation industry that grows at 30% per annum (Table 7.4). This is challenging, particularly given that, so far, renewables in the UK have only increased at 15% per annum since 1996 (DTI 2004d). This is a huge step requiring changes in infrastructure, householder perception, manufacturing, and employment, education and training of installers. It is the creation of a new industry, in line with the goal of the Energy White Paper to promote competitive markets. However, the UK lags behind many OECD countries, for example, Germany for PV, Scandinavia in community heating and heat pumps, the US in community heating, PV and heat pumps. The technology is available, but needs the right market framework to grow.

7.5 Cost and finance issues

7.5.1 Cost issues now and in future

Few LZC technologies are commercially cost effective at present or as cost effective as energy efficiency. Many struggle to pay back within their lifetime. However, technologies and markets for LZC are not mature and current cost-effectiveness is no guide to future cost-effectiveness. Even technologies which are considered mature (if little understood), such as community heating with CHP, can strongly benefit from increased market volumes to bring down costs. Hitchen (2004) suggests that for heat pumps, UK costs appear to be higher than those overseas, so increasing market size and the consequent more efficient use of resources and increased skill levels could lead to cost reductions.

'Technology learning' – reductions in cost through learning by doing and examining the underlying cost trajectory of a technology – is a well understood concept (Kobos et al in press). Achieving cost reductions depends on technologies being developed, economies of scale being achieved, the market for installers being expanded to a state of full competition and the costs of connection to the electrical network standardized with appropriate metering in place.

One technology that will particularly be affected by a change in costs is PV, the cost of which is commonly estimated to halve every ten years, with current costs at around £7250/kW peak. Greenpeace and EPIA (2001) estimate costs in 2020 to be a third of costs now, although this is clearly dependent on the international policy framework. Such a reduction in costs would bring payback within product lifetime and therefore increase installation rates. However, to payback in a timeframe competitive with other investments (eg five years) and increase installation further, costs need to be 16 times less, which may take four decades. Over half the cost of installation is labour, requiring good competition and training to bring it down. A good portion of the cost is scaffolding, which can be avoided if installation is required at the time of roof replacement.

As highlighted in Chapter 9, the cost of any given technical improvement is strongly dependent on policy. The future cost of LZC technologies is a political decision and depends upon the support framework now. Market transformation policies need to pay close attention to changing the cost structure of LZC, with R&D support targeted at improving efficiency, as well as a range of measures aimed at significant price reductions, including installer training and finance mechanisms.

7.5.2 Financing

The sceptic would read this and point out that it has taken some 20 years to get condensing boilers into 5% of homes. If decisions are left to householders, nothing very much happens. Householders are, by comparison to institutions, ill-informed and do not put a high priority on emissions or cost savings; they only make a decision on boilers once every 15 years or so. Incentives or requirements are therefore more likely to be effective if targeted at installers or energy suppliers or group decision-makers (like builders and housing managers) than at households.

Indeed, many of the products discussed here are best delivered through an Energy Service Company (ESCo) approach. For example, most schemes under Community Energy are being delivered through ESCos, and many of the benefits of micro-CHP accrue to the supplier, not to the household. ESCos currently serve a very small portion of the housing stock, but could potentially supply more than half of homes, for instance, with CHP at the levels given in the 40% House scenario. Where there is more than one LZC system in each home, the ESCo approach becomes even more important for several reasons: to ensure the best interactions between LZC technologies; to support investment in fabric measures and in efficient lights and appliances; and to deliver appropriate support systems such as metering and billing.

7.6 LZC market transformation

The market transformation approach, outlined in Chapter 1, can support the movement of heating systems away from those based on boilers and electric heating, to one where the provision of heat and electricity is very substantially from LZC.

At the moment, the focus is on transforming the boiler market, through the Market Transformation programme, EST and the EEC. However, there is a limit to the carbon saving opportunities possible once efficient A or B rated boilers are a Building Regulation requirement. Programmes focused on renewables are supporting the larger scale technologies such as offshore wind, wave and tidal. There is a need to move resources away from condensing boilers onto building integrated LZC if the substantial carbon savings available are to be realised.

7.6.1 Provision of information

Provision of information on products that deliver a heating service should allow a comparison of boilers with the LZC options such as solar hot water, micro-CHP, or community heating. This includes product labels (although this will not be straightforward) as well as advice to householders and larger decision-makers such as councils, housing associations and house-builders. Information at the level of the building, through the Energy Performance of Buildings Directive (EPBD), will clearly help to show the improvement that can be gained through LZC.

7.6.2 Financial incentives

Introducing new technologies and techniques to market is a vital component in building the market for LZC technologies and will be essential if the potential is to be achieved. To create long term investor confidence, there needs to be clarity that support will be maintained for a sufficient period to build the market and establish expertise in every geographical area and specifier group, so that the costs per house have come down, before support is withdrawn.

The Government, along with Ofgem, EST and the Carbon Trust, needs to develop a clear strategy that supports the techniques and technologies during their introduction to market. Indeed, the Government has committed to a micro-generation strategy by 2005 (Green Alliance 2004). LZC technologies are suited to non-domestic as well as domestic applications, therefore a cross-sectoral approach is appropriate. Lessons from the Community Energy, Clear Skies, and Solar PV programmes have shown that it is not only the grant support, but development of guidance and case studies, as well as support for training and approving consultants, specifiers and installers, that has helped begin the process of transforming markets. These programmes could also benefit from being better integrated with schemes involving visits to install energy efficiency measures, resulting in installation of LZCs at the same time.

Options for large scale support include expanding the scope of the Enhanced Capital Allowances scheme (ECA website) to include LZC; reduced VAT for installation needs to be extended to all LZC; and stamp duty rebates for improvements may include LZC. The difficulty is that whilst all these are welcome, they are, individually, small support, and there is a high transaction cost in ensuring consumers understand what support is available. All of these mechanisms need to consider the relative importance of support for the householder and the installer or ESCo.

Ultimately, a tariff-based approach is far more effective, as used in Germany to support PV. Amendments to the UK's Renewable Obligation (RO) could include tariff support for LZC technologies, including electricity generated in natural gas based CHP. The RO could also be extended to include a heat obligation for heat-only renewables.

7.6.3 Regulation to increase market share

A range of measures may provide regulation to support LZC in new build, such as the EPBD and the 2005 Building Regulations. The energy strategy of the London Mayor requires planning applications to include renewables, CHP and community heating where viable, and expects the London Development Agency to promote these technologies in its work (GLA 2004). Developers are already taking this on in their thinking, with a range of LZC options built into proposals for new urban communities (BioRegional 2004).

Existing dwellings are more challenging. Heating system replacement needs to become a controlled service, ie bringing it within the scope of the Building Regulations. An easy change might be in social housing by laying out a methodology requiring LZC, or measures achieving an equivalent reduction in carbon emissions, to be installed as electric heating is replaced. A more difficult, and more distant change, might be to require the same of owner-occupiers.

The Sustainable and Secure Buildings Act 2004 (the Stunell Act) may help to support uptake of LZC, two-way metering and fiscal incentives as well as requiring a report on the extent to which own-generation is integrated into the building stock.

7.7 Priorities for action

A complete market transformation to LZC could be achieved over the course of 2005 to 2050, which could be considered as three heating system replacement cycles of 15 years each.

- The first of these could be characterised by technology development, eg through innovation support, grant or preferably tariff support programmes, testing, training and

Photovoltaics are presently expensive – but future costs depend on the policy support framework implemented now

production of guidance. Building Regulations could require a portion of LZC in new build. Whilst around 6 million units might be installed, this technology support period is the expensive period.

- The second period could be characterised by a requirement in Building Regulations to install LZC in existing dwellings replacing a controlled service. The achievement of this second period is absolutely dependent on success in the first period of testing innovation and in delivering solutions to a wide range of issues. The second period should see significant economies of scale from increased production and installation.
- The third stage could be characterised by installing more than one LZC in any home. Costs should continue to come down through increasing economies of scale.
- Markets take a long time to develop and it is assumed that more than a third of the 53.6 million installations are made in the decade between 2040 and 2050. By 2050, the LZC market could become largely a replacement market, with ownership saturated, much as the central heating boiler market is today.

7.8 Conclusions

This chapter has shown how in the 40% House scenario, over 80% of heat demand and more than 100% of electricity demand could be met by LZC by 2050, with significant carbon benefits. This requires a substantial switch away from gas boilers and turns dwellings from net importers of high carbon content electricity, into net exporters of low carbon electricity. In summary:

- Existing but refurbished homes are expected to need around 6,900 kWh useful energy for space heating. Around 20% of homes (those built after 2020) have very low (1,500 kWh useful energy) space heating demand. All homes are estimated to have around 4,000 kWh pa water useful heat demand.
- 72% of homes have LZC as the main form of heating. 20% have gas boilers or electric heaters.
- 53.6 million LZC installations are expected by 2050. This equates to 1.7 installations per dwelling.
- LZC installations account for 260 TWh of heat generated by 2050, which is 82% of the 318 TWh space and water heating needed in that year.
- LZC installations generate 100.7 TWh electricity, compared to 85.6 TWh needed in homes by 2050, thus 15 TWh is exported in 2050.
- The carbon savings from these measures are assessed in Chapter 8.

Whilst few LZC technologies are cost effective right now, this is not a good guide to the real cost of achieving this change – costs are dependent on uptake and uptake is policy dependent.

Diversity is hugely important, with different technologies making contributions in different types of housing and at different parts of the load curve, thereby providing security and sustainability.

The installation of LZC technologies would need to grow by around 30% per annum, which will be challenging. The technology exists, though improvements will be needed to bring down costs. The UK lags behind many OECD countries in the use of LZC and can import much technical, market and policy know-how.

Market transformation policies have a role in creating the right environment for investment which will be needed to deliver the required annual 30% growth. Investor confidence is key and for this reason, support needs to range from installer training to advice to large-scale decision-makers, to financial support. Stamp duty rebates, enhanced capital allowances, and lower levels of VAT, would all help, but tariff support is the most promising option, based on experience in Germany. In the longer term, Building Regulations need to focus as much on LZC in existing build as in new build.

The strategy outlined here is not meant to be a forecast or a prediction, nor is it about picking technological winners and losers. It is difficult to predict which technology will benefit most from technical or market driven reductions in cost: if one technical route proves difficult, another will fill its place. Some combination of most or all of these technologies is a necessary component of a sustainable energy future a basket of technologies offers diversity and resilience.

Electricity and gas implications

This chapter discusses the impact of the 40% House scenario on the energy infrastructure, bringing together the substantial changes in gas and electricity demand and high penetration of low and zero carbon technologies (LZC) discussed in previous chapters, and looking at the implications for operation of the electricity network. The influence of these changes for carbon savings, peak demand, required new plant capacity, and associated policy and investment decisions are considered.

8.1 Introduction

UK generation capacity will change over the next twenty years as 11.6 GW of coal plant are retired and 10.5 GW of nuclear power stations are decommissioned. New capacity will certainly be required – the question is, what form should this take? The 40% House scenario envisages a capacity of 55.6 GW in residential LZC by 2050, sufficient to meet the majority of heating and electricity demands in households, whilst assuming minimal changes in the carbon intensity of centrally generated electricity. Major changes in policy and investment patterns will be required to support the family of LZC technologies, thus avoiding building new centralised fossil fuel plant and associated grid reinforcement. New plant can also be avoided by minimising peak demand for electricity through the implementation of measures under the 40% House scenario.

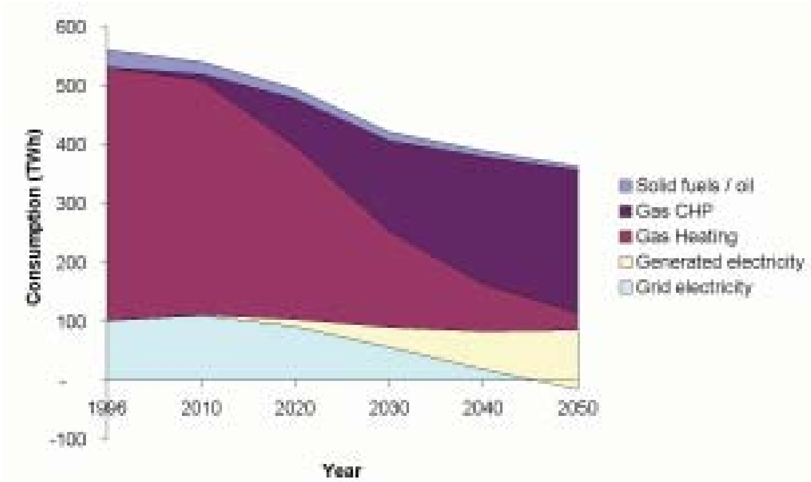


Figure 8.1: UK residential energy use, 40% House scenario, 1996-2050

8.2 Demand, supply and carbon emissions

Overall, by 2050, energy demand in the home is reduced to 64% of 1996 values under the 40% House scenario (Figure 8.1), with changes in both consumption of electricity and gas and the way in which the demand is met.

Gas demand for space and water heating and cooking is reduced by 38% due to better building fabric, improved efficiency and use of solar thermal systems. There is a dramatic switch from conventional heating systems to combined heat and power (CHP) boilers in 2030 which slows the reduction in gas consumption, as additional gas is required for the electricity generation component of CHP.

Electricity consumption falls by 16% from 1996 levels by 2050, from 101.7 to 85.6 TWh. The 27% reduction achieved in residential lights and appliances (RLA) is offset by the increased use of electric space and water heating in homes with minimal space heating demand. These homes are without a central heating system (since heating demand is so low) but still require hot water and some top-up heating, supplied by electricity generated in the home.

Homes have become significant generators of electricity, driven by the high levels of photovoltaic (PV) installations and fuel cell micro-CHP (Figure 8.2), and net annual exporters by 2045. Any individual dwelling with these LZCs installed will both import and export electricity, depending on demand, as will be the case for the residential sector as a whole by 2030. These imports and exports will inevitably make national demand balancing and operation of energy markets more complex. A change from the present centralised operation towards a more flexible decentralised approach is required,

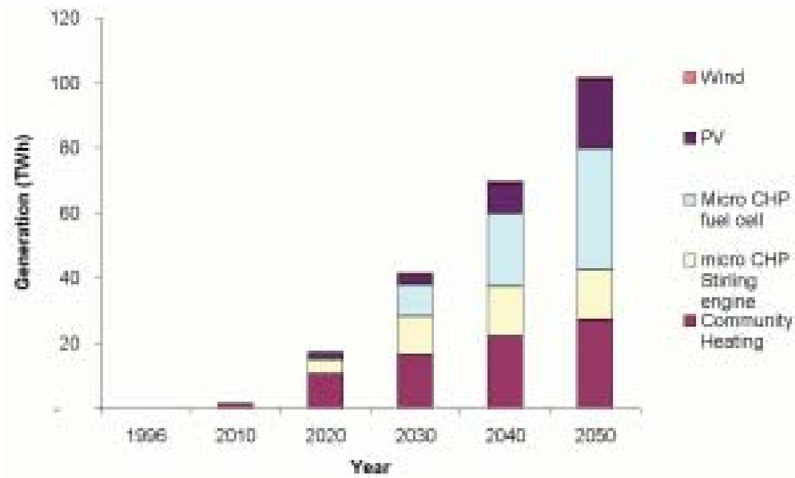


Figure 8.2: Electricity generated by UK residential LZC technologies, 40% House scenario, 1996-2050

capable of supporting high penetration levels of distributed generation. Such issues are beyond the scope of this project, but will be addressed by future studies such as EPSRC's SUPERGEN consortium on highly distributed power systems.

8.2.1 Carbon emissions

The carbon savings under the 40% House scenario depend on the relative emissions factors of centrally generated electricity, residential gas combustion and LZCs. The target of a 60% reduction in carbon emissions is reached in 2045, with additional savings from this point onwards reducing emissions still further (Figure 8.3). From 2050, the residential sector remains on a falling carbon trajectory. The 40% target is reached at the same time that the residential sector becomes a net exporter of electricity. In contrast to recent studies (Johnston et al 2005), this implies that the required savings can be made *within the housing stock alone*, as a combination of improved building fabric, reduced demand from RLA, and introduction of LZC, and without reliance on 'supply-side fixes' or the effect of the net export of electricity.

Conservative assumptions have been made regarding emissions factors from network supplied electricity (see box) requiring greater savings to be made within the building fabric, lights and appliances and through installation of LZC capacity to meet the 60% reduction target. Emissions factors for LZC generated electricity, from renewables and CHP, are assumed to be zero. Renewables are inherently zero carbon technologies. Emissions from CHP are more complex since the electricity generated requires additional gas consumption beyond that required for heat alone (79 TWh of electricity generated from 110 TWh of additional gas in 2050). For simplicity, all emissions from CHP are attributed to the heat demand, since CHP essentially replaces central heating boilers; the electricity from CHP is therefore assigned an emission factor of zero.

Despite electricity demand rising to 2050, carbon emissions reduce over the entire period. This is primarily due to the widespread uptake of LZC, especially post-2030, and reduced gas consumption. Reductions in residential gas and electricity consumption contribute 8.3MtC and 15.6MtC respectively. All this is achieved despite the rise in household numbers. The average house in 2050 will produce around a quarter of the carbon emissions of 1996 (1.66 tC to 0.42 tC).

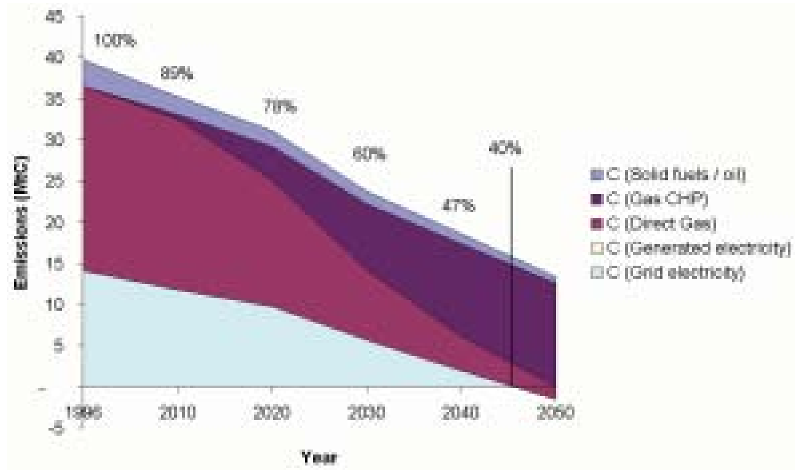


Figure 8.3: UK residential carbon emissions, 40% House scenario, 1996-2050

Emissions factors

The emissions factors for network supplied electricity assumed in the UKDCM are outlined in Table 8.1. The projections from the Market Transformation Programme (MTP) are based on historical data from the National Atmospheric Emissions Inventory with future emissions utilising DTI energy projections (DTI 2001a). The general trend is towards a decrease in emissions factors as renewables and gas replace nuclear and coal.

The 40% House scenario takes the MTP emissions factors and projects these beyond 2020, assuming nuclear retirements are offset by an increase in renewables, so there is no net change in emissions factor. It is also envisaged that gas will replace coal. This gives an emissions factor of 0.1 kgC/kWh from 2030 onwards.

Table 8.1: Emissions factors (kgC/kWh), UK, 1996-2050

Year	*MTP predictions*	*40% House scenario*
1996	0.139	0.139
2000	0.136	0.136
2005	0.111	0.111
2010	0.106	0.106
2015	0.110	0.110
2020	0.107	0.107
2030	–	0.1
2040	–	0.1
2050	–	0.1

Source: Market Transformation Programme, 40% House project

8.3 Peak demand and supply issues

The 40% House scenario has consequences for the electricity network, with a change in the diversity of demand. In particular, generation capacity and transmission and local distribution networks must be sufficient to meet peak demand to ensure security of supply. None of the Royal Commission on Environmental Pollution (RCEP) scenarios to achieve the 60% target have sufficient generating plant to meet peak winter demand, implying back-up plant capable of peak operation (RCEP 2000 para 9.27).

8.3.1 Present peak demand

There are two key issues relating to the existing network operation:

- The generation capacity required on the network is determined by the height of the maximum annual peak, presently winter evenings (Figure 8.4). Minimising peak consumption will reduce the amount of new fossil fuel plant that will need to be built.
- Meeting the predicted rate of increase in demand (gradient changes) requires plant to operate at part-load for a significant period of time (spinning reserve) in preparation for the change in demand, which has a carbon consequence. Traditionally coal plant has been used, with additional pumped storage for rapid response. Gradient changes can also be met from modern gas plants, but the response is not so rapid as for coal. Fewer and less steep gradient changes in the national demand profile would help save carbon and simplify demand balancing.

The current peak load occurs on a typical winter day in early evening. In 2002, the average winter peak was 51 GW (Figure 8.5), from an installed capacity of approximately 77 GW; the 25% excess capacity covering plant unavailability (maintenance, failure etc). This was sufficient to meet the maximum recorded UK peak of 61.7 GW in 2002 (DTI 2004a). Summer profiles are smaller in magnitude and smoother, with no clear evening peak, but a rapid gradient change (ie a rapid increase in demand) still exists in the morning (Figure 8.6).

The residential sector is partially responsible for the morning gradient (Figure 8.5) and entirely accountable for the evening rise and maximum peak (EA 1998). The morning gradient arises from people getting up at the same time for work, and

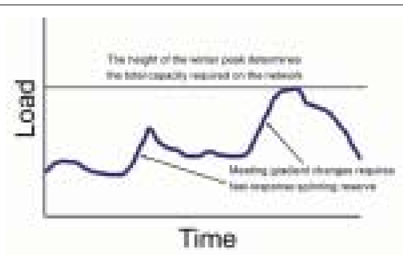


Figure 8.4: Influences of load profile on network operation

The residential sector is responsible for the winter evening peak in demand

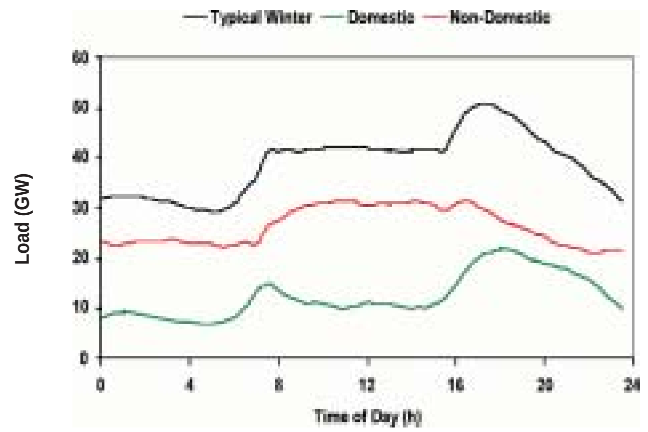


Figure 8.5: UK residential and non-residential profiles for typical winter demand, 2002

Source: 40% House project, based on Electricity Networks Association data

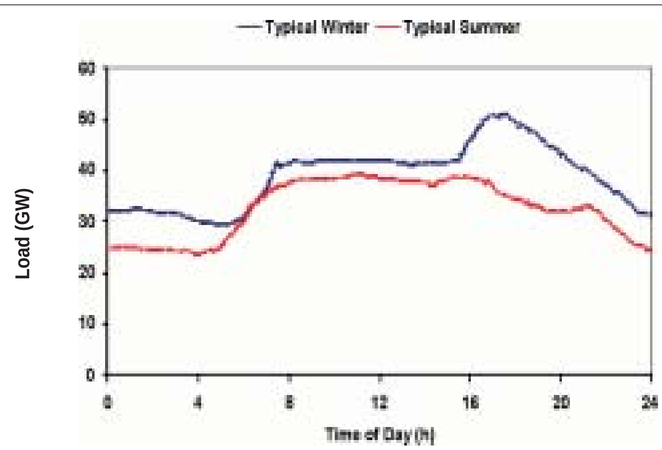


Figure 8.6: Winter and summer demand profiles, England and Wales, 2002

Source: National Grid (2003)

the maximum peak from people leaving centralised shared workspace and schools and returning home to distributed, lower-occupancy space.

The residential sector offers the greatest potential for reducing peak demand and therefore plant capacity. The non-residential sector, despite using more electricity in total, is less able to reduce consumption at peak times due to the higher load factor (ratio of average to maximum demand).

8.3.2 Influence of lights and appliances

Since the demise of the Electricity Association, load monitoring has not been conducted and data availability is poor. The precise contribution of different appliance loads to the evening peak caused by the residential sector has not been quantified since 1988 (Boardman et al 1994). However, qualitative assessments of the influence of technological changes in RLA and LZC are possible. Examples of how technological advances may influence the present demand profile are illustrated in Figure 8.7.

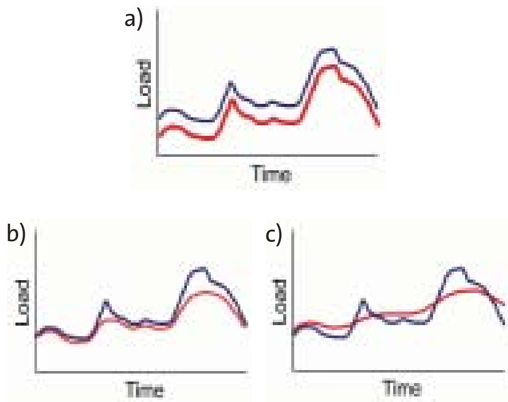


Figure 8.7: Schematic influence on load profile of a) improved energy efficiency, b) improved efficiency of lights and appliances, c) demand shifting through use of smart appliances

Note: blue-current, red-altered

The potential impacts of lights and appliances on load management are as follows:

- Efficiency improvements in those appliances used mainly at peak times (eg lighting, televisions) will reduce both the height and gradient of the peak.
- Lighting is responsible for at least 20% of peak residential demand (Boardman et al 1995). On a typical winter's day, this represents a minimum national residential lighting load of 3.3 GW (150 W per household) at peak demand. Switching to 100% LED lighting would reduce this demand to 0.55 GW – implying 2.75 GW of avoided plant capacity.
- Cookers are significant users of peak time electricity but it is socially difficult to shift the load to another time. Ovens have particular scope for efficiency improvements (Chapter 6).
- Consumer electronics are the fastest growing component of residential demand and are likely to be in use at peak times. In stand-by mode, they represent a significant baseload component.
- Efficiency improvements of appliances in constant use (eg refrigerators) will reduce both the height of the peak and the baseload. However, the rate of change in demand (the gradient) will not be altered by such improvements.
- Smart appliances – appliances capable of shifting load to times of low demand, or turning off during peak periods – would reduce both peak load and gradients in demand. There is also the potential to use smart appliances to shift load to times of low carbon generation. At present, carbon intensity is virtually constant during daylight hours but drops at night (Figure 8.8). In future, carbon intensity will fluctuate more, as penetration of wind, PV and other LZCs increases. Smart appliances could be switched on at times of home generation to minimise export of electricity to the grid. However, smart appliances will require more sophisticated meters to be installed and possibly new pricing tariffs (Section 8.3.4).
- Spreading demand for individual appliances and dwellings across the day will also help minimise peak load (Newborough 1999). Coincidence of high power activities such as electric cooking, dishwashers and laundry can result in peak demand in excess of 10 kW from a single dwelling. Appliances may be redesigned to reduce their peak load: washing machines and dishwashers can use lower power heaters for longer and ovens may cascade the on/off cycles of individual heating elements such that coincidence of demand does not occur.

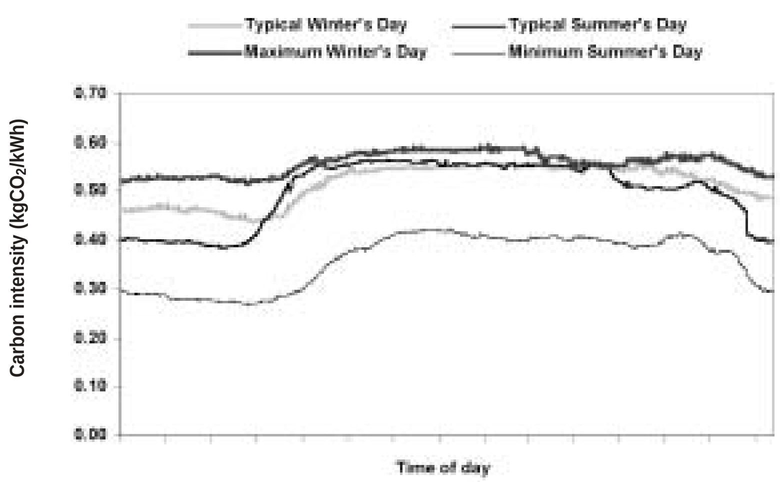


Figure 8.8: Carbon intensity variations throughout the day, UK, 2002

Source: 40% House project

8.3.3 Influence of LZC Technologies

Some LZC technologies have beneficial influences on required capacity or carbon (eg micro-CHP reduces peak winter demand), whilst others may exacerbate it (eg PV reduces daytime demand and therefore accentuates the summer evening peak). However, once the nature of these influences is understood, there is an opportunity to design appliances, and the mix and operational modes of LZCs, to minimise peak height and gradient change. There is a benefit in diversity of supply to ease grid-management. The potential influences of LZC technologies on load management are as follows:

- Community heating with CHP can replace both gas and electric heating with heat storage and back-up and top-up boilers providing heat at other times.
- Stirling engine micro-CHP devices (with a high heat to power output) are most likely to be heat demand led with electricity for the home generated as a by-product, but electricity generation with heat storage would allow operation at peak electrical demand.
- Fuel cell devices with a lower heat to power output may simply not run at peak times. Small units may operate close to baseload whilst modular units may provide more at peak than at baseload.
- Heat pumps in well-insulated buildings with low temperature emitters (eg underfloor heating) would have a relatively steady electrical demand, rather like a refrigerator. However, they would utilise electricity more at times of peak heat demand compared to the systems they would replace (eg Economy 7 heating).
- Photovoltaics reduce demand for centrally-generated electricity during the day time, especially in summer, but create a day time 'valley' with higher gradient changes, thereby increasing the spinning reserve on the system. Seasonally, they can generate eight times as much energy per day in summer as in winter, which is the converse to residential demand. However, PV matches extremely well with non-residential demand (Figure 8.5) although ensuring supply can be delivered to the right location to meet this demand may be problematic.

8.3.4 Influence of tariffs

As well as technological innovation to reduce peak demand, changes in consumer behaviour can also influence the shape of the demand profile. Most notably, novel pricing tariffs can be implemented by suppliers to encourage movement or reduction of peak demand, thereby reducing the price they pay to generators.

Time-of-day tariffs charge different prices at different times of day, with peak usage more expensive than baseload consumption. This is usually a simple two-tier pricing structure, but more advanced systems charge real-time prices on a half-hourly basis, as with national demand balancing. The expectation is that once consumers are aware of the tariff, they will transfer the use of some appliances (typically washing machines and dishwashers) to off-peak hours. In future, smart appliances may be able to shift load automatically. Time-of-day tariffs have already been implemented in the USA to minimise peak demand of air conditioners and this has reduced requirements for new installed, centralised generating capacity. Such tariffs applied to LZC electricity exported from the home would also benefit the demand profile. Technologies operating at peak times (eg CHP) would be rewarded over those generating at times of low demand (eg PV). Market signals would therefore encourage the optimum mix of LZCs for ease of national demand balancing.

Another option is maximum demand tariffs, which are common in the UK industrial and commercial sectors and in the residential sectors of other countries. With these, the tariff is determined by the customer's peak (maximum) power demand, providing a strong incentive to smooth load throughout the day.

Although tariff structures may aid LZC deployment and decarbonisation of the network, there remain concerns about the equity of such schemes, which may penalise the greater heating requirements of the fuel poor. Hence solutions have to be researched to ensure that they are equitable.

8.3.5 Storage

In the longer term, storage will be required once penetration of LZCs and other intermittent renewables reaches a critical threshold – likely to be between 2020 and 2030 – with facilities incorporated into the electricity network at household, substation or national level. These

Table 8.2: Impact of 40% House scenario on UK electricity load, 2050

	Winter evening peak (maximum)	*Mid merit (average demand)*	*Summer midday*
Current demand	61.7 GW	Around 35 GW	Around 20-25 GW
40% House scenario			
Lighting	3.3 GW demand down to 0.55 GW at peak (–2.75 GW)		
Consumer electronics	likely peak expected to rise from 2 GW to 4 GW (+2 GW)*		
Community heating with CHP/biomass	4.9 GW new capacity operating for around 5500 hours a year (–4.9 GW)	4.9 GW new capacity operating for around 5500 hours a year (–4.9 GW)	
Stirling engine micro-CHP	12.8 GW of new capacity operating at peak (–12.8 GW) most of which available at peak		
Fuel cell micro-CHP	around 9.3 GW of new capacity operating circa 4000 hours pa depending on operating strategy (–9.3 GW)	around 9.3 GW of new capacity operating circa 4000 hours pa depending on operating strategy (–9.3 GW)	
Heat pumps	2.5 GW peak (+2.5 GW)	2.5 GW peak (+2.5 GW)	
PV		up to 14 GW (winter midday)	around 28.3 GW peak new capacity, operating during daylight hours (–28.3 GW)
Net effect in 2050	reduction of demand on central plant of up to 25 GW (–40%)	reduction of demand on central plant of up to 25 GW (–75%)	surplus of 3-8 GW over demand, requiring storage or export (–112%)**

Source: UKDCM

* Current maximum demand from all consumer electronics devices used simultaneously is 4.3 GW. This is expected to rise to 8.9 GW by 2050. However, not all appliances are used together.

** The total stock of PV will rarely, if ever, be operating at peak simultaneously across the UK. The peak output of 28.3 GW is notional, but still implies some need for storage.

devices will be capable of smoothing intermittent generation and demand profiles, providing a truly flexible network capable of keeping the lights on with minimum active demand balancing. This allows each individual generator to operate at maximum efficiency.

Storage may be for a microsecond, seconds, minutes, hours or even over seasons. Technologies include: pumped storage (already used to meet times of peak demand in the UK) which store energy as potential energy; flywheels, which store energy as kinetic energy; batteries and hydrogen stores for fuel cells, which store as chemical energy. Less storage is required with the careful planning of intermittent sources, ensuring the optimum geographical distribution of a full range of technologies (HoL 2004). Power storage is beyond the scope of this study but forms a key part of both industry and Government work in moving to sustainable energy (EPRI and DTI websites).

8.3.6 Overall impact on peak demand

The 40% House scenario proposes high penetration of all LZC technologies, which, in combination, have less effect on the grid than an individual technology and ensure greater security of supply.

Table 8.2 illustrates the maximum level of change in demand and supply measures under the 40% House scenario, in relation to current demand. The implication is that, particularly post-2040 when uptake of PV is strong, renewables or LZC will run as baseload, if available, with fossil plant operating over a shorter and more intermittent run time. Many modern gas plants embedded in the distribution network could balance demand, both spatially and temporally. Figures shown are the maximum possible changes – in reality, electricity from LZC is not guaranteed generation since the individual technologies will operate at different times.

The influence of all measures combined is substantial – demand profiles seen by central generation will be significantly different from

Installing LZC will cause significant imports and exports from the home. By 2045 the residential sector is expected to be a net exporter of electricity

today, to the extent that the peak may not occur in winter evenings. Winter peak is predicted to reduce by approximately 40% and mid-merit (average demand) by up to 75%. Summer midday could see household output exceed current national demand, requiring some level of storage.

8.4 Finance and policy implications

With 22.1 GW of coal and nuclear plant to be retired over the next twenty years, there is a need for new capacity. The question is: what form should this new capacity take and how might it be managed? The current approach in the electricity supply industry is to let the solutions regarding installed capacity and supply-demand balancing be determined by the market. The only incentive at present is via the Renewables Obligation – additional market mechanisms are required.

Delivering the 40% House scenario would imply some 55.6 GW of LZC supplying around 100.9 TWh – just over a quarter of UK generation in 2004 (DTI 2004a). This implies a much-reduced role for new centralised generation and a radically different pattern of expenditure in electrical network renewal.

The current costs of LZC are higher per unit capacity than conventional plant. In addition, LZC operates at lower load factor than conventional plant and so greater capacity would be required. A combination of policy support and commercial factors would be needed to drive the change from new conventional plant to LZC. Policy support might include:

- Market transformation to reduce the costs of LZC, making it cheaper than reinvesting in new centralised plant (Chapter 7).
- Policies that favour or require LZC over centralised plant. For example, the Electricity Act 1989 and Energy Act 1976 allow the Secretary of State power to withhold consent for new capacity of 10 MW and above for gas, and 50 MW or over for other fuels. Applied consistently over a long period (excluding good quality CHP or large-scale renewables), this could be a key tool in ensuring that new capacity to replace coal and nuclear is embedded and possibly building-integrated. Current guidance on power station consents only requires consideration of CHP (DTI 2001d), which is not likely to be sufficient to encourage LZC over central plant.

Commercial factors centre around four main themes:

- Peak demand. Whilst LZC technologies may be more expensive per kW of firm capacity, those that operate at peak generate more valuable electricity. Micro-CHP for example, avoids the need to buy in capacity at peak times thus avoiding purchase of the most expensive electricity. The savings made could be used to offset the cost of installation.
- Competition. LZC technologies can help win new customers and retain existing customers in a competitive market. This could be achieved through free installation of LZC (paid for by long-term contracts for provision of lower-cost electricity, heat and servicing), as well as branding and affinity marketing based around the offer of energy with low environmental cost.

22 GW of nuclear and coal plant are to be retired. This capacity could be met by LZC technologies in the residential sector

- Added-value services. Supplying a range of services (heat, electricity, servicing) through the same billing system results in cost reductions. There is also an opportunity to provide additional services such as the provision of energy-efficient lights and appliances.
- Risk management. LZC technologies represent an incremental risk in what is likely to be a rapidly changing investment environment. Capacity can be made available flexibly and rapidly without the need to select and acquire sites, obtain consent or incur time delays between a decision to invest and plant coming on line. Investment cycles are likely to be nearer the 15 year life of a boiler, rather than the 40 years or so associated with conventional plant. This means the portfolio of investments can be fine tuned to match requirements more readily than with conventional plant.

This would mean a transformation of the market for delivery of energy services well beyond the products that deliver the energy. An Energy Service Company (ESCo) approach is one option. This would require a substantially different regulatory framework to create a system in which an ESCo model was more attractive to suppliers than the current business model and represents a challenge for Government, with Ofgem a key player. Such a change in business and in structure is radical, but possible over a 50-year time horizon. The last half century or so has seen nationalisation of supply through the 1948 Electricity Act, re-privatisation in 1989 and the introduction of new generators and suppliers with competition in supply.

8.5 Priorities for action

The following have been identified as the key priorities for action in this area:

- To avoid new fossil fuel plant, efficiency improvements in appliances that operate at peak time need to be a focus for market transformation policy, particularly for lighting and televisions.
- Minimising consumption of residential lights and appliances should be a priority as technical potential can be achieved rapidly. This could also avoid investment in new central plant.
- Demand side management should receive higher priority in future network design, both at a micro and macro scale.
- Diversity of LZCs has operational benefits for grid management and so the full range of options need to be supported by policy.
- Electrical storage technologies, including hydrogen generation as a means of storage, should remain priority research goals for smoothing demand and minimising any effect of intermittent generation.
- An ESCo approach would need support to divert

finance from investment in central plant and network towards the implementation of LZC technologies and demand reduction measures. Withholding consent for new build centralised plant (that is not CHP or renewable) would be a key incentive for encouraging the implementation of LZC technologies.

8.6 Conclusions

- The 40% House scenario is achieved in 2045, as a combination of improved building fabric, reduced demand from RLA and introduction of LZC, and without reliance on 'supply-side fixes'.
- Emissions from electricity are reduced by 15.6 MtC primarily due to widespread uptake of LZC.
- Emissions from gas reduce by 8.3 MtC, due to the lower heat demand of both existing and new-build dwellings.
- Decommissioning of nuclear power stations and closure of coal plant over the next 20 years means new capacity must be built to ensure security of supply. This could be either central or embedded generation. The 40% House scenario assumes high penetration of embedded generation.
- The amount of national system capacity required is determined by peak demand, which arises from the residential sector.
- The residential sector is responsible for the evening rise and peak in total demand.
- Demand profiles seen by future centralised generation will be very different to current profiles. Implementation of LZCs and reduced peak demand from appliances could reduce winter peak by 40%.
- Minimizing investment in centralised plant will allow money to be diverted towards households for implementation of LZCs, which could be achieved through an ESCo approach.
- An ESCo approach needs to be researched since households are unlikely to be able to deliver the investment envisaged. There are compelling commercial reasons for the development of ESCos over conventional energy supply businesses and such an approach could be supported by policy.
- The residential sector becomes a net exporter of electricity after 2045.

Achieving the 40% House scenario

The policies that will deliver a 60% reduction in carbon dioxide emissions in the residential sector involve a wide range of decisions and decision-makers. A market transformation approach is outlined as a possible delivery mechanism.

9.1 The 40% House scenario

The 40% House scenario achieves a reduction of carbon dioxide emissions to 40% of 1996 levels at least by 2050 and probably by 2047 and contributes to all four Energy White Paper objectives. This is based on a host of initiatives to control energy use and carbon emissions in this sector, resulting in the following changes:

- electricity consumption in lights and appliances has been reduced by nearly half, to 1680 kWh per household in 2050;
- all energy services have increased, per person (more warmth, hot water, space and access to appliances);
- the standard of new build means that homes have close to zero heating requirements from 2020 onwards. The average rate of construction has been increased by a third to 220,000 pa, so 10 million homes are built between now and 2050;
- about 87% of today's houses are still in use in 2050, but only those that can be refurbished up to a standard equivalent to 2004 new build;
- demolition is focused on the least energy efficient dwellings that are unhealthy to live in. The rate has increased from 0.1% pa of the housing stock in 2003 to 0.25% pa in 2050, by which time it will take only 400 years to replace the stock;
- there is an average of nearly two LZC technologies per house by 2050 and the housing stock as a whole is producing more electricity than it is consuming;
- national grid peak demand has been lowered by up to 25 GW.

The targets set are challenging but feasible, if Government starts now, and 45 years provides a substantial period of time in which to achieve a major new trajectory for residential carbon emissions, even acknowledging the inertia of the housing stock. In reality, these targets are approaching the extreme end of the policy envelope: it would be close to inconceivable to plan for tougher standards on lights and appliances or more low and zero carbon technologies on this timescale. Higher demolition and construction could be possible – and higher construction rates were proposed in the Barker Review (2004) – but a higher rate of demolition was deemed to be socially unacceptable.

Finding: The target of a 60% reduction in carbon emissions by 2050 is achievable in the residential sector, but requires a strong commitment by many sectors of society. The 40% House can be achieved.

Finding: The level of energy services increases per person: the average individual is warmer, has more hot water, more space and access to more appliances.

The 40% House scenario is demanding and demonstrates the task to be faced if the UK is to achieve its commitment to mitigating climate change. It may be that a tougher target should be aimed for, because:

- more may be expected and demanded from the residential sector, to compensate for the greater challenge posed in areas like transport, where reductions of 60% are even more difficult to envisage;
- climate change is proving to be more of a threat than previously anticipated, so action and cuts are more urgent and should be stronger than 60% by 2050 (Hare and Meinshausen 2005, Hillman and Fawcett 2004).

The 40% House scenario demonstrates an appropriate basis for policy. It is recognised that different combinations of measures to the ones proposed in the scenario are possible, but any lowering of activity in one area has to be offset by more stringent standards elsewhere. For instance:

- if the number of demolitions is not as high, then tougher Building Regulations will be needed, eg getting to zero space heating

There will be more hot water, space, warmth and appliances per person in 2050 – but carbon emissions are reduced by 60%

demand in 2010, rather than 2020;
- if the full technical potential in lights and appliances is not met, or substantial demand from unexpected new uses occurs, then each home will need more than two LZC technologies.

Finding: The individual targets in the 40% House scenario can be traded off against each other (more of one, less of another), but the options are limited.

9.2 Constraints

All of this could be achieved, despite the following conservative assumptions made by the project:
- The carbon emissions factor for electricity does not change after 2030 – it does not even include the effect of any electricity exported from the domestic sector, because of uncertainty about what is happening elsewhere.
- There are no major technological advances, just the strong development of known technologies, such as light emitting diodes, vacuum insulated panels in fridges and freezers, photovoltaics, micro-combined heat and power.
- The stock grows from 23.9 million properties in 1996 to 31.8 million in 2050 because of population growth and a diminishing household size (down to 2.1 people per household) – factors which are not amenable to policy intervention. Other things being equal, this would produce a 33% increase in energy demand and an immense policy challenge. This is one area where energy policy has to cope with the consequences and prepare for such an increase.

The 40% House scenario has numerous implications for other parts of society and the economy. These are recognised as of importance, but not included within the boundaries of this project. There is no intention of shifting the problem from the residential sector elsewhere, but the energy system is an integrated whole, so affecting one part will inevitably have implications in other places.

Finding: Over time, changes in population and declining household size result in more households and hence could lead to up to a 33% increase in energy demand, if nothing else changes. This demonstrates the scale of the challenge of achieving a 60% reduction.

Finding: The 40% House scenario is achieved, despite cautious assumptions on household numbers and the carbon intensity of electricity. The savings will be greater if these assumptions are too conservative.

9.3 Policy focus

The main focus of the project has been on product policy, using a market transformation strategy. In the past, housing has not been considered a traditional product, partly because it is not a commodity that can be moved around, although building components and technologies can. However, the European Commission is increasingly looking at making policy on buildings more consistent across Member States, for instance through the Energy Performance of Buildings Directive (EPBD). The novel approach taken in this project has been to investigate how market transformation may be extended to houses in order to promote a more rapid turnover of the housing stock and the development of ultra-low carbon technologies and lifestyles (Section 9.9). This requires a combined energy and housing strategy, focused on carbon mitigation. This moves away from the present suite of policies, which encourage the continuing use of the existing stock even if energy-inefficient.

Product policy has to be a priority, especially when prices are rising as a result of resource scarcity and political pressures or there is a focus on raising prices through taxation. Consumers need information to help identify which products to buy in order to use energy efficiently and cut costs. The scale of the challenge – and the increasing concerns about climate change – means that policy should aim at certainty of outcome. For this reason, there is a strong emphasis on regulation, for instance Building Regulations and minimum standards for new appliances and existing houses.

Certainty of outcome requires that policy shifts more from reactive to proactive mode: ensuring the right products come to market, rather than trying to minimise the impact of harmful equipment once it is being manufactured. Unless a genuine concern for the environment envelopes industry, Government may have to take stronger measures to protect consumers and the planet.

Another component of a proactive policy is education of the public about the seriousness of climate change and the vital role of personal responsibility. This is an essential backdrop to the 40% House scenario, so people begin to learn about the need to control their energy consumption and carbon emissions, and recognize that this can be achieved without a drop in standard of living and, probably, with an enhanced quality of life.

Finding: A combined UK energy and housing strategy covering all energy use in the home is required, with the main criterion being to ensure the best contribution to carbon mitigation.

Finding: A market transformation strategy for housing represents a novel application and identifies the way policy can be proactive, rather than reactive.

9.4 Timescales

This report is primarily concerned with the target of a 60% carbon reduction by 2050, but this date should be seen as part of a continuum, with the necessary carbon savings being long-lasting, permanent and irreversible. By 2100, the UK will have to reduce carbon emissions by 80% in order to achieve atmospheric carbon dioxide concentrations of 550 parts per million (RCEP 2000), or even more if recent claims about the likely scale of climate change are correct. Whilst there are currently no formal commitments over this time period, the scale of reductions is in line with the philosophy of contraction and convergence (GCI 2001). A prompt, decisive introduction of the policies outlined in 40% House scenario would help towards the achievement of a low carbon society in the long term as well as improving the chances of meeting existing targets. For the latter, improved standards for lights and appliances are particularly important, as turnover is already rapid and energy standards are undemanding.

Finding: A key policy objective is to make savings that are long-lasting, permanent and irreversible, that contribute to carbon reduction targets both before and after 2050.

Finding: An early requirement of the energy and housing strategy is to identify the timescale for policy action, so that future targets are not jeopardised by a failure to act soon. The timetable is tight and the aspirations substantial.

9.5 Opportunities for action: the housing stock

The slow turnover of the housing stock means that improved energy efficiency is limited by opportunities in existing dwellings and the rate of new construction and demolition. The biggest benefits come from replacing old, energy inefficient properties with new, low-carbon dwellings, if on a sufficient scale. The rate of demolition is an important component of the 40% House scenario, although this is a complex issue given the UK's architectural heritage and the fact that 70% of homes are owner-occupied.

9.5.1 Historic buildings

Many of the buildings that form the historic centre of UK towns and cities were originally houses but are now occupied by the offices of lawyers, accountants and doctors. These are no longer part of the housing stock, though they are often part of the image people have when discussing the country's architectural heritage. There are, however, 1.2 million dwellings in conservation areas and about 300,000 individual residential buildings listed as architecturally important. This 5% of the housing stock is treated as sacrosanct and not included in any plans for demolition; it represents about a quarter of the dwellings built before 1919. Hence, the majority of homes that are approaching 100 years of age are not protected under either of these pieces of legislation, at the moment. They have not been identified as part of the UK's 'official' architectural heritage. By implication, three-quarters of pre-1919 homes could be demolished if deemed unhealthy and incapable of providing affordable warmth.

Finding: Preservation of the architectural heritage focuses primarily on 25% of the pre-1919 housing stock.

9.5.2 Refurbishing the existing stock

The main factor determining decisions about the demolition rate is the extent to which the existing stock can be improved. In the 40% House scenario, existing homes that are still occupied in 2050 (21.8 million dwellings) have all been brought up to the standard of current Building Regulations for new building (ie a SAP of approximately 80), with an average heating demand of about 9,000 kWh pa. At present, only about 9% of the stock has a SAP of 70 or more.

The policies to achieve this will be based on the Building Regulations – which already cover major improvements – and on existing policies, such as the Decent Homes standard for much rented accommodation. A substantial upgrade in the effectiveness of these policies is needed, combined with local authority action on the worst housing and new initiatives such as financial incentives through stamp duty rebates on investments to reduce the carbon emissions from a building. The rebates should be linked to a proportion of the investment, not to a percentage of the duty paid as this would unduly favour the richest householders.

Finding: The aim is to achieve the maximum reduction through retrofitting the existing stock, to minimise costs and social disruption.

Finding: The target of getting 21.8 million homes up to an average of SAP 80 (heat demand of 9,000 kWh pa) by 2050 will require substantial, forceful new policies that need to be implemented as soon as possible.

9.5.3 Demolition

There is a direct relationship between demolition levels, the resultant lifespan of the average dwelling and the energy use in the whole stock. Present levels of demolition (20,000 pa) are demolishing barely 0.1% of houses each year, implying a stock lifetime of nearly 1,300 years (Table 9.1). Energy demand from the total stock will continue to rise if the amount of energy used in new buildings (for growth in household numbers) is not offset by reductions in the existing stock through demolition.

Table 9.1: Housing stock demolition rate, lifetime and energy consumption, UK

Annual demolition rate	*Lifespan (years)*	*Average SAP, 1996*	*Average SAP, 2050*	*% over 100 years, 2050*	*Energy change by 2050*
20,000	1300	44	66	31	+6%
150,000	250	44	77	25	-12%
234,000	120	44	84	19	-24%

Source: UKDCM

Under the 40% House scenario, the demolition rate increases from 20,000 pa now to 80,000 pa in 2016 and stays at this level until 2050, giving a total demolition over the whole period 2005-2050 of 3.2 million properties. By this stage, the demolition rate will have increased to 0.25% of the housing stock, taking 400 years to replace the 2050 stock of houses. The majority of homes demolished would have a low SAP (for instance there are currently 3 million below 33 SAP points), or be deemed unhealthy under the Housing Health and Safety Rating Scheme. Savings beyond those in the 40% House scenario would come from increasing the demolition rate further to 150,000 pa and would reduce the notional lifespan of the average building to 250 years. To get down to 120 years, demolition would have to rise to 234,000 pa. The latter would enable energy consumption for space and water heating to be reduced by 24% and the average SAP to rise to 84.

Finding: The current demolition rate needs to be increased fourfold, targeted at the most inefficient and unhealthy homes.

9.5.4 New construction

A key focus of the 40% House scenario is on the standard of construction – both as designed and its performance in practice – and on the size and type of dwelling. By 2020, the standard in the Building Regulations results in homes with nearly zero space heating demand.

The rate of new construction in the UK under the 40% House scenario is an average of 220,000 pa from now to 2050. This is 38% above the current rate of 160,000, but lower than the annual figure of 242,000 recommended at least for a period to bring house price inflation in England down to 1.8% pa (Barker 2004). Barker did not consider the rate of demolition, therefore the rate of construction may need to be even higher than the one proposed under the 40% House scenario.

In addition to the quantity of new homes required to reduce pressure on house prices, there are several other important interlocking issues related to new construction, which are beyond the remit of the project. These include whether the homes (and related jobs) should be moved out of the South East, the relative importance of different tenure groups and whether more social housing should now be constructed.

In recognition of the growth of single-person households, the 40% House scenario assumes that much new construction is of smaller homes: the average new dwelling is 74m² by 2050. This links to the quantity and density of construction (Table 9.2). If the space per person is kept the same, the projected 33% increase in household numbers only results in a 15% increase in total residential floor area. Whereas, if the size of the average dwelling is maintained, then the 33% increase in household numbers does result in a 33% increase in total floor area, with 14% extra space per person.

The Government is already encouraging development of denser housing. From March 2005, it aims for 30-50 dwellings per hectare in London and the South East, South West, East of

Table 9.2: Effect of space per person on total residential built fabric

	Number of households (million)	*Size (m^2)*	*Total residential floor area (billions m^2)*	*People per household*	*Space per person (m^2)*
1996	23.9	84	2.0	2.4	35
2050	31.8	74	2.3	2.1	35
2050	31.8	84	2.7	2.1	40

Construction of new homes must average 220,000 per year until 2050. By 2020 they use only 2000 kWh per year for heating

England and Northamptonshire (ODPM 2005). But this is still treating the dwelling as the main measure. There needs to be more recognition of the interaction between the space per dwelling, the space per person and the quantity of built fabric in total (including communal space), as the latter has implications for the amount of land that is needed for new housing construction.

Finding: The rate of construction is increased from 160,000pa to 220,000pa, with only 30% (3.2 million) replacing demolished houses; the rest is for new household formation. In total there are 10 million new homes.

Finding: The need for cooling is minimised in the design of new buildings (eg high thermal mass) and there are strategies to retrofit existing buildings (eg with shading grills).

Finding: The remit of the proposed energy and housing strategy covers location, tenure, size and density of housing developments over the next 50 years.

9.6 Opportunities for action: lights and appliances

Historically, the greatest increase in energy demand in the home has come from the acquisition of more electrical equipment – up 70% from 1970 to 2001 (Figure 1.2). The biggest threat to additional residential energy consumption, at least over the next decade or so, comes from the acquisition of more electrical equipment. There has to be a strong policy focus on lights and appliances, if the residential sector is to contribute to the 60% carbon reduction. However, much UK policy in this area is determined by the European Commission as these are traded goods that should be of a common standard. In the 1990s, EU policy was fairly rigorous and beginning to be influential, through the use of market transformation strategies. For some groups of appliances, notably refrigeration and washing machines, consumption declined. In the last few years, the Commission has become less interventionist, for instance relying on voluntary agreements with industry, rather than mandatory minimum standards. As a result, there has been less constraint on demand and electricity consumption is rising.

Finding: Unless the present rate of growth of electricity use in lights and appliances can be curbed and reversed, the 60% carbon reduction in the residential sector will be all but impossible. This requires the UK, together with other Member States, to focus on strong European policies, with immediate effect.

Finding: The rapid turnover of the stock of lights and appliances means that savings can be achieved quickly, once policy is implemented. This could, even now, contribute to additional savings to achieve the EU's Kyoto target for 2008-12.

In the last few years, there have been examples of manufacturers producing new designs and equipment that is particularly profligate in its consumption of energy – the plasma TV is a good example, as it has a power rating of 350 W in comparison with the 75 W TV that it replaces. The unnecessary high demand in digital set-top boxes is another example. In certain sectors, particularly consumer electronics, a reactive policy approach cannot keep pace with the evolution of new technology. The introduction of eco-design requirements under the European Energy-using

Products Directive would encourage manufacturers to place greater importance on energy efficiency and demand reduction as part of product design, helping to control the introduction of profligate appliances.

Finding: Manufacturers must be encouraged to view energy efficiency as a vital component of product design to prevent energy-profligate equipment appearing on the market. This could be achieved under the European Energy-using Products Directive.

Finding: Existing market transformation programmes, and forthcoming EU Directives, provide useful experience and the appropriate framework for tough reductions in residential lights and appliances.

Finding: To aid consumer choice, all energy-related products would have an energy consumption label, before being placed on the market.

9.7 Opportunities for action: space and water heating and low and zero carbon technologies

The 40% House strategy is to plan for the next generation of technologies for space and water heating as low and zero carbon emitters. Policy is dealing with the short-term by ensuring that gas-fired condensing boilers become the norm and the gas network is extended, but a longer-term view is necessary.

Low and zero carbon technologies include methods of generating electricity at the household level (photovoltaics, PV, and combined heat and power, CHP). Many of these technologies are not yet cost-effective and will need support to become so. Substantial development of existing technologies is required, for instance, considerable advances and cost reductions in both photovoltaics and micro-CHP.

At present, a significant number of households use electricity either for space or water heating, or for both. The use of electricity in the UK emits at least twice as much carbon dioxide per unit of delivered energy as gas in the UK. In the 40% House scenario, the use of electricity from the national grid in the home for space and water heating is minimised.

Finding: The LZC technologies could contribute about a third of the savings to the 40% House. They are a portfolio of building-integrated measures (micro-CHP, solar thermal, photovoltaics, heat pumps and perhaps some wind) and community heating either with CHP or fired by biomass.

Finding: 53.6 million LZC installations for the residential sector will stimulate new employment, both in their manufacture and installation.

Finding: This level of LZC installation will only occur if there is considerable support to ensure that the technological improvements are achieved, the cost per installation drops and that they can be financed.

Finding: LZC can provide 81% of the heat demand for space and water and all of the electricity used in the home, by 2050.

Finding: This transformation of energy demand in the residential sector has major implications for the utilities and particularly the electricity supply industry.

Finding: The preferred residential fuel may vary by region and by house type. In the 40% House scenario, the use of electricity from the national grid is at a minimal level.

9.8 Opportunities for action: peak demand

This project has examined the proportion of peak demand that comes from the residential sector and the extent to which this can be reduced, as a contribution towards maintaining integrity of the electricity supply. This is particularly important at a time when substantial capacity (coal and nuclear) is about to be retired from the system. This is not so much a carbon reduction strategy (though it contributes), more a component of the Energy White Paper aim to improve security of supply.

There are two ways in which peak electricity demand can be reduced through a focus on those uses that already contribute to the residential peak: first by installing and accelerating the deployment of known, efficient equipment, for instance light emitting diodes. Secondly by specifically designing new equipment with a lower maximum demand, which would generally contribute to lowering the peak. There are small additional savings available, for instance through fuel switching out of electricity for peak demand uses, such as cooking. Some of these – a return to gas kettles – may not match consumer preferences. When peak demand reduction is combined with the installation of equipment that produces electricity in the home (eg micro-CHP), the net effect is considerable. Under the 40% House scenario, UK peak demand is reduced by 25 GW in 2050, in comparison with a 2002 peak of 62 GW.

Finding: Residential energy policy can contribute substantially to lowering peak electricity demand and hence reducing the need for generating capacity and infrastructure, with considerable expenditure reductions and security of supply improvements.

Finding: The design and installation of lights and appliances can be optimised to reflect the need to keep peak demand low.

9.9 Market transformation strategy and housing

There is already considerable experience of the ways in which market transformation can work, successfully, with lights and appliances (Boardman 2004a, b). The same strategic approach, integrating a range of policies, would facilitate the implementation of the 40% House scenario. The main components of a market transformation strategy are labels, minimum standards, procurement, grants and rebates. Such an approach would form the basis of an overall UK housing and energy strategy.

9.9.1 Labels

A home energy label on its own will have minimal impact – there are too many competing factors affecting the way people choose where they live – but is central to a product policy approach. An accurate, complete national labelling system, with the information stored in a central database, is vital to a coherent housing strategy.

Currently few properties have any type of energy label and there is no consistent format or publicity. Consequently, the public, and policy makers, are unaware of the inefficiency of the properties they occupy and cannot differentiate the good from the bad. Labelling of individual houses is being incorporated into the Building Regulations (although compliance is poor) and in other policies such as the Home Information Pack, as a result of the Energy Performance of Buildings Directive. Neither of these cover all energy use in the home, which would be the ideal approach, particularly when future homes have zero heating demand and most of the energy used will be in lights, appliances and water heating. In many homes, the majority of appliances are incorporated into a fitted kitchen – a trend that seems to be increasing – and should be considered as fixed entities. In all cases, the label is based on a theoretical calculation – for instance, what would be required to achieve a defined internal temperature – rather than reflecting the bills and unknown lifestyle of the occupants. It is therefore a rough guide, but still one that allows for useful comparisons.

The Sustainable and Secure Buildings Act 2004 (the Stunell Act) enables the Building Regulations in England and Wales to cover the protection of the environment and facilitate sustainable development. This includes renewable technologies, two-way metering and fiscal incentives for energy efficiency measures. The Act also requires the Secretary of State to provide a report every two years on the change in the efficiency with which energy is used in buildings, the emissions of greenhouse gases and the extent to which own-generation is integrated into

Homes that are unhealthy and do not provide affordable warmth should be the target for improvement or demolition

the building stock. Local authorities have to keep supporting documentation.

Under the Home Energy Conservation Act 1995, the 400 local housing authorities have to provide annual reports on the energy efficiency of all the houses (no matter what tenure) in their geographical area. In this way, the whole country is covered. The HECA reports are, apparently, of limited accuracy at present (Smith 2000). One way to deliver the necessary focused action and clear reporting would be to upgrade the standard of the HECA reports, make them more sophisticated and use them as the basis for policy. This fits well with the requirements of the Stunell Act and could utilise the results from Home Information Packs.

Finding: For a comprehensive market transformation strategy, the dwelling energy label would cover all uses of energy in the home (not just space and water heating). The use of labels would be enforced and coverage of the whole stock achieved as quickly as possible.

Finding: The information from the label could be held in an address-specific database, for each geographical area, to provide a national policy resource. This would support local authority compliance with the Stunell Act and link to existing HECA reports.

9.9.2 Minimum standards – unhealthy dwellings

At the moment, there is no strategy to ensure a minimum level of efficiency for all occupied dwellings. There are still homes with a SAP rating below zero – a situation that was deemed virtually impossible when the scheme was devised – and 9% of properties with a SAP below 30 in England in 2001 (ODPM 2003a). Many of these are solid-walled properties, dependent upon electricity for the main fuel, the vast majority occupied by low-income families. The poorest people are purchasing the most expensive warmth.

The Housing Act 2004 introduces a new system for defining homes that are unhealthy or unsafe, called the Housing Health and Safety Rating System (HHSRS). This provides for cold homes to be included for that reason alone. The effectiveness of the HHSRS will depend upon the obligations placed on housing authorities to identify and act on unfit properties. The Building Research Establishment estimates that about 8% of properties in England are 'actionable' for one or more reasons (Nicol 2003). Whilst the HHSRS is mandatory, the action and funding may be discretionary, therefore it is difficult to predict the extent to which this new legislation will result in the removal of the worst houses from the stock, particularly in the short term. The legislation does, however, provide a strong potential force.

It is not suggested that an unhealthy property has to be pulled down and certainly not when it is valued highly for its architectural heritage. The requirement is for improvement to a greater level of energy efficiency so that it provides affordable warmth. The upgrade should be substantial so that it does not require further work as standards rise in the future. This could be delivered by the individual housing authorities, through a rolling target that combines average improvements with the minimum standard: a 10% improvement by 2010, 20% by 2020 and so forth.

Finding: A primary objective of the proposed energy and housing strategy is to define a minimum standard of thermal performance and ensure that it is rigorously and quickly enforced. The new Housing Health and Safety Rating System provides the mechanism for this, as long as funds are available for local authorities and utilised.

9.9.3 Minimum standards – Building Regulations

The Building Regulations define the minimum standard of heat loss in new buildings and major conversions. The next upgrade in 2005 is likely to be framed in terms of carbon emissions per m^2, rather than U values of individual components. The 40% House scenario assumes continuing, substantial improvements in the Building Regulations at regular intervals, including the installation of LZC progressively, in both existing and new dwellings. From 2020 onwards, there is close to zero heating demand.

Research to establish the energy efficiency gains achieved in practice from the current Building Regulations – post-occupancy evaluations – together with better analysis of the U values ascribed to individual construction methods would both go towards ensuring that the standards are accurate in their consumption predictions (Olivier 2001). At present, new houses are often built in ignorance. Poor design details and construction methods can annul many of the benefits of the added insulation. Thus, enforcing the Building Regulations, both through the standard of what is built and in their application to the existing stock, is a major challenge. It requires:

- a better-educated public to demand good quality advice and service, and to know when their plans might interact with the Building Regulations;
- more training in the construction industry (including small builders) to ensure that they are scrupulous at informing the public about the required standards and that what is promised is actually delivered;
- more resources for local authorities, so there are more and better-trained building inspectors and less reliance on builders self-certificating;
- greater emphasis in the Building Regulations on performance criteria, for instance pressure testing, to ensure that the whole building achieves the defined and designed standard.

The standard of new accommodation provided by social landlords – local authorities and housing association – will improve with the Building Regulations. The homes of low-income households should be disproportionately efficient and higher than specified in the Building Regulations. This is already the situation in Scotland where new housing association dwellings have to obtain a SAP rating of 85-90, which is above the present English Building Regulations. In Wales, sustainable development is a legal requirement of all policies.

The Energy Efficiency Partnership for Homes has already introduced an annual training programme for 45,000 people, to prepare for the anticipated, mandatory installation of condensing boilers in the 2005 Building Regulations (EEPH 2004). Each successful trainee gets a City and Guilds certificate. This process should be repeated to include low and zero carbon technologies. If, under the 40% House scenario, the Building Regulations require the installation of technologies such as solar hot water heaters, then the building industry will be required to upgrade their skills on a regular basis.

Finding: In order to provide affordable warmth, despite higher fuel prices, the standards of new construction of social housing would be to a higher standard than those for the general public.

Finding: To ensure that the expected savings are achieved, the Building Regulations would incorporate, or be redefined as, performance standards.

Finding: To aid the deployment of LZC technologies, they could be specified in the Building Regulations, increasingly, for both new and existing dwellings;

Finding: If an ongoing strategy for Building Regulation standards is identified, even in the most general terms over the next 40 years, the extent of improvements can be identified, appropriate technologies prepared and mandatory training provided for installers and the construction industry.

9.9.4 Procurement and exemplars

A clear policy focus on procurement and the testing of low and zero carbon techniques (in preparation for new Building Regulations) is required. Demonstration projects in the UK and experience in other European countries would clarify any lessons and causes of concern surrounding new approaches and technologies, such as ever-wider cavity walls. To date, there are only a few advanced demonstration schemes, such as BedZED and the York housing development being constructed as a test for the likely 2005 Building Regulations (Lowe et al 2003).

New building-integrated technologies are currently supported by £60 million pa in grants through Clear Skies to encourage the take-up of more efficient new equipment, for instance solar thermal, photovoltaics and heat pumps. Most of the initial grants have been used for solar thermal installations, as the individual grant level is inadequate to encourage the more advanced and expensive technologies. Really innovative technologies, such as integrated wind turbines, are not yet considered. This scheme provides token support for new ideas rather than a developed procurement programme.

Finding: Knowledge of the combined effects of demand reduction and building-integrated low and zero carbon technologies would be increased substantially if each local authority had at least one demonstration development, like BedZED, as soon as possible.

9.9.5 Grants and rebates

The traditional role of grants in a market transformation strategy is to grow the market for new technologies by reducing the unit cost. This should be a limited initiative, until demand for the product is secure and it is manufactured by several companies. With housing, however, existing grant schemes are used principally to improve the worst housing, mainly for the fuel poor occupants – not to boost demand for a new technology. The effect of most of these grants is to improve the energy efficiency of the property by about 20 SAP points. The recent fuel poverty action plan sets the objective of raising properties to 65 SAP points in England (DEFRA 2004c), as fuel poverty is deemed to be unlikely above this level. In Scotland the target is 65-70 SAP points. The fight against fuel poverty is both a moral imperative and a legal requirement, but resources are scarce and there appears to be no strategic debate about the validity of insulating buildings that should, sometime soon, be pulled down. The present approach is fossilising the existing stock, albeit for humane reasons.

The rented sector suffers from the problem of 'split incentives' – it is the tenant that benefits from investment in energy efficiency by the landlord. This problem is particularly acute in the privately-rented sector, where there is a concentration of old, energy-inefficient properties occupied by low income households suffering from fuel poverty. In 2004, the Government introduced the Landlord Energy Saving Allowance (energy efficiency investments can be offset against tax), lower VAT on some energy saving measures and a Green Landlord Scheme. The net effect of these initiatives is difficult to predict.

The role of grants needs to be reassessed, in the context of a realistic approach to eradicating fuel poverty. As fuel prices rise, the numbers in fuel poverty will increase again, forcing the development of a clearer fuel poverty strategy. Meanwhile, there is a role for grants to the non-fuel poor, for instance to encourage greater energy efficiency through stamp duty rebates. The point of sale is a good time to intervene.

Finding: An energy and housing strategy would clarify the role of grants and the extent to which these are primarily focused on eliminating fuel poverty, as at present, and whether additional resources are also needed to encourage best practice, as in a traditional market transformation strategy.

9.9.6 Summary: the complete strategy

The net effect of policy today is a few initiatives which maintain the present housing stock, rather than transform it towards greater energy efficiency. The proposed energy and housing

Table 9.3: Main variables in 40% House scenario compared to 1996 baseline

Variable	*1996 – baseline*	*2050 – 40% House*
People and dwellings		
Population (millions)	59	66.8
Household size (people per household)	2.47	2.1
UK household numbers (000s)	23,900	31,800
UK rate of new construction (pa)	162,000	220,000
UK demolition rate (pa)	8,357	80,000
m^2 per person	34	38
m^2 per dwelling	84	84 (refurbished) 74 (new)
Building fabric		
Space heating demand (kWh per household)	14,600	8,300 existing 2,000 new
Ventilation rate (air changes per hour) for new buildings	3.5	0.5
Energy uses		
Internal temperature (°C) – zone 1	18.3	21
zone 2	17.3	18
Cooling temperatures	No air conditioning	No air conditioning
Electricity consumption in lights and appliances, including cooking (kWh per household)	3,000	1,680
Energy for hot water, kWh per household	5,000	3,400*
Supplying energy demand		
Gas boilers ownership efficiency	 69% 68%	 8% 95%
Electric heating ownership efficiency	 9% 100%	 10% 100%
Community heating with CHP and biomass ownership	0%	22%
Micro-CHP ownership efficiency (heat:electricity)	 0% 85:10	 21% (Stirling) 80:18 (Stirling) 20% (fuel cell) 55:35 (fuel cell)
Heat pumps ownership efficiency	 0% 300%	 9% 300%
Photovoltaics (electricity production) ownership	 0%	 30% (20m^2, 15% efficiency)
Solar thermal water heating ownership	 0%	 60% (5m^2)
Emissions factors electricity (kgC/kWh) gas (kgC/kWh)	 0.136 0.049	 0.1 0.049

Source: UKDCM

* net of solar hot water

strategy would develop a proper market transformation approach with clear, stated targets (Table 9.3). In the 40% House scenario by 2050, the 21.8m existing homes have been refurbished up to a high standard.

Finding: By 2050, the aim is for the average, existing property to have a SAP of 80 (the level of today's new build) and for there to be no homes with a SAP lower than 51 points (today's average).

Finding: A detailed, comprehensive market transformation strategy for all energy use in the housing stock could be a major delivery mechanism for the 40% House scenario. This would identify the contribution of individual policies, the target standards for specific dates and the role of different delivery agents.

In addition to the Energy White Paper, the starting point for this project was the Royal Commission on Environmental Pollution's 2000 report and its four scenarios (Table 1.2). The main differences between the RCEP scenarios is the extent to which demand could be reduced and then the way in which the resultant demand is met from varying combinations of renewables, nuclear and carbon sequestration. The carbon reduction achieved in the 40% House scenario comes from a combination of demand reduction (two-thirds) and the provision of building integrated low and zero carbon technologies (one-third).

The carbon intensity of the electricity from the national grid has been kept stable at the 2030 level until 2050. Further or alternative reductions could come from the energy supply system – there has been no assumption of carbon capture and storage (also known as carbon sequestration), seen by some as a necessary end-of-pipe solution to reducing carbon emissions, and no new nuclear. The supply mix has been kept at the 2030 level and the effect of the reductions in residential demand on carbon emissions per unit of centralised electricity have been ignored.

Finding: The 40% House scenario has demonstrated the substantial extent to which residential demand can be reduced through a coherent policy approach, without resorting to cleaner centralised electricity generation. Indeed, central capacity is reduced.

9.10 Other considerations

There are a number of considerations that underpin the development of a market transformation for housing which must be addressed to ensure full coherence and effectiveness of any strategy.

9.10.1 Responsibilities of local and regional authorities

The local and regional housing authorities have a major role in the delivery of housing policy and this could be reinforced. There are numerous individual policy activities and reports that influence the housing stock – Warm Zones, Housing Market Renewal, English Partnerships, Energy Efficiency Plans for Action, the Egan Review and Sustainable Building Partnerships – to name but a few. It has been beyond the scope of this project to examine the potential combined effect of all these initiatives, but one of the reasons behind the call for an energy and housing strategy is to ensure that these components add up to a coherent whole.

The devolution of greater, but flexible, responsibility to local authorities (whether regional or district) appears appropriate. The first study on Housing Market Renewal demonstrated that the local authorities, when given the freedom and resources, give priority to demolition of obsolete properties as a housing renewal strategy (Cole and Nevin 2004).

The new Regional Housing Boards are gaining a clearer remit, which will be defined further in 2005 (ODPM 2004i). They were established following the publication of the Sustainable Communities Plan in February 2003 by the ODPM, with the aim of improving regional planning for housing.

Finding: The devolution of responsibility to both regional and district housing authorities, if properly funded, represents an opportunity for a targeted approach to an energy and housing strategy, whilst recognising the need for flexibility.

9.10.2 Energy efficiency versus energy conservation

The trend is towards larger appliances (fridges and washing machines) and more housing area per person, increasing the demand for energy, sometimes in the name of energy efficiency.

Property developers need to design dwellings for smaller households

Energy efficiency is a relative term – in the context of the European Energy Label, it is defined as the demand for energy per unit of 'service', for instance the volume of a refrigerator or the weight of clothes washed. As the equipment gets larger, it is easier to achieve a high level of energy efficiency, which is the strategy that manufacturers have adopted. In 1996, many washing machines had a capacity of 4.5-5kg. Now most of them are 6-7kg, even though the average number of people using that washing machine has declined. The machines are both more energy efficient and using more energy than they would have if they had stayed the same size.

The energy penalties of larger, but efficient, appliances are not great, but they are there. If the format of the EU Energy Label is the main reason they are being designed, manufactured and marketed as larger appliances, it would be beneficial to alter the label and remove the incentive. If the trend is then still towards larger appliances, it will clearly be because of consumer preferences. The expectation is that energy labels based on absolute consumption, not relative performance, would encourage downsizing. This is the policy behind the design of the energy label for cars in many countries, such as Denmark.

A similar theme is developing with housing, where the two dominant trends are occurring at different timescales: the turnover of the stock is slow, whereas new (smaller) household formation is relatively rapid. As a result, smaller households have to live in properties that were originally built for much larger families and the amount of space occupied per person is increasing. The energy penalties of additional space per person are not large if the home is energy efficient. In 1996, a super-efficient home cost £2/m² pa to heat, whereas the average was £6/m². However, in the least efficient homes, the cost was £15/m² – a very substantial penalty for extra space (DETR 2000).

Most developers (outside London) have been building properties for the archetypal family, despite its diminishing importance, without paying sufficient attention to the present and future household mix. With household size now below 2.4 people per household and falling, smaller properties and denser developments may be more appropriate. In 2002, there were already 7.4 million single-person households, 29% of the total. With an ageing population, this group is of growing importance, and many are living in large, underused properties (Houghton and Bown 2003). The poorest people spend more money per person on household energy because the lowest quintile consists predominantly of one or two person households (Fawcett 2003).

Finding: Separate, but interacting, policy initiatives are needed to enable people to move into more energy efficient homes and into smaller homes. These particularly apply to elderly, single pensioners living in under-occupied dwellings.

Finding: The replacement of policy on energy efficiency with policies on absolute energy demand may encourage downsizing and could inhibit, then reverse, the present trend towards larger equipment and more space per person. This would apply to policy on the energy labelling of buildings in the UK, under the Energy Performance of Buildings Directive and through the Home Information Pack.

9.10.3 Capital expenditure

The home of the future will have more capital equipment – this could be solar panels, micro combined heat and power, heat pumps – all of which will involve additional capital expenditure to the single boiler there at present. Consumers may obtain the same economic utility from each piece of equipment – it is used less frequently, so lasts longer – but there is a peak of capital expenditure when a new technology is adopted.

At the same time, the utilities will have to invest less in central plant, as there will be a lower level of demand for centralised electricity. This is because:

- the demand for electricity will be lower, as lights and appliances become more efficient;

- there will be less use of electricity for space and water heating – because of its carbon intensity, policy will have focused on reducing this through insulation and alternative energy sources;
- there will be more building-integrated generation, for instance through photovoltaics and micro- and community level CHP.

This situation requires a switch in capital outlay, from utility to householder. This could be achieved through a greater outlay by the individual householder or result from the development of energy service companies (ESCos), whereby the utilities invest in individual homes instead of centralised plant.

The net effect for society could be beneficial because the electricity transmission and distribution systems will only need to be upgraded and maintained to a lower capacity level. Significant replacement of the ageing electricity grid is needed in the near future and this, along with the decommissioning of coal and nuclear plant, gives the opportunity to plan strategically now.

One of the issues for policy is to recognise these different capital requirements and to support householder investment. Policy support is particularly important for low-income households that are renting or have no capital: 28% of all households have no savings and, by implication, no access to capital loans. Amongst the poorest households, those with a weekly income of less than £200, the proportion with no savings rises to nearly half (46%) (NCC 2004). The aim of policy has to be to ensure that the homes of the poorest people are disproportionately energy efficient so that they have affordable energy services, even at their low incomes.

Finding: Strong financial support will need to be focused on the owners of existing properties if they are going to improve their properties to the extent envisaged. These could include stamp duty rebates.

Finding: The policies envisaged in the 40% House scenario involve substantial capital flows, in non-traditional directions. Policy is needed to promote investment in energy efficiency and low and zero carbon technologies for all groups in society, both individually and collectively. One route of financing the LZC technologies in the home may be through energy service companies.

9.10.4 Equity

Equity is now a main driver of energy policy, through the provision of adequate and affordable warmth (and all other energy services in the home), and an important component of the approach taken in this project: climate change mitigation must not be achieved at the expense of the poor.

Recent policies to reduce fuel poverty have focused on raising incomes and lowering energy prices, and have had less effect on improving the energy efficiency of the properties they occupy. This makes the fuel poor vulnerable to energy price increases as a result of world energy trends. Additional upward pressure, particularly on electricity prices, will come from the increasing scale of the Energy Efficiency Commitment, the Renewables Obligation and other utility-based policies, if these result in higher costs being passed through to customers. In February 2004, before the recent price increases, the Fuel Poverty Advisory Group stated that Government expenditure on reducing fuel poverty needed to increase by 50% (FPAG 2004). This is now a considerable underestimate.

Existing policies are strongly criticised because they are having difficulty identifying and treating the worst homes. However, if they become better targeted, money will be spent on continuing the life of the worst properties. Although this is essential whilst occupied, there must be immediate intervention once one of these properties becomes vacant, so that no new occupant suffers. A complementary approach is to increase the quantity of new dwellings with low carbon footprints (from all uses of energy), probably also smaller in size (45-65m^2) specifically for the young or elderly in town centres. These would provide an acceptable choice for those fuel poor currently living in dreadful homes.

Finding: The 40% House scenario includes new, appropriate construction as a major contributor to reducing fuel poverty and releasing homes for demolition. The existing homes of the fuel poor need to be upgraded to a standard of SAP 80, as quickly as possible, to offset fuel price rises whilst ensuring that fuel poverty is eradicated.

9.11 Minimising costs

Policy can be used to reduce the cost implications substantially through an integrated, well-structured strategy such as market transformation (Boardman 2004b). Capital costs will be offset by considerable savings in running costs, particularly if fuel prices continue to rise. Hence, these details interact strongly with an assessment of the costs of the programme and of the constituent parts. The emphasis in the 40% House scenario has been on refurbishment rather than demolition, partly in recognition of the differing costs associated with these policies. The following are some of the components of the debate about ways to minimise costs:

- Early warning to industry about pending legislation and standards means they can plan and incorporate the necessary design changes into normal product development. This was achieved with the European minimum standard for fridges and freezers when a 15% improvement in the efficiency of models sold was achieved over a 15 month period, whilst the retail cost per appliance dropped 14% (Schiellerup 2002; Boardman 2004b). The aggregate saving to consumers was £285m pa, so there was a substantial net benefit to society.
- Expenditure on awareness-raising (eg through advertising) is necessary for an informed, supportive public and the cost accrues to Government or utilities.
- Incorporating more efficient lighting equipment into the home will require some necessary household expenditure, for instance the switch over to light emitting diodes over the next 25 years.
- Upgrading the quality of the existing housing fabric to the standard required will be costly. The expected increase in activity to eradicate fuel poverty and offset the effect of rising fuel prices will mean that some significant proportion of this expenditure stays the responsibility of central government, for instance in homes where the energy and money savings are insufficient to repay the capital.
- Incentives to richer households, for instance through stamp duty rebates, would involve government expenditure, but this could be offset by VAT receipts on the same investments.
- The introduction of LZC technologies to individual houses is expensive and the extent to which this is offset will depend upon the tariff paid to individual householders for the export or own-use of electricity. A feed-in tariff that covers the cost of the electricity generated would reduce some of these costs to nil. An alternative funding avenue is through energy service companies.
- Demolition potentially involves the largest expenditure. The costs depend upon the value of the property demolished: if it is already declared unhealthy or is sitting in a flood plain and uninsurable, then they will be lower. The sale of a development site will offset the costs in the former, but not the latter, case. If responsibility has been transferred to local authorities or regional housing boards, then central Government has to ensure they have sufficient funds.
- A lack of planning, or emergency responses, increase the costs considerably. An early commitment to a trajectory that gets the UK to the 60% target would minimise these costs,

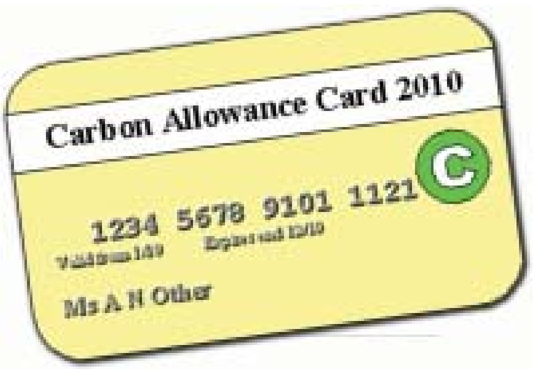
whether they fall on the householder, the Government or other funders.

Finding: The capital investment associated with achieving the 40% House scenario will be considerably higher than present levels of expenditure on demand reduction in the residential sector, whether funded by Government, the utilities, or private individuals.

Finding: The cost implications of a 40% House scenario will be minimised by an early, clear, rigorous approach to planning, so that everyone, from the construction industry, to appliance manufacturers, to local authorities and householders, knows the direction of policy and can plan accordingly.

9.12 People transformation

Achievement of the 40% House scenario requires the active involvement and commitment of the public, particularly if gains in the efficiency of the housing stock are not to be lost through the purchase of additional electrical equipment. Whilst product policy can deliver a great deal, it is most effective when working with the grain of society. Therefore, policy should focus on developing an informed society that is supportive of strong climate change mitigation. This will not be easy, particularly as the dominant mindset appears to be in line with the World Markets scenario at present (Figure 2.2). The importance of public education (including practical initiatives) to develop understanding, support and everyday skills for low-impact ways of life cannot be stressed enough. This is needed at all levels and for all ages.



Methods to encourage personal responsibility will be needed by 2050

More specifically, the 40% scenario also implies a huge programme of training in the skills needed to design, construct and maintain a low-energy building stock, the appliances used within it and the technologies on which all will depend. The integrated approach to education and training for sustainable communities set out in the Egan review (ODPM 2004g) is one very much in keeping with the scenario, and one that needs implementing urgently.

Finding: An immediate training programme will ensure that the workforce has the skills to implement and maintain the 40% House scenario.

Finding: If UK society continues to develop along current trends, no carbon emissions reductions are expected by 2050.

A key element of the 40% House scenario is the development of a high level of carbon awareness, so that people want carbon reductions and are prepared to take personal responsibility. One way of achieving this would be through a system of personal carbon allowances (or tradable domestic quotas). This has a number of benefits, as it:

- is equitable – everyone has an equal allowance;
- will rapidly lead to an informed society, as people understand the carbon impact of their direct fuel purchases;
- ensures that carbon reductions can be guaranteed (by the amount of allowances issued);
- gives individuals the choice of where to make their carbon cuts, for instance offsetting emissions from travel with carbon reductions in the home.

Although not a major focus of this project, it is a fast developing concept – there has already been a Domestic Tradable Quotas (Carbon Emissions) Bill, introduced by Colin Challen, MP. Further work is being undertaken in this area through the UK

Energy Research Centre's Demand Reduction theme.

There is a strong link between policies on fuel poverty and personal responsibility: low-income households cannot be expected to take responsibility for their carbon impact when they have no capital or control over the energy efficiency of their home. Progress towards personal carbon allowances or residential carbon taxation depends upon minimising hardship for low-income households.

An alternative approach to triggering public action and involvement would be considerably higher energy prices. To achieve the 60% carbon reduction target, real prices would have to rise significantly. Household energy costs are already rising, with resultant increases in fuel poverty. The expectation is that UK governments would be reluctant to have a policy that relied on major additional increases in fuel prices, particularly those sufficient to confirm a 60% reduction in carbon emissions, as these are both unpopular and regressive.

Finding: Research is needed into the role that could be played by personal carbon allowances and to identify appropriate precursor policies that prepare and aid the public. The timescale for implementation needs to be considered, but a slow approach (longer than 10 years, say) jeopardises the 60% carbon reduction by 2050.

In preparation for greater carbon awareness, policies would be introduced to help make the public more aware of their carbon budgets – some are already in development. For instance, Ofgem is in discussion with utilities about the development of more informative bills that identify the actual amount of energy consumption over the last five quarters at the household level. Elsewhere in Europe this has proved to be an effective way of focusing people's minds and bringing forward energy-saving activity (Roberts et al 2004, Darby 2001). A separate initiative, required by the European Directive on electricity liberalisation, is the provision of information about the electricity fuel mix being purchased (the quantity that has come from coal, gas, nuclear or renewable generation) with or on utility bills (known as disclosure). The Department of Trade and Industry are requiring this information to be sent to customers from October 2005. Another way in which to encourage low-carbon responses from consumers is through a change in the tariff structure, so that unit costs increase with consumption. The reverse is the current situation.

Finding: The design of utility bills, electricity disclosure labels, tariff structure and the existence of the standing charge could all be considered in terms of discouraging consumption and improving the energy literacy of society. At the moment, they neither inform nor encourage careful consumption. This is a disservice to consumers at a time of rising energy prices and carbon concern.

9.13 Summary and conclusion: a 40% society

Society in 2050 under the 40% House scenario would contain these elements:

- there is considerable concern about climate change and a strong support for effective international action to reduce greenhouse gas emissions, particularly in the developed world;
- this concern is translated into comprehensive formal and informal training for low-carbon ways of life, from childhood through to professional and vocational training;
- a 60% reduction in carbon dioxide emissions in 2050 is seen as a minimal EU level of commitment that must be achieved;
- the UK has a national target of a higher reduction in greenhouse gas emissions;
- there is a high level of carbon literacy in society, so actions are focused and effective;
- there is a willingness by individuals to take action at home and elsewhere;

- companies are developing low carbon products: insulation, low-energy lights and appliances, and for generating electricity and providing heat in the home. The UK is at the forefront of these developments, supported by Government;
- proven low carbon technologies are adopted quickly by householders, creating and maintaining a market for these innovative industries;
- a strong community focus imbues decisions, reinforcing a regional housing policy and giving rise to denser town centres and the development of community-level energy networks;
- world fuel prices have risen substantially;
- equity is an important dimension, resulting in priority being given to policies that help the disadvantaged and elderly, along with a focus on healthy housing to provide the poorest with affordable warmth and other energy services;
- all of this has been achieved as a result of a clear energy and housing strategy that originated in 2005, despite the large number of Government departments and stakeholders involved.

The overarching conclusion of this project is that there is a desperate need for a clear strategy that brings housing and energy policy together, in the context of climate change commitments. The range of stakeholders, Government departments and present policy initiatives is not delivering the rate of change and focus required by the 60% target. The project has demonstrated that major reductions of carbon dioxide emissions could be achieved by 2050 in the residential sector, but only if tough decisions are taken soon in several policy arenas. These policies will contribute to all four of the Energy White Paper objectives: in addition to the climate change targets, the 40% House scenario reduces fuel poverty, increases security of supply and even improves competitiveness by creating a demand for low and zero carbon technologies that could well be developed in the UK.

Glossary

Absorption chiller A type of chilling plant that uses heat as its energy source, as opposed to electrical energy.

ACE Association for the Conservation of Energy.

Anaerobic digestion A process for making useful fuel gas (methane) by controlled decomposition of organic matter by micro-organisms.

Baseload Electricity from generating plant that runs constantly through the day and night.

Bedroom standard An indication of occupation density: a standard number of bedrooms are allocated to each household according to its composition with respect to age, sex and marital status. See also Overcrowding.

Biomass Anything derived from plant or animal matter (though not fossilised) – including agricultural and forestry wastes or residues and energy crops. Biomass requires processing before use, eg chipping of tree material, drying and pelletising of crops, digestion of food or farm waste to produce methane.

Biomass boiler A device for burning biomass to provide space and water heating to a whole dwelling (or to a collection of end-users via a heat network) on a controlled time and temperature regime, and with continuous fuel supply.

Biomass stove A device for burning biomass to provide direct radiant heat to a single room.

Building Research Establishment (BRE) The BRE is a UK centre of expertise on buildings, construction, energy, environment, fire and risk.

BREDEM Building Research Establishment Domestic Energy Model.

BREHOMES Building Research Establishment Housing Model for Energy Studies.

Carbon In this report carbon is an abbreviation of carbon dioxide. Emissions of carbon dioxide are measured in terms of the weight of carbon emitted. To convert tonnes of carbon (tC) into tonnes of CO_2 (tCO_2), multiply by 3.67.

Carbon dioxide (CO_2) Carbon dioxide contributes approximately 60% of the potential global warming effect of human-made emissions of greenhouse gases worldwide. The burning of fossil fuels releases CO_2 fixed by plants millions of years ago and thus increases its concentration in the atmosphere (DTI 2004a).

Carbon Index (CI) The CI is based on the total annual CO2 emissions associated with space and water heating per square metre of floor area. It is expressed as a number between 0.0 and 10.0 rounded to one decimal place. The Carbon Index (CI) can be used to demonstrate compliance with the relevant standard under the Building Regulations 2002: Approved Document L1 (England and Wales), Technical Standards Part J (Scotland), or Part F (Northern Ireland).

Carbon Storage Long-term storage of CO_2 in the ocean or underground in depleted oil and gas reservoirs, coal seams and saline aquifers. Also referred to as engineered carbon sequestration (DTI 2003a).

Carbon Trust The Carbon Trust is an independent company funded by government to assist the UK move to a low carbon economy by helping business and the public sector reduce emissions and capture the commercial opportunities of low carbon technologies.

Cathode ray tube (CRT) A vacuum tube in which a beam of electrons is produced and focused onto a fluorescent screen. The traditional technology for computer monitors and televisions, CRTs are now being superseded by liquid crystal display screens.

Climate Change Levy (CCL) A levy applied to the energy use of all non-domestic sectors, subject to some exemptions and reductions to encourage energy efficiency (DTI, 2003a).

Climate Change Programme (CCP) The UK contribution to the global response to climate change. It sets out a strategic package of policies and measures across all sectors of the economy.

Centrally-generated electricity Electricity generated in power stations and supplied via the National Grid.

Clear Skies A grant scheme for a number of low- and zero-carbon technologies, open to householders and community groups in England, Wales and Northern Ireland. See http://www.clear-skies.org/

Scottish householders and not-for-profit community organisations can apply for grants from the Scottish Community and Household Renewables Initiative – see http://www.est.co.uk/schri

Combined Cycle Gas Turbine (CCGT) Combined cycle gas turbines use both gas and steam turbine cycles in a single plant to produce electricity with high conversion efficiencies and relatively low emissions.

Combined heat and power (CHP) Combined Heat and Power is the simultaneous generation of usable heat and power (usually electricity) in a single process, thereby discarding less waste heat than conventional generation (DTI, 2003a).

Comfort factor The proportion of an energy efficiency improvement which results in improved comfort or higher levels of service, instead of reduced energy consumption. For improvements to space heating, the comfort factor is typically 30-50%. In lighting it is usually less significant.

Communal establishment An establishment providing managed residential accommodation (2001 Census).

Community heating A community heating system provides heat to more than one building or dwelling from a central plant via a heat network.

Compact fluorescent lamp (CFL) Commonly referred to as low energy light bulbs, CFLs are energy-efficient replacements for 'ordinary' incandescent light bulbs.

Condensing mode The efficiency of a boiler can be improved if it is designed for and operated in 'condensing mode'. In the right conditions, extra energy is retained in the heating system as water condenses (thereby giving up some heat), rather than all being lost in exhaust gases.

Conservation Area An area of special architectural or historic interest, the character or appearance of which it is desirable to preserve or enhance.

Contraction and convergence The science-based, global climate policy framework proposed by the Global Commons Institute. Contraction means all governments agree to be collectively bound by an upper limit to greenhouse gas (GHG) concentration in the atmosphere, subject to periodic review. Convergence means that developed and developing countries converge on the same allocation per inhabitant by an agreed date. It combines the 'global commons' of the atmosphere with the principle of equal rights per person.

Daytime valley A reduction in the national electricity demand profile in between the morning and evening peaks.

Decent Homes Standard Set by the ODPM, the Decent Homes Standard is a minimum standard that all social housing in England should achieve by 2010. A decent home is 'wind and weather tight, warm, and has modern facilities'.

DEFRA UK Department of the Environment, Food and Rural Affairs.

Delivered energy Energy supplied to a customer. Also referred to as 'energy supplied'. See also primary energy and useful energy.

Demolition Any building work which involves demolishing and rebuilding 50% or more of the external walls. Where a façade is retained (eg for heritage/building conservation reasons), this is still a demolition if a substantially new building is built behind the old façade.

Distributed generation Electricity generation plant that is connected directly to distribution networks rather than to the high voltage transmission systems (the National Grid). It includes much renewable generation (eg wind farms) as well as LZC technologies that generate electricity.

District Heating See community heating.

District Chilling Provision of space cooling to more than one building or customer, via chilled water in a network of pipes.

Domestic Energy Efficiency Scheme (DEES) The Northern Ireland equivalent of Warm Front.

Domestic Tradable Quota (DTQ) See Personal Carbon Allowance.

DTI UK Department of Trade and Industry.

Dwelling A dwelling is a self-contained unit of accommodation. Self-containment is where all the rooms (in particular the basic facilities ie kitchen, bathroom and toilet) are behind a door that only the household can use. A dwelling can therefore be a single household or a number of households which share at least one of the basic facilities but do not share living accommodation. In all stock figures, vacant dwellings are included but non-permanent dwellings are generally excluded. For housebuilding statistics, only data on permanent dwellings are collected.

Energy Efficiency Commitment (EEC) The Energy Efficiency Commitment is an obligation placed on all domestic energy suppliers to achieve a specified energy saving target through the installation of energy efficiency measures in homes across Great Britain. At least 50% of the benefits should accrue to vulnerable households. A similar scheme (the Energy Efficiency Levy) operates in Northern Ireland.

Energy Performance of Buildings Directive (EPBD) This European Union directive requires each member state to: establish a methodology for rating the energy performance of buildings; ensure that energy certificiates are issued when a building is built, sold or rented; establish an inspection regime for large energy installations in buildings; ensure that LZC technologies are considered when a new building is being designed.

Energy Efficiency Standards of Performance (EESoP) The precursor of EEC.

Energy-using Products Directive A European Union framework directive to reduce the environmental impacts of energy-using products (except vehicles), paving the way for the development of eco-design requirements on a product-specific basis.

Embedded generation An alternative term for distributed generation.

Emissions factor The carbon emitted as a by-product of generating one kilowatt-hour of energy from a fuel or mix of fuels. Different electricity generators are brought on-line to meet peak demand, so the overall fuel mix typically changes, resulting in different emissions factors at different times of day and at different seasons. Expressed as kilogrammes of carbon (or carbon dioxide) per unit of delivered energy (kgC/kWh or $kgCO_2$/kWh).

Energy centre In a community heating scheme, the energy centre is the building that houses the energy generating plant. This may include boilers or CHP units.

Energy Conservation Authority (ECA) One of the 408 local authorities in Great Britain responsible for reporting on all the housing in their area under the Home Energy Conservation Act. The Housing Executive for Northern Ireland acts as ECA for the whole province.

Energy from waste Electricity, and sometimes heat, generated from municipal waste. Cleaner techniques than incineration include pyrolysis or gasification of waste (see Methane UK report at www.eci.ox.ac.uk).

Energy Saving Trust (EST) The Energy Saving Trust was set up by the UK Government following the 1992 Rio Earth Summit, with the goal of achieving sustainable and efficient use of energy, and cutting carbon dioxide emissions from the residential sector. The EST is a non-profit organisation funded by government and the private sector.

Energy Service Company (ESCo) An organisation that can provide energy supply (both conventional and low and zero carbon) and demand management to enable implementation of the least cost option, taking into account the cost of borrowing.

Foresight The DTI-sponsored Foresight programme produces visions of the future, to guide strategy. Foresight projects aim to identify opportunities from new science and technology, or to consider how future science and technology could address key future challenges for society. http://www.foresight.gov.uk/

Fuel cell A fuel cell produces electricity in a chemical reaction combining hydrogen fuel and oxygen (present in the air). Hydrogen is often extracted from natural gas (CH_4). There are many different designs of fuel cell, each with advantages and disadvantages. In the context of the 40% House report, fuel cells could be used to generate electricity in combined heat and power applications, with better electrical efficiencies (and thus carbon savings) than current designs using a Stirling engine.

Fuel Poverty Of the various contested definitions, the one most often used in policy-making is: A household is in fuel poverty if, in order to maintain a satisfactory heating regime, it would be required to spend more than 10% of its income (including Housing Benefit or Income Support for Mortgage Interest) on all household fuel use.

Geothermal energy Energy from below the surface of the earth. In a small number of locations, the geology allows useful heat to be extracted from deep below the ground.

Government Actuary's Department (GAD) The source of forecasts, studies and reports on UK population.

Greenhouse gas (GHG) A greenhouse gas is one that contributes to global warming. The most significant GHGs are carbon dioxide, methane and nitrous oxide. Water vapour is also a GHG, but the water vapour in the atmosphere is largely beyond human control.

Heat network A system of pipes taking heat, typically in the form of hot water, from a centrally sited energy centre to any number of homes, or other end-users.

Heat pump Heat pumps work like a refrigerator, moving heat from one place to another. To move heat takes energy. Energy can come in the form of electricity (vapour compression) or be thermal energy (absorption heat pumps). Heat pumps can provide space heating, cooling, water heating and sometimes exhaust air heat recovery. A ground-source heat pump typically gives out 3 units of warmth for each unit of electricity used.

Heat recovery A technique for maximising efficiency by making use of heat that would otherwise be wasted (eg in hot exhaust gases).

Home Energy Conservation Act (HECA) HECA requires all Energy Conservation Authorities to report annually on the energy efficiency of the housing stock in their area.

Home Energy Efficiency Scheme (HEES) A grant scheme for low income, fuel-poor households to fund a range of insulation and heating measures. The name HEES is still in use in Wales, but has been superseded in England (Warm Front), Scotland (Warm Deal) and Northern Ireland (Warm Homes).

Homelessness A homeless person is someone who has no accommodation available, or has accommodation which cannot be secured or is moveable.

Household A household comprises one person living alone, or a group of people (not necessarily related) living at the same address who either share at least one meal a day or share living accommodation, that is, a living or sitting room. The occupant(s) of a bedsit who do not share a sitting or living room with anyone else comprise a single household.

Housing Benefit Housing benefit is paid by local authorities to assist with rent payments of tenants who are on state benefits or on low incomes.

Housing Corporation Funds and regulates registered social landlords (RSLs) in England. Other bodies perform similar roles in Northern Ireland, Scotland and Wales. The Corporation is sponsored by the ODPM. http://www.housingcorp.gov.uk/

Housing Health and Safety Rating System (HHSRS) This replaces the Housing Fitness Standard by the autumn of 2005. The central concept is one of hazard, and separate hazards in a dwelling are weighted according to the harm that could result. Excessive cold and high temperatures are classified as potentially hazardous to the elderly (no other age group). For each, the 'ideal' is stated to be a SAP rating of 80-85, with minimum and maximum temperatures of 16.25ºC and 25.25ºC.

Income Support for Mortgage Interest (ISMI) Government assistance for those on low incomes with repayments on mortgages of up to £100,000.

Infiltration Uncontrolled exchange of (cold) outside air for (warm) inside air, leading to unnecessary heat loss. The term 'infiltration' is used to refer to uncontrolled losses: controlled exchange of air, which is necessary for human health and to avoid damage to the building fabric through excess water content, is 'ventilation'.

Kyoto Protocol The Kyoto Protocol binds those industrialised nations that are signatories to reduce emissions of greenhouse gases by an average of 5.2% below 1990 levels by 2008-2012. The UK is legally bound by its Kyoto target to reduce greenhouse gas emissions by 12.5% over that period. Originally signed in 1997, the protocol came into force on 16th February 2005.

Learning and Skills Council (LSC) The Learning and Skills Council is responsible for funding and planning education and training for over-16-year-olds in England and Wales.

Light emitting diode (LED) A semiconductor device that emits visible light when an electric current passes through it. It is highly efficient and long-lived, and has a low power requirement.

Listed Building A building of special architectural or historic interest.

Load factor Usually applied to generating plant, load factor is the ratio of the average electrical load to the theoretical maximum load, expressed as a percentage.

Low or zero carbon (LZC) technologies Low or zero carbon technologies are taken to be renewable energy generators or technologies with better fuel efficiency than conventional technologies, and which are retrofitted to or integral to the building or community. Examples of LZC technologies are community heating with CHP or biomass, combined heat and power (CHP), solar water heaters, ground-source or air-source heat pumps, solar photovoltaics, and wind turbines.

Major photovoltaics demonstration programme A programme funded by the DTI to install photovoltaic systems on domestic and community buildings. Grants of up to half the installation cost were provided.

Market transformation Changing the market for products and services to reduce environmental impact, using a combination of information, incentives and regulation in a coherent strategy.

Market Transformation Programme (MTP) The MTP is a DEFRA initiative that develops policy strategies for improving the resource efficiency of traded goods and services in the UK. MTP uses market projections and policy scenarios to explore alternative future developments.

Micro-CHP CHP at the scale of a single dwelling, and used in place of a domestic central heating boiler.

MtC Million tonnes of carbon (ie carbon dioxide weighed as carbon only).

Municipal Solid Waste (MSW) All rubbish collected by local authorities (or their contractors), including rubbish from homes, schools, colleges and co-collected trade waste.

ODPM UK Office of the Deputy Prime Minister, responsible for policy on housing, planning, devolution, regional and local government and the fire service.

Ofgem Ofgem (Office of Gas and Electricity Markets) is the UK energy regulator, charged with: making gas and electricity markets work effectively regulating monopoly businesses intelligently securing Britain's gas and electricity supplies meeting its increased social and environmental responsibilities. Ofgem oversees the operation of the Energy Efficiency Commitment.

Overcrowding The UK Census of 2001 uses an occupancy rating to give a measure of under-occupancy and overcrowding, based on the 'room standard' of the 1985 Housing Act. This relates the actual number of rooms to the number 'required' by members of the household, based on the relationship between individuals and their ages.

Payback The capital cost of a device can be related to the energy savings it makes in terms of a payback period. If a device costs £120 and saves £20 a year, the simple payback period is six years. Payback should also take account of the cost of borrowing the initial investment.

Permanent dwelling A building whose structure should satisfy at least one of the following criteria: the walls are of brick, stone and mortar, concrete, breeze block or similar material the roof is of ceramic tiles, slate, thatch, shingle or concrete the length of the shortest wall is at least 4.5 metres – it has over 60 years of life span (Housing Statistics 2002)

Personal Carbon Allowance (PCA) Under a system of PCAs, each adult would be given an equal allowance covering carbon emissions generated from fossil fuel energy used within the home and for personal transport, including air travel. Allowances would be tradable, and would decrease over time within a mandatory, UK-wide scheme. The primary aim of the scheme would be to deliver guaranteed levels of carbon savings in successive years in an equitable way.

Photovoltaics (PV) A photovoltaic solar cell converts light directly into electricity. Light striking the front of a solar cell produces a voltage and current – it has no moving parts. A group of interconnected cells creates a solar panel and solar panels, in turn, can be connected in series or parallel to create a solar array and any voltage-current combination required.

Primary energy Primary energy to deliver a given service is the energy converted when a fuel is burned, for instance, to generate electricity. With the current electricity generation system, primary energy is roughly three times delivered energy: for each unit of electricity delivered to the consumer, two units are lost in generation and transmission. See also delivered energy and useful energy.

Pyrolysis The production of gaseous fuels by heating hot materials containing organic matter in the absence of air.

Royal Commission on Environmental Pollution (RCEP) An independent standing body established in 1970 to advise the Queen, the Government, Parliament and the public on environmental issues.

Reformer A device for processing a fuel such as methane (CH_4) into hydrogen (H_2) for use in a fuel cell.

Refurbishment Repairs and alterations to a building that involve a lesser degree of destruction than demolition.

Registered Social Landlord (RSL) Housing associations, trusts and co-operatives registered with the Housing Corporation.

Renewable energy Energy flows that occur naturally and repeatedly in the environment. This includes solar power, wind, wave and tidal power and hydroelectricity. Solid renewable energy sources include energy crops and other biomass; gaseous renewables come from landfill and sewage waste.

Renewables Obligation The obligation placed on electricity suppliers to deliver a stated proportion of their electricity from eligible renewable sources.

Renewables Obligation Certificate (ROC) Eligible renewable generators receive ROCs for each MWh of electricity generated. These certificates can be sold to suppliers. In order to fulfil their obligation, suppliers can present enough certificates to cover the required percentage of their output, or pay a 'buyout' price per MWh for any shortfall. All proceeds from buyout payments are recycled to suppliers in proportion to the number of ROCs they present.

RLA Residential lights and appliances.

Solar thermal/solar hot water A system for using solar radiation to heat water, typically in a roof-mounted panel connected with pipes to a storage tank.

Standard Assessment Procedure (SAP) The SAP is the Government's recommended system for energy rating of dwellings. It is used for calculating the SAP rating, on a scale from 1 to 120, based on the annual energy costs for space and water heating; and for calculating the Carbon Index, on a scale of 0.0 to 10.0, based on the annual CO_2 emissions associated with space and water heating. The SAP rating is used to fulfil requirements of the Building Regulations to notify and display an energy rating in new dwellings, and for monitoring the energy efficiency of the housing stock. Revisions to SAP in 2005 will include a recalibration of the scale from 1-120 to 1-100.

Stirling engine An external combustion engine used for generating electricity. Heat moves a piston inside the device, and the moving piston can be used to power an electrical generator. Early designs of micro-CHP units use Stirling engines, although there is potential to increase the overall efficiency of micro-CHP with new, emerging technologies, such as fuel cells.

Takeback See comfort factor.

Teleworker The UK Labour Force Survey defines teleworkers as people who do some paid or unpaid work in their own home and who use both a telephone and a computer (Hotopp, 2002).

Total Fertility Rate (TFR) Total Fertility Rate is the average number of children a woman would have if she experienced the age-specific fertility rates of a particular cohort for her entire childbearing years. Changes in the number of births are in part due to changes in the population age structure. So the TFR is commonly used to look at fertility because it standardises for the changing age structure of the population (NS 2004f).

Under-occupancy A dwelling is under-occupied when it contains two or more bedrooms above the bedroom standard, calculated in accordance with age/sex/marital status composition and the relationship of the members to each other (Definitions in ODPM 2004d).

United Kingdom Climate Impacts Programme (UKCIP) The UK Climate Impacts Programme publishes scenarios that show how our climate might change and co-ordinates research on adapting to our future climate. UKCIP shares this information, free of charge, with organisations in the commercial and public sectors to help them prepare for the impacts of climate change.

United Kingdom Domestic Carbon Model (UKDCM) A highly disaggregated computer model of the energy and carbon emissions associated with the UK housing stock and the residential sector. The UKDCM was developed as part of the 40% House project, and provides all of the key numbers behind the 40% House scenario, described in the 40% House report.

Useful energy The net energy provided to a dwelling for space or water heating, from a heat source (ie the delivered energy multiplied by the boiler efficiency). See also primary energy and delivered energy.

U-value The U value of a building element (wall, floor, roof, window etc) is an expression of the rate of energy flow (Watts) for a given surface area (m^2) and a given temperature difference between indoors and outdoors, conventionally expressed on the Kelvin scale (K), but practically measured in degrees celsius. U values are measured in W/m^2K. The lower the U-value, the better the thermal insulation.

Vacant dwelling A dwelling is defined as vacant if all the household spaces within it are empty.

Vacuum insulation panel (VIP) A VIP consists of a special panel enclosed in an air-tight envelope, to which a vacuum is applied. This product gives three to seven times as much insulation as the equivalent thickness of materials such as rigid foam boards or foam beads. Panels can be made in almost any size, so that they can be fitted within products. They are currently used in large-scale refrigeration and in container systems, with potential for residential refrigeration and the insulation of solid walls.

Ventilation The controlled exchange of outside air for inside air. Fresh air is necessary for human health and to avoid damage to the building fabric through excess water content, but it needs to be controlled to minimise heat loss. The principle of 'build tight, ventilate right' is important to super-efficient buildings, maintaining adequate fresh air without wasting heat. See infiltration.

Vulnerable A vulnerable household is one in receipt of at least one of the principal means-tested or disability-related benefits (ODPM 2004b). Alternatively, it is an older household, one with children, or one where there is disability or long-term illness (DTI 2002b).

Warm Deal (Scotland) A scheme for the provision of energy efficiency improvements to households in receipt of a range of benefits, administered by EAGA partnership for all housing stock and by local authorities for their own stock (DTI, 2003a).

Warm Front (England) A scheme for the reduction of fuel poverty in vulnerable households by improving energy efficiency. It is aimed at households with children, the over-60s and the disabled or long-term sick (DTI, 2003a). Annual expenditure is approximately £150m (NAO, 2003).

Warm Homes (Northern Ireland) A scheme for the provision of energy efficiency improvements, designed to increase access to energy efficiency advice, including grant availability, among low-income households with young children, particularly single-parent families. It also aims to reduce the incidence of fuel debt within the target group, improve comfort levels and prevent cold-related illness (DTI, 2003a).

Warm Homes Act The Warm Homes and Energy Conservation Act 2000.

W/m^{2}K See U value.

UNITS OF ENERGY

Energy is the ability to do work. In this report, energy is measured in multiples of Watt-hours (Wh). 1 Wh is the amount of energy used by a 1 W device operating for an hour, or a 2 W device operating for half an hour, and so on.

kWh (kilowatt-hour) 1 kWh = 1,000 Wh

MWh (megawatt-hour) 1 MWh = 1,000 kWh = 1,000,000 Wh

GWh (gigawatt-hour) 1 GWh = 1,000 MWh = 1,000,000,000 Wh

TWh (terawatt-hour) 1 TWh = 1,000 GWh = 1,000,000,000,000 Wh

UNITS OF POWER

Power is the rate at which energy is converted. The SI unit of power is the Watt (W).

kW (kilowatt) 1 kW = 1,000 Watts

MW (megawatt) 1 MW = 1,000 kW = 1,000,000 Watts

GW (gigawatt) 1 GW = 1,000 MW = 1,000,000,000 Watts

TW (terawatt) 1 TW = 1,000 GW = 1,000,000,000,000 Watts

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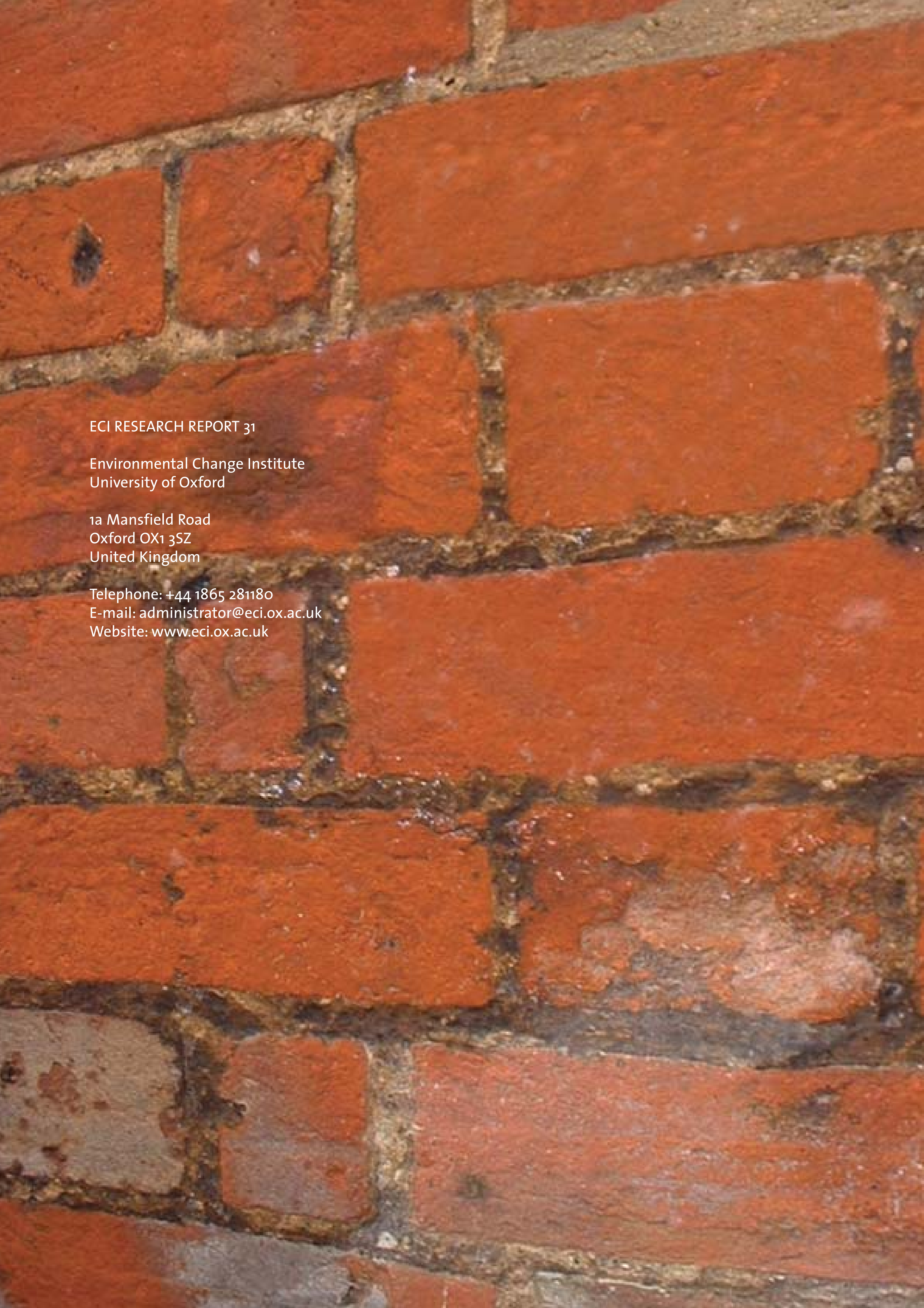

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