Government Office for Science

Foresight

Powering our Lives: Sustainable Energy Management and the Built Environment

FINAL PROJECT REPORT

Powering our Lives: Sustainable Energy Management and the Built Environment

This report is intended for:

Policy makers and a wide range of professionals and researchers whose interests relate to Sustainable Energy Management and the Built Environment. The report focuses on the UK but is also relevant to the interests of other countries.

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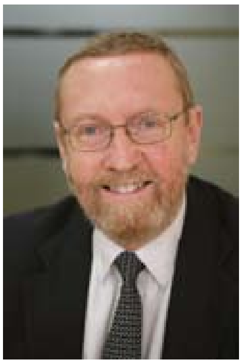
The Government Office for Science (GO-Science) would like to thank the Project's Lead Expert Team who oversaw the technical aspects of the Project, who were involved in much of the work, and who contributed to drafting this final Report. They were led by Yvonne Rydin and are: Patrick Devine-Wright, Chris Goodier, Simon Guy, Lester Hunt, Martin Ince, John Loughhead, Lorna Walker, and Jim Watson.

Particular thanks are due to the Project's High Level Stakeholder Group as well as the many experts and stakeholders who contributed to the work of this Project, who reviewed this Report and the state of science reviews and who generously provided advice and guidance.

The Foresight Programme in the UK Government Office for Science is under the direction of the Chief Scientific Adviser to HM Government. Foresight strengthens strategic policy-making in Government by embedding a futures approach.

Foreword



In 2006, when my predecessor Sir David King commissioned this Report, there was already a pressing need to understand how the UK could shift its systems of energy production and patterns of energy consumption to help mitigate the impacts of future climate change.

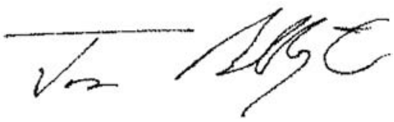
During the life of the project the case for change in our energy systems and the built environment has become stronger than ever. The scientific work of the Intergovernmental Panel on Climate Change has pointed to the need for more radical cuts in emissions and the Government has responded in its Climate Change Bill. Changes in the geo-political environment and the evolving global economic situation have added new energy uncertainties in recent months. The recent peaks in energy prices put fuel poverty on the agenda for very many more households.

There is considerable activity across Government on different aspects of this agenda. The Departments for Communities and Local Government, for Environment Food and Rural Affairs, and Business, Enterprise and Regulatory Reform have all contributed to the project. The new Department of Energy and Climate Change is sharpening the policy focus on decarbonisation, energy efficiency and energy security.

Energy-consuming activities in the built environment account for around half of the UK's carbon emissions. This Foresight Report is distinctive in looking at energy systems and the built environment in the round, in conjunction with the human values and behaviours that shape them. It has brought together evidence and expertise from a very wide range of disciplines – from the physical sciences underpinning energy systems, to economics, construction, sociology and planning – to understand what might drive or inhibit future changes. Sixty evidence review papers have been published and over 200 experts and professionals have contributed to workshops and discussions. I am most grateful to these contributors, to the core team of lead experts, to the group of senior stakeholders who have advised on the scope and direction of the project, and to the leading experts from around the world who have peer-reviewed the work.

A strength of Foresight projects lies in their combination of evidence, expertise, and futures thinking. This project, as well as presenting an evidence-based analysis of the challenges, has created four narrative scenarios of possible future worlds. I hope that these will stimulate policy makers and other communities of interest in thinking creatively about how to increase the pace of change to meet the pressing challenges ahead.

Through the publication of this report I have pleasure in handing over the project findings to Government.



Professor John Beddington CMG, FRS
Chief Scientific Adviser to HM Government, and
Head of the Government Office for Science

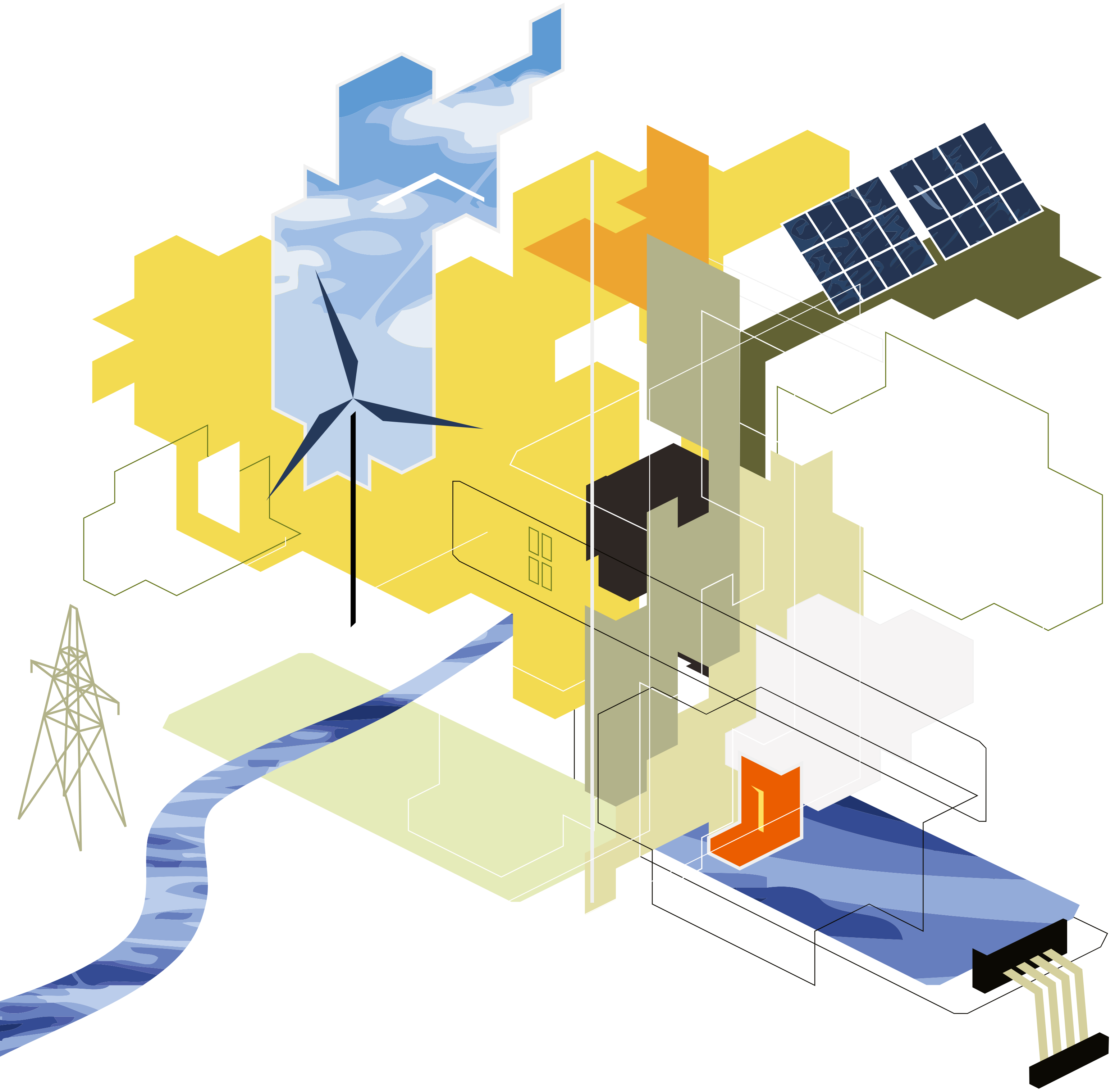
Preface

I am delighted to receive this Report from Professor John Beddington on behalf of the Government. Its findings will have relevance for the work of the Department for Communities and Local Government (CLG) in a number of areas, from building regulations and the planning aspects of new development to the broader arena of renewal and development of sustainable communities.

Reducing carbon emissions from buildings, and ensuring that buildings are adaptable and resilient to climate change, are crucial parts of the Government's programme for tackling climate change and promoting sustainable development. We will need innovative and integrated solutions across building standards, urban design, planning and energy systems. The real value of the Foresight process, reflected in this report, is its ability to draw together the different strands into a set of long term scenarios, to identify uncertainty and risk, and to develop new insights into how the challenges can be met.

Over the next few months, the Government will be responding to the advice of the independent Climate Change Committee on the first three carbon budgets, which take us up to 2022. We are putting in place strategies, including for reducing emissions from both new and existing buildings, to meet those budgets. But we need to be looking long term, beyond 2022, to 2050. The Foresight scenarios set out in this report, the evidence and analysis which support them, and the questions and issues which flow from them, will make an important contribution to thinking on how to meet that long term challenge.

Rt Hon Margaret Beckett, MP
Minister of State for Housing, Communities and Local Government



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ES1 Project aims and approach

The UK is entering a period of energy transition. The main forces driving change are a growing consensus about the scale and importance of climate change, and the need to ensure secure energy supplies for the UK in the face of rising global demand. There is an urgent imperative to re-shape policy in order to decarbonise the energy we use and to secure sustainable supplies for the long term. Achieving these goals will require attention to the relationships between energy systems, the built environment, and the human activities within it, since half of all UK carbon emissions come from energy used in buildings.[1]

The UK Government's Foresight Programme in the Government Office for Science was asked to explore how the UK built environment could evolve to help manage the transition, over the next five decades, to secure sustainable, low-carbon energy systems that meet the needs of society, the requirements of the economy, and the expectations of individuals. Announced by the government in its 2006 Energy Review,[2] the project aims to inform the re-shaping of policy currently underway in government. The project takes a longer term perspective and provides an assessment of the important interconnections between the various policy areas.

An independent look

The analysis in this Report provides an independent look at the challenges ahead and how they might best be addressed. As such, the findings do not constitute Government policy. Rather, they are intended to inform strategic and long term choices facing Government departments, business and society as a whole.

Evidence based futures

Foresight works across departments to analyse major cross cutting issues. Its projects make structured use of scientific and other evidence to inform futures thinking in Government. The 'Sustainable Energy Management and the Built Environment' project has involved over 200 experts and a wide range of stakeholders. It has reviewed the evidence base, and used a variety of futures techniques to examine the important interconnections between key policy areas.

Co-evolution

Project contributors emphasised repeatedly that the issues involved in *Powering our Lives* are not solely technological. A framework of co-evolution is used in this Report to examine interdependencies between social, political, economic and technological aspects of energy use, energy generation and the built environment. These aspects and their interconnections determine how energy systems develop, and shape the demands made on those systems. The concept of co-evolution recognises that technological innovation needs socio-economic viability and appropriate governance arrangements if it is to be successful.

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1 http://www.tyndall.ac.uk/events/past_events/dti_210301_full_report.shtml
2 Department of Trade and Industry (2006)

ES2 The challenges ahead

Three important drivers are shaping energy policies and will strongly influence energy systems and the built environment in the future:

- **Climate change**. The Intergovernmental Panel on Climate Change (IPCC) makes it clear that human activity is changing the world's climate. Deep cuts, by at least a half, in global carbon dioxide and other greenhouse gas emissions are needed by 2050 to avoid some of the most dangerous impacts in the future. Infrastructure systems and society not only need to change in order to mitigate these long-term effects, but will also need to adapt to the inevitable but unpredictable climate-related changes in coming decades.
- **Energy security**. Volatility in oil and gas prices, the end of UK self-sufficiency and the need to replace ageing infrastructure have increased concerns about energy security.
- **Fuel poverty**. Tackling fuel poverty has long been a focus of UK energy policy. A downward trajectory in the number of households in fuel poverty in the early years of this century has been reversed, as energy prices have risen. In 2006 about 3.5 million UK households were affected. This is set to rise again, with an additional 1.2 million households likely to be affected in England alone in 2008.

Decarbonisation

Climate change establishes the overarching need to set a decarbonisation agenda. There are multiple pathways to achieving decarbonisation. They include reducing energy use, increasing energy efficiency, switching to low carbon energy sources and capturing carbon emissions for long term storage. Progress towards decarbonisation is likely to follow a number of paths simultaneously, with differing implications for security and fuel poverty, depending on the combination.

A time for transition

If goals of decarbonisation and sustainability are achieved then a significant transition will have occurred. Today, renewable energy sources amount to less than 2 per cent of primary demand in the UK. The built environment is dependent on centrally supplied electricity largely generated by fossil fuels, and the national gas grid fuels the majority of heating needs, whether water, space or food. A range of different routes to a decarbonised future exist. The actual transition will be shaped by many factors including: technological possibilities and investment decisions; prevailing institutional arrangements; economic conditions and social values; changing policy priorities and regulatory environments; and different spatial strategies and planning regimes.

Although the routes that UK energy systems and the built environment will follow over the next five decades are uncertain, and the ways in which it will contribute to energy security and decarbonisation are unknown, decisions made now will have long term effects. The high costs of providing or adapting the infrastructure of energy systems, combined with low turnover in the built stock, makes taking a long term view particularly important. In the face of a period of uncertain energy transition ahead, there is currently no consensus on how policy should develop to deal with evolving economic and climatic circumstances. There is some agreement that the markets need to be directed or reshaped in some way but there is debate about how far this should be taken and what level of intervention is required.

To help understand the possibilities, and the opportunities or risk they may bring, the project developed a set of long term scenarios.

ES3 Visualising the future

Scenarios

Foresight scenarios are neither predictions nor forecasts, nor comprehensive critiques. They are informed narratives, developed to support a systematic exploration of possible futures with the aim of helping to make current policies robust and resilient to future change.

Four scenarios were developed for the project, to stimulate thinking about alternative ways in which energy systems and the built environment could evolve. They are summarised briefly in Box ES1.1. The full scenarios have been designed to act as a tool for use in strategic policy-making. They are framed by uncertainties in the wider geopolitical environment: will the world be open, interdependent and multi-lateral in outlook or will fragmentation occur, with strongly independent states or regions engaging in bi-lateral approaches? Will the focus of future investments and innovation in the UK favour disruptive new technologies which stimulate new systems, or technologies targeted on exploitation of existing systems?

Different mixes of energy supply and different approaches to developing the built environment emerge in the different scenarios, underpinned by quite different social values and economic circumstances.

Assessing the evidence

The Report combines the scenarios and the expert evidence to analyse four important issues:

- the contribution of energy across the full spectrum of scales – from national to regional and local and through to building-level systems;
- the impact of people's behaviours and social values on energy systems;
- the scope for decarbonisation through renewal and refurbishment of the built environment;
- the links between decarbonisation and future challenges for the resilience and security of energy systems.

Drawing conclusions

The analysis concludes that the key strategic challenges are:

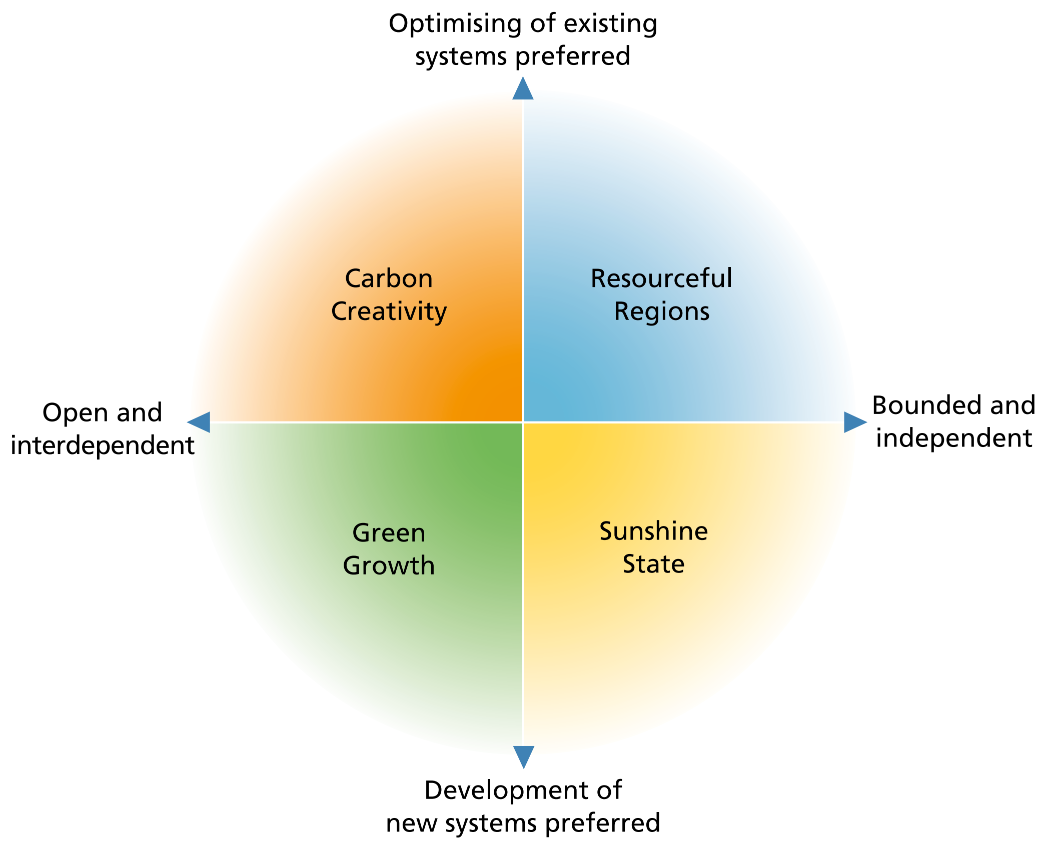
- overcoming the lock-in to current centralised systems;
- enabling greater activity at a wider range of scales;
- exploiting an improved understanding of social and psychological components of energy behaviours to encourage engagement with decarbonisation;
- assessing security and resilience matters in an appropriately integrated way.

It also draws attention to significant implementation challenges:

- upgrading buildings, places, and spaces;
- encouraging innovative development and construction industries;
- building the evidence base and fostering effective policies;
- leading by example across government and the public sector.

Box ES1.1 Scenarios summaries

2x2 axes of project scenarios



Resourceful Regions

This is a world in which political trust has diminished on a world scale, although bilateral trade continues. Most UK energy comes from fossil fuels with innovation being focused on the optimisation of existing systems. These are used more efficiently than in the past, but the focus is more on energy security and the cost of fuel. English sub-regions have a high degree of autonomy, matching Scotland and Wales. In situations of resource scarcity, regional trade in fuel carries considerable leverage. Some regions do deals with overseas countries on energy supplies. Nuclear power still plays a role but many regions have also invested in appropriate renewable technologies. In the built environment, retrofitting rather than new build is the preferred approach. New buildings are increasingly built in a local vernacular style, and there is urban green space to tackle overheating. Living conditions vary widely as regions have their own economic structures and differing levels of economic success. Most regional governments support public transport.

Box ES1.1 Scenarios summaries *(continued)*

Sunshine State

International solidarity has fallen by the wayside in response to climate change and expensive energy. There is an emphasis on localism to respond to energy problems. Energy efficiency measures are universal. Retrofitting is sometimes done alongside adaptation work to help buildings cope with warmer and wetter conditions. Green roofs and parks are common to counter flooding. New build commonly uses off-site construction methods, often from overseas. People are active energy users and know about the energy use of everything they own. Many belong to local 'time banks' (where people use their time, rather than currency, as a form of transaction) or use local currencies. Innovation has led not only to the introduction of novel technologies but also new organisations, ideas and approaches. There has been considerable expansion of renewables including solar energy and biomass..

Green Growth

In this world, fossil fuel depletion and climate change are serious concerns. Novel technologies and systems are regarded as the way to deal with them. Social values emphasise universalism and benevolence. There is an emphasis on decoupling economic growth from carbon emissions and a substantial carbon tax to drive change. By 2050 the building industry reflects these developments and there are now many highly energy-efficient new houses and other buildings and less emphasis on retrofitting old property. People take responsibility for their energy use. Most energy comes from renewable sources including big projects such as the Severn Barrage, offshore wind farms, and solar energy farms in Africa. There is some local renewable energy, including energy-from-waste schemes, partly to offset the inherent instability of electricity supplies transmitted across thousands of kilometres

Carbon Creativity

Decarbonisation is a major theme in this world, prompted by a carbon market in which all goods and services carry a carbon price. There has been considerable investment in Carbon Capture and Storage. Renewables are small in scale and volume and little renewable power is connected to the grid. There has been a boom in carbon consultancy, in which there are EU-recognised qualifications and London is the centre of world carbon trading. Europe also plays a major role in regulating energy markets. Energy costs and regulation have driven substantial retrofitting and renewal of the existing built stock, both domestic and commercial. High-density, mixed-use developments are popular because of their community feel as well as their energy efficiency and proximity to transport nodes. They feature optimisation of existing technology for capturing energy, especially from solar power, and for using it effectively, for example advanced glazing.

ES4 Strategic Challenges

4.1 Overcoming lock-in to enable decarbonisation

The current UK energy systems are characterised by lock-in, with certain technologies remaining dominant despite the existence of others that could meet current and future needs more effectively. This dominance of particular technologies is linked to institutions, regulations and behaviours that reinforce their dominance, strengthening the lock-in effect. The lock-in effect in energy systems is further reinforced by the relatively slow rates of change in the physical structure of the built environment. The UK's built environments today have been laid down over centuries of incremental development.

New construction offers opportunities to incorporate new energy systems and to implement much higher standards of energy efficiency. But 65-70 per cent of the dwelling stock in existence in the 2050s is likely to have been built before 2000. Even in the non-residential sector, much of the 2050 environment will not have been designed or constructed with energy efficiency and decarbonisation standards in mind. Many existing buildings will have to be retrofitted, refurbished or renewed in the decades ahead. Although there are strong path dependencies that constrain change, incremental shifts over decades do reshape the physical fabric of towns, cities and the countryside. Social change can radically alter the use made of the built environment and the demands it places on energy systems.

The challenge is to stimulate a faster pace of change

History shows that lock-in can be overcome but that the pace of change has often been slow.

- If the full range of options for future decarbonisation is to remain available, existing lock-ins need to be disrupted. Investment patterns need to be shifted in a more low carbon direction, both in energy systems and in the built environment. Since it is impossible to predict the precise changes that will be required in the long term, there should be an emphasis on flexibility and reversibility.
- Investment and evaluation frameworks need to move away from short-term economic optimisation towards multi-criteria methods and processes which include a variety of perspectives. These methods can help to reconcile decisions made today with long-term policy goals.

Fostering experimentation and innovation

Policy needs to foster experimentation and innovation, for example through reform of the energy regulatory system, and policy decentralisation. Energy systems and the built environment both need to demonstrate that they are open to change and capable of learning, both from successes and from failures.

- Purposeful and strong action from government is required to overcome lock-in and open up the energy system to experimentation and new ideas.

Innovation in energy networks will be crucial, particularly if energy systems become more decentralised, increasing the complexity of distribution networks. New heat networks might be constructed in urban areas, some of which may also be designed to deliver 'coolth' in hot weather. Networks of carbon dioxide pipelines may be needed to transport carbon dioxide to storage sites. Electricity grids may need to be extended and reinforced to facilitate electric vehicles or an expansion of electric heating.

Even in a future where electricity generation continues to be centralised, growth in the use of variable sources such as wind power will pose challenges for transmission network operation. Policies and regulations will need to do more to promote network innovation.

Exploiting the IT revolution

There is still a long way to go before energy systems and the built environment will have embraced the 'IT revolution'. Smart meters may improve awareness of energy consumption but cannot deliver a full range of services – from time of day pricing to automatic load control – without extensive investment in IT and data management infrastructure.

- Investment in ICT and data management could revolutionise current perceptions of the kinds of energy systems which are considered to be desirable and feasible, especially if coupled with breakthroughs in energy storage technology.

4.2 Exploiting the full range of energy system scales

Beyond centralised energy systems?

Highly centralised energy systems have served the UK well since World War II, delivering economies of scale and enabling the vast majority of people to access modern energy services. Centralised natural gas supplies have brought affordable heating to most UK homes. Yet, looking back over the last 150 years, the UK has experienced different mixes of fuel and different models of energy supply, supporting evolving patterns of economic activity and different lifestyles and working practices. There is no need for the current centralised systems to retain their dominance in future if lock-in is overcome.

The challenges facing UK energy systems in future can be addressed through either centralised or decentralised approaches, or by a combination of these, although there may be tensions in regulating an energy system and market that includes both. For example, market rules, regulations and institutional arrangements conducive to local investment in heat and power facilities may be unsuitable for large, centralised investments in power generation or gas storage

However, targets for large reductions in carbon emissions coupled with other specific goals such as the expansion of renewable energy are likely to require the deployment of energy systems at a range of more decentralised scales - from urban Combined Heat and Power systems to renewable heating systems in households. Moreover, decentralisation can help address fuel poverty, enhance security, and enable communities to play a more active role in addressing climate change. Decentralisation is more than a technological issue – it has important social, regulatory and institutional components.

Reaping the benefits of different scales

Decentralised systems are particularly likely to require innovation and far reaching changes to energy networks in order to reap their potential benefits to the full. In particular there will need to be a much more sophisticated use of ICT and control systems, and appropriate incentive mechanisms, particularly in the electricity system.

If government and other stakeholders want more decentralised energy to help meet policy targets, it will be essential to overcome the current lock-in so that investors readily invest in electricity and heating systems at a variety of scales. Bolting on new regulations and institutions to support them, whilst leaving the 'mainstream' policy and regulatory system intact will not be sufficient.

- The experience of the past two decades during which governments have sought to encourage the contribution of decentralised energy sources shows that a piecemeal approach is unlikely to be enough. The costs of decentralised options can appear to be prohibitive, because economic appraisal techniques do not consider how these options might 'measure up' in a radically different future energy system; the long term costs and risks associated with incremental change to the current centralised system are not assessed for comparison.

4.3 Encouraging engagement with decarbonisation – changing energy behaviours

The complexity of energy behaviours

Substantial changes in human behaviour are implied if decarbonisation is to be achieved and future energy supplies secured. Behaviours associated with energy consumption and energy production are shaped by and arise from social, psychological, economic and political influences, and reflect contemporary social values. The demand for energy in the built environment is a consequence of people's demands for a wide range of energy-consuming services.

- The fact that there is not a single route through the transition to decarbonisation, that different routes require different behaviours that are sometimes in tension, and that people's motivations in respect of energy efficiency and of reduced carbon emissions may well differ, creates a complex environment for the development of policies to effect behaviour change.

Sustained behaviour change requires systematic intervention which recognises this complexity. Key issues for policy makers are the extent to which intervention to increase the pace of change in people's energy behaviours is appropriate or practicable, and how then to design interventions that achieve the desired effects. The complex nature of the challenge is increasingly recognised, as the work done by the Department for the Environment, Food and Rural Affairs in developing models of behaviour and social marketing frameworks illustrates.

Shaping the environment to drive changes in energy use

One approach is to intervene to reshape the environment in which people exercise choices and use energy-based services, in ways that automatically limit the energy consumed or the carbon emitted. Building regulations, and the regulation of energy suppliers, both attempt to create environments in which people use less energy for the same level of service. But unless these interventions are well-designed, users may resist or inadvertently undermine their intended effects. Alternatively, they may deploy savings on additional energy-consuming services, creating what is known as the rebound effect.

Stimulating different forms of engagement

Evidence shows that conceiving behaviour as a problem that must be addressed at the level of individuals or households, for example by correcting supposed deficits in information, is unlikely to be successful. Encouraging more varied and potentially more active forms of engagement with energy systems will be necessary. Such engagement will be diverse and context dependent:

- Feed-in tariffs for electricity and heat might encourage more energy users to become energy suppliers by installing micro-generation.
- Community-level structures could become an important means of creating new forms of engagement in some localities. Local authorities could be enabled and encouraged to collaborate with small businesses or individual citizens in playing a more active role in local energy service provision.
- Consumers might have a different relationship with energy suppliers if suppliers are regulated differently so that they make money by providing services (comfort, warmth and entertainment) rather than units of energy.
- In certain circumstances, individuals might choose more passive roles, for example by consenting to the direct management of domestic appliances such as 'fridges by utilities or network operators, so as to respond dynamically to electricity load shifts and prices. This responsiveness and energy storage could aid the large scale deployment of intermittent renewable energy, such as wind power.
- If ICT makes energy consumption more transparent, the provision of this information could empower individuals to alter energy use behaviours, shifting demand to times of day when prices will be cheaper or when 'greener' forms of energy are available from building, neighbourhood, or urban scale energy systems.

Government needs to stimulate engagement with a more sophisticated understanding of the role of energy and the built environment, leading people either to take conscious decisions to reduce their energy consumption, or to transfer greater responsibility for management of their energy efficiency to innovative multi-utility service companies or community-based organisations. Such a transfer of responsibility will need appropriate regulatory and market incentives from government for the creation of such bodies.

Pricing energy services, pricing carbon?

Changing the relative costs of services linked to their carbon emissions is another potential approach to stimulate changed behaviour. This link to emissions is typically made indirectly, through energy price signals, but could be made more directly through carbon allowances, carbon trading, or even a carbon taxation scheme. People have not yet responded to energy prices and energy efficiency measures at the scale and pace required to meet future emissions targets. Their motivations to do so are likely to be strongly linked to economic circumstance as well as prevailing social norms.

- As a starting point, consideration should be given to a move away from the current tendency to use energy consumption and energy price as a proxy when seeking to influence behaviours that result in carbon emissions.
- The serious pursuit of decarbonisation may require interventions that create a willingness to change behaviours aligned explicitly to carbon, rather than to energy use *per se;* this will require a range of measures including an effective carbon market. However, making carbon visible through high prices would take strong political

leadership. Government should give more attention to communicating clearly about carbon when the reduction of carbon emissions is the primary goal.

Ultimately attention must be paid to carbon, although the process of transitioning to a decarbonised energy system will be helped by behaviour changes that lead to energy savings, whether through direct reductions in consumption or through improved energy efficiencies. However, policies to improve energy efficiency will need to be accompanied by investments in a low carbon energy system based on a different fuel mix, with more renewable and low-carbon fuels, or by a shift to systems and behaviours compatible with a world where carbon capture and storage, or as yet unproven geo-engineering processes, permit the continued use of fossil-fuels with reduced release of carbon emissions.

4.4 Future security and resilience

The overarching concern with decarbonisation has to be addressed in ways that acknowledge future threats to energy supply security, and which strengthen resilience to potential future shocks. Geopolitical threats often dominate the debate but domestic factors such as ageing infrastructure and inflexible distribution networks, civil disruption, or extreme weather events, as well as the potential impact of technological failures, also need attention.

Infrastructure

Electricity networks require substantial investment to replace existing assets and to develop the control and automation systems that will allow systems to be deployed at a more decentralised scale, accommodating potential power flows into networks from a large number of sources.

- The availability of sufficient electricity generation to meet demand may become more significant in future if electricity increases its share within the UK energy system, in the way foreseen by some of this Report's scenarios, and new generation capacity needs to be consistent with the UK's low carbon goals.
- The security of UK gas infrastructure is also essential, given its importance for electricity generation, home heating and industrial processes. In future, the security of heat networks, carbon storage sites, and networks to refuel hydrogen vehicles may also be important.

Strengthening resilience and tackling vulnerabilities

A range of strategies can be used to develop the built environment in ways that improve the resilience of energy systems. These include:

- Designing new buildings for reduced energy consumption;
- Encouraging the implementation of district heating and cooling in and beyond the development site and encouraging landscaping to manage solar gain in buildings;
- Using multiple energy sources and distribution routes to increase the diversity of energy systems, and hence their security through additional supply technologies (e.g. solar hot water), distribution routes (e.g. more interconnections in electricity distribution networks) and infrastructures (e.g. heat networks).

Approaches to strengthening resilience can contribute in various ways to addressing local vulnerabilities to energy insecurity. Vulnerability is unevenly distributed across the UK. There is considerable fuel poverty in major cities but vulnerabilities also exist in rural areas, where the absence of the national gas network can force reliance on more expensive alternatives such as oil, and amongst the elderly. In future, more frequent heat waves could trigger new vulnerabilities amongst those in dwellings that have poor cooling characteristics or who cannot afford cooling systems. Local energy systems have the potential to alleviate some of these vulnerabilities, as does wider consideration of public space and public realm assets that in turn affect indoor temperatures and associated energy demands.

An integrated assessment of resilience

An integrated assessment is required to improve understanding of the future threats to security and challenges to resilience, and of the possible impact of mitigation options within the built environment.

- The overall requirement is a form of integrated resilience assessment and planning, at the level of the neighbourhood, urban area and region, which incorporates energy efficiency and carbon reductions and anticipates the need to adapt to future climate change and to address future vulnerabilities.
- This would extend the work already being undertaken within regions and at the city level on integrated climate change assessment and resilience planning, to consider the positive contribution that diverse and flexible energy systems could make and how the built environment could be managed to accommodate such systems.

ES5 Implementation challenges

5.1 Upgrading buildings, places and spaces

New build

Improving the thermal efficiency of new homes and appliances to reduce total energy consumption and to mitigate fuel poverty effects has been a focus of regulations for some years. Improved building standards were introduced in 2006 and ambitious targets have been set for all new homes to be zero carbon by 2016. Implementation is likely to be challenging.

- Enforcing and monitoring the new regulations will be necessary, to ensure that they are actually delivering energy savings once buildings are in use; such monitoring has been largely absent.

Even if the standards are met consistently in the construction of new buildings, actual, in-use, energy performance may deteriorate. Evidence from existing dwellings shows that occupier behaviours can be a stronger determinant of energy use than building design.[3]

In the commercial sector cooling requirements dominate over heating. While some larger developers and financial institutions are moving towards higher energy efficiency standards, the bulk of new non-domestic construction and development does not match the best energy efficiency standards. Few in the non-domestic development

3 Wright (2008)

industry are geared up to deliver zero-carbon properties and social pressures for sustainable use of energy in the non-domestic sector appear to be having relatively little impact on the building industry as a whole. The sector's conservative approach will be difficult to change unless radical steps are taken to reframe demand and expectations.

Retrofitting existing stock

Although new buildings and new built environments can, when well designed and well executed, make real contributions to decarbonisation, they alone will not deliver the emissions reductions that are needed to meet targets.

The major task is to tackle existing buildings. They will continue to form the largest proportion of the built environment in the future, and yet their current energy and carbon efficiency is extremely poor. Promoting decarbonisation in existing environments and buildings requires a judicious mix of regulation, fiscal measures and proactive area-based planning by local authorities.

Evidence shows that:

- Existing stock is slowly being improved but a step change in the rate of improvement is needed to meet carbon emission targets.
- Technologies are available to retrofit, and there are a number of exemplars from around the world. There are further technological innovations in the pipeline, such as paint-on insulation and new glazing technologies. Continued R&D is important to ensure that innovation makes retrofitting easier, more cost effective, and better aligned to social expectations.
- Effective implementation and use of these technologies will take time, investment and a willingness to act on the part of very large numbers of building owners, managers and occupiers, and the involvement of many small energy and building companies.
- People's motivations to invest in their homes, and companies' motivations to upgrade the buildings in which their organisations operate, are poorly understood, and multi-faceted.
- Even in new build, the deployment of appropriate technologies is only a small part of the picture. The regulatory, financial, inspection and monitoring arrangements that surround the construction industry will be crucial in shaping the built environments of the future.

Bearing in mind future climate change, retrofitted buildings should also be designed to stay cool in hot weather.

A significant increase in incentives for action

There are patchy and insufficient pressures for improved carbon performance in the existing built environment. Tackling the scale and rate of retrofitting will require an integrated approach.

- Better designed incentives are needed to overcome the current imbalance between the perceived benefits of taking action and the monetary and other costs of that action.

- For tenanted property in the domestic and non-domestic stock, attention needs to be given to how the costs of energy efficiency measures should be borne between tenant and landlord and how the financial savings from reduced energy consumption would be distributed. Often the efficiency measures need to be undertaken by the party with the least to gain commercially.
- Premises rented by SMEs may be a particular problem because energy management or improvement is not a priority for them, or for their landlords. There is potential for new contractual arrangements to influence behaviour in these sectors. Green leases together with real-time metering could ensure that the financial benefits of reduced energy consumption are shared between parties, while innovative facilities management contracts might drive behavioural change.
- There are powerful arguments for strong regulatory frameworks which, if effectively implemented, can deliver change within a short timescale. Such frameworks need to be carefully designed to avoid perverse effects.
- To push households and firms into taking action, it will be necessary to signal a strong intent to impose mandatory regulation at a given time in the future, say in 3 to 5 years. In the interim, a package of measures could support and encourage voluntary take-up through provisions such as subsidies, property tax rebates and information services.
- To be effective, these measures will need to feature targeted information, increased subsidies and transparent and salient tax rebates. Linkage of mandatory regulation to a system of annual or biennial performance tests for the built stock akin to the annual MOT test for vehicles could encourage continuous attention to the level of energy efficiency of the building.

Beyond individual buildings – area-based approaches

The problems of dealing with literally millions of people and organisations in retrofitting the existing stock suggests that area-based approaches may offer considerable advantages. The lessons of area-improvement policies from the 1960s and 1970s can be built on to develop area-based retrofitting schemes with energy efficiency in mind. This approach has the potential of dealing with a larger proportion of the stock and overcoming some of the barriers to individual action, by making the benefits of retrofitting visible, reaping economies of scale and building capacity in local retrofitting firms. It also aligns well with the community empowerment agenda.

Local areas and the planning of the built environment are also critical if diversity in the energy systems is to be fostered through decentralisation. Some options are already routinely considered within new development schemes. This has considerable potential to change local areas.

We propose a number of possible area-based initiatives:

- Schemes could be developed for linking new in-fill and adjacent developments to energy improvements to existing stock in the surrounding area. The integration of decentralised energy generation and distributed energy and heating schemes would form part of this process.
- Variants on town centre management could be developed to bring an integrated approach to managing an urban area for improved energy management, alongside greater resilience to climate change and other improvements to the public realm.

- The flexibility of the Local Development Framework could be used to develop innovative development plans which promote and integrate energy efficiency, innovations in energy generation and distribution, greater resilience in energy systems and attention to impacts on vulnerable social groups.
- Existing zoning schemes such as Enterprise Zones and Simplified Planning Zones could be used as a framework for schemes intended to achieve higher energy and carbon efficiency standards. New development in zero carbon zones would be required to achieve zero carbon emissions in use or even zero carbon emissions over the lifecycle of the development.
- Relief from selected taxes might also be available, possibly together with targeted central government funds, on demonstrating achievement of zero carbon targets.
- Support from local planning in terms of carbon assessment, urban design advice and consultation with local communities would be provided but the emphasis needs to be on facilitating innovation in building design and energy systems to meet the zero carbon standards rather than regulating the details of the development proposal.

Whether new or renewed, successful, sustainable future built environments are likely to encompass energy systems at a wider range of scales than today and to place greater emphasis on public realm and community assets. Such environments will require new approaches to governance so that they are appropriately managed.

5.2 Innovative construction and development industries

The lock-in within contemporary energy systems impacts on possible approaches to speeding up innovation. The construction and development sectors, including those responsible for retrofitting as well as new development, are also typified by strong path-dependencies and established routines. To drive change throughout the development and construction sectors will be a major challenge.

Regulation has already made an important contribution in moving the sectors towards a zero-carbon standard, through targets for zero-carbon housebuilding and non-domestic development. But this contribution is limited in scale and is confined to specific market sectors and locations. Furthermore, the achievement of these targets may be slower than desired because it is so dependent on new development being viable.

New business models for development

Current business models in the development sector limit the stake of the developer in the site to the period of construction and subsequent sale and this is a particular barrier to change. In the future, models will be needed that sustain the developer's stake into the operational life of the development.

- The demands of managing complex, localised, energy systems require institutional arrangements for the longer term management of the development.
- Longer term returns from more efficient, or even carbon negative, energy systems which accrue in part to the developer, would create a new set of incentives for developers to innovate both in building form and estate energy systems.

It may even be possible to envisage local communities sharing in both the management and financial returns of such innovative developments provided new institutional arrangements can be created.

- Urgent consideration needs to be given to how such models may be developed in consultation with the property, construction and development sectors.

Demand for high quality skills

The regulatory threshold for energy performance of buildings is being raised in the UK and, whilst the construction sector internationally has demonstrated that it can deliver high energy and carbon standards, it has not yet demonstrated a strong track record in the UK, whether in terms of ambition or of achievements that match specifications in operation. Currently, doubts exist over the capacity of the construction industry to deliver all housing to zero-carbon standards by 2016.

- A step change is needed which is likely to require substantial policy support, including action on new skill requirements as well as consideration of how the property, land and labour markets might be reshaped through fiscal and regulatory measures.
- Voluntary and market-based approaches have not yet achieved high quality, high volume retrofitting. While the SME sector which typically undertakes modifications to buildings is capable of rapid expansion and great flexibility, it has been regarded as generally low-skilled with low productivity and efficiency.
- Capacity and skills in the SME construction sector with regard to retrofitting are limited but market forces are likely to address this shortfall in the medium term.
- Any predictions for demands for future skills over a timescale of 50 years will be highly uncertain. But future demand for construction professionals who are also likely to be IT-literate, multi-skilled and highly-mechanised will remain high. The increasing sophistication in building design and technology may attract young people who are IT-literate and committed to energy and environmental protection.
- The skills challenges are not confined to the construction sector. Managing the range of issues concerning sustainable practices, including carbon-efficient forms of new development, calls for a rapid rate of learning for the planning profession and for local politicians, and suggests the need for increased training, information and support.

Ensuring high quality of construction

There are questions of how skills are put into practice, and how redress for poor quality of installation and maintenance can be provided. To ensure that actual construction, retrofit, and maintenance practice is of a high standard, the means by which redress for poor quality can be obtained needs to be considered.

- Professional and trade accreditation schemes establishing liability for poor quality work would be one such means. Reviewing the current insurance schemes underpinning both new build and refurbishment in the domestic and non-domestic sectors would be another, especially where innovative building forms and localised energy systems are incorporated into schemes.

5.3 Fostering effective policies and building the evidence base

The design and implementation of effective policies to manage the transition to secure sustainable, low-carbon energy systems is currently hampered by a lack of firm knowledge and information. Steps should urgently be taken to remedy this state of affairs:

Improved data gathering

- There is a lack of data on energy consumption and building energy performance, particularly for the non-domestic stock. An observatory on energy and the built environment to produce and hold consistent, comprehensive databases on all the different dimensions of energy use within buildings is needed.
- There needs to be better understanding of what determines energy behaviours:
    - More knowledge is needed about the dynamics of behaviour in both the domestic and non-domestic sectors to understand how energy consumption as modelled for the Building Regulations differs from performance after construction, and from performances once the building is occupied and in use.
    - Such an understanding requires a multi-disciplinary effort. The Research Councils are well-placed to join together and fund multi-disciplinary research to these ends and are already beginning to tackle some of these issues. It will be necessary though to continue to support and even extend such research efforts.
    - It will also be important to ensure that research results are linked to policy development, deployment and evaluation.

Fostering effective policies

There needs to be much greater attention to learning within the policy process to ensure that knowledge of problems of implementation on the ground is fed back into revised policy design.

Evidence shows that some policies are confused, contradictory or ineffective. For example:

- The differential between VAT rates on refurbishment and on new build, which makes refurbishment activity more expensive. Refurbishment could be a central element of improving the overall energy performance of the existing stock.
- In new build, the Building Regulations are an example of a policy that is perceived to be poorly monitored to ensure that the modelled energy savings are actually delivered, and where there is also a lack of resources for enforcement.
- Subsidy schemes for household energy efficiency measures, such as loft insulation, are widely accepted a having a low take-up. The household is often blamed for such outcomes but in fact this reflects a failure of policy design to incorporate an understanding of how such household investment decisions are taken.

A comprehensive review of policies concerning energy and the built environment, which assessed the extent to which they are individually contributing to the overall goal of reduced energy consumption and carbon emissions, would be highly beneficial. Such a review should consider how different policies are interacting, identifying contradictions and tensions. Work to be done within Government to set carbon budgets, and define how they will be met, should provide the foundation for such a review.

5.4 Leading by example

Government must take a lead. The public sector directly occupies buildings across the UK, is a major owner of the domestic and non domestic built stock and is a major client of the development and construction sectors. Changes to public procurement and management practices could make a substantial contribution by providing examples of good practice and by building capacity within critical sectors such as construction and facilities management.

Because of its size and volume, public procurement can drive change along the supply chain so that firms supplying services and equipment develop the capacity to deliver different forms of buildings and building management practices to other clients.

This is an area where some advances are being made, for example, in the 'Building Schools for the Future' initiative. The extension of this approach across the public sector estates will require an innovative strategy on behalf of the many different government departments and agencies that develop and manage public buildings and spaces.

Barriers to innovation

Managers of the government estate have traditionally been risk averse.

- Fear of failure may otherwise inhibit pushing the boundaries of good practice. The practices of bodies that audit government at all levels may need to adjust so that innovative practice – where there has been positive learning from failure – is not penalised.
- Methods of evaluation will need to adjust to take account of this. Providing that mechanisms for monitoring past experience and learning from it are in place, organisations should be allowed to innovate and occasionally fail.

Integrated leadership of the different initiatives is needed across different departments, public bodies and different parts of the government estate to enable learning across organisational boundaries and making implementation effective. Urgent consideration needs to be given to where such leadership responsibility should reside.

In view of the scale of the challenges ahead it will be crucial to go beyond the incremental change that has resulted from policies to date. Strong leadership from Government is needed to deliver real change and to set the agenda for sustained populat engagement with decarbonisation.

1 Introduction

1 Introduction

Chapter 1 explains why the Project was undertaken, and sets out the aims and scope of the Project. In so doing, it explains how it adds value to other technical work in the UK.

The concepts of decarbonisation and co-evolution are introduced. These are key themes which run through the Report. The structure of the Report is set out with a brief description of the subsequent chapters.

1 Introduction

1.0 Background

The UK is entering a period of energy transition. The main forces driving this change are a growing consensus about the scale and importance of climate change, and the need to ensure secure energy supplies for the UK in the face of rising global demand. Higher global oil prices have also led to concerns about fuel poverty and energy equity. These pressures are driving an imperative to re-shape policy in order to decarbonise the energy we use and to secure sustainable supplies for the long term. Both goals will depend on development of low-carbon technologies, the evolution of regulatory frameworks, and the scale and nature of investment. Neither can be achieved without attention to the relationship between energy systems and the built environment since half of all UK carbon emissions come from energy used in buildings.[1]

This Foresight Project explores how the UK built environment could evolve to help manage the transition, over the next five decades, to secure sustainable, low-carbon energy systems that meet the needs of society, the requirements of the economy, and the expectations of individuals.[2] Announced by the government in its 2006 Energy review, [3] the Project aims to inform the re-shaping of policy currently underway in government. Much technical work has already been done by government departments and agencies on standards for new buildings,[4] regulating energy systems,[5] promoting energy efficiency,[6] promoting sustainable construction[7] and developing a low carbon industrial strategy.[8] This Project takes a longer term perspective and provides an assessment of the important interconnections between the various policy areas. It pays particular attention to social as well as technical dimensions and offers important insights for policy makers in two key areas:

- the strategic issues that need to be addressed in future policies for energy systems and the built environment;
- the factors leading to the effective implementation of policies.

This Report does not, however, aim to make a case for change in energy systems and the built environment. The case has been made forcibly by others such as the Stern Review[9] and the UK's Climate Change Committee, and is an accepted starting point for policy.

1 http://www.tyndall.ac.uk/events/past_events/dti_210301_full_report.shtml

2 Whilst recognising that roads, rail and other forms of mobility are a vital part of the built environment, this Report focuses on energy for purposes other than transport. The future of transport was the focus of a previous Foresight project: Intelligent Infrastructure Systems. Project Overview. January 2006. Office of Science and Technology, Department of Trade and Industry.

3 Department of Trade and Industry (2006)

4 E.g. Code for Sustainable Homes (2008)

5 E.g. Ofgem (2008)

6 E.g. HM Government (2008)

7 HM Government (2008)

8 Department for Business, Enterprise and Regulatory Reform (2008c)

9 Stern (2006)

Energy infrastructures and built environments are interdependent (see Box 1.1). The development of built environments depends on energy systems and how they grow and change, while the physical infrastructure of energy systems is part of the built environment.

Box 1.1

What do we mean by the built environment?

The built environment includes all buildings, places and settlements that are created or modified by people. It includes, for example, homes, shops, schools, workplaces, hospitals, parks and recreational areas, and green and blue spaces. The built environment is defined partly by its physical makeup and partly by the ways in which people use it. Both aspects change over time.

What do we mean by energy systems?

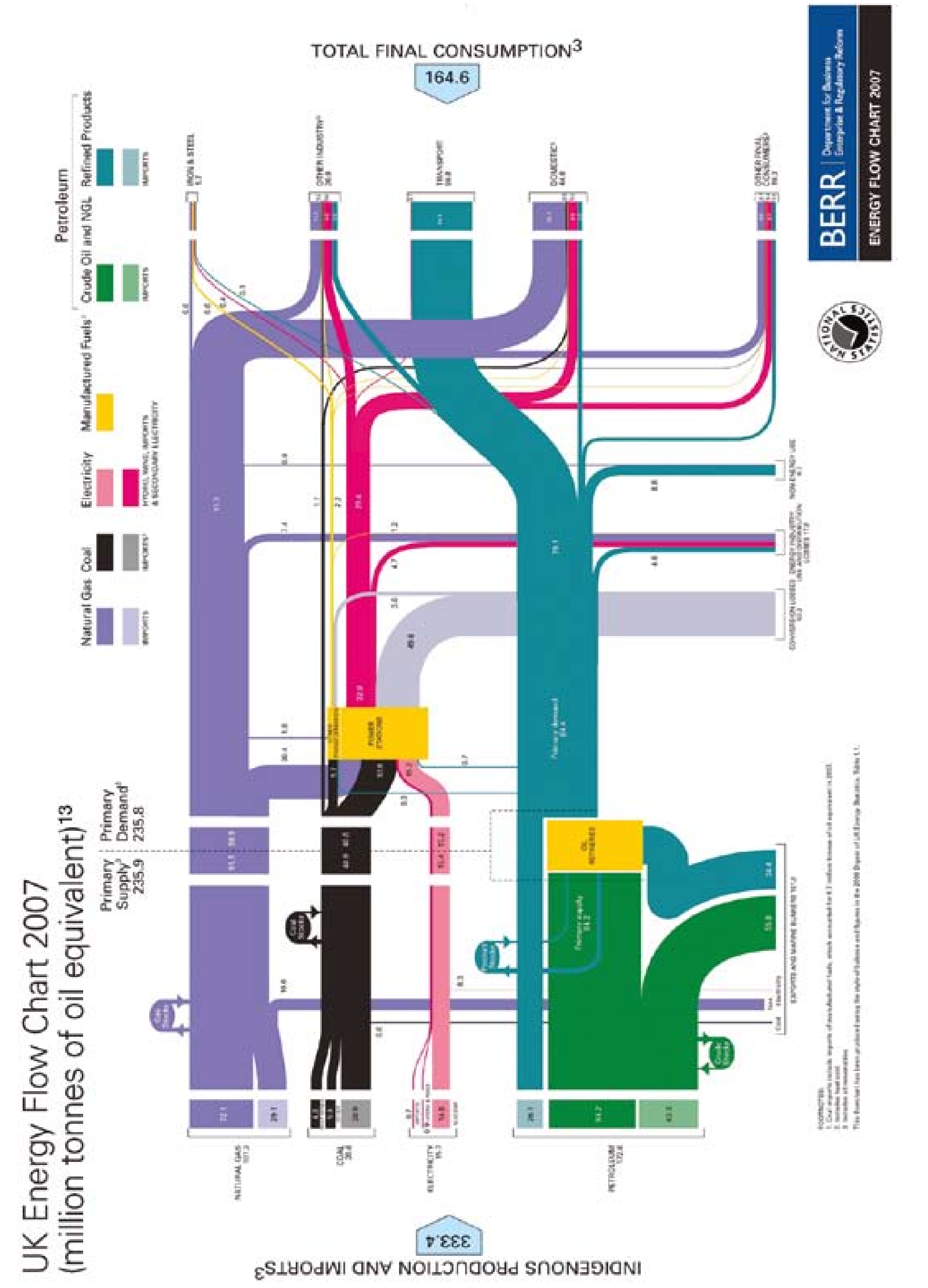
The energy system includes (1)infrastructures (such as buildings) and technologies (fittings, appliances and transportation) that deliver energy services, and (2) infrastructures and technologies (such as oilfields, mines, pipelines, solar collectors and power stations) that produce, process and deliver the fuels and electricity required for energy services. The energy system also includes the markets, policies, and regulations that co-ordinate and govern how the system operates.

Energy systems in the UK currently allow most people to live their daily lives in the built environment without reflecting on the energy needed to support their activities. In fact, activity in the built environment accounts for approximately 50 per cent of energy use[10] (see Figure 1.1 for the full UK energy flow chart). Around 58 per cent of the energy used in the built environment is supplied by gas, mostly to heat space, water and food.[11] Mains electricity to power appliances and information technologies is the other major component. But the systems that supply these two sources of energy have evolved over many decades, and superseded others, to meet the requirements of past and present generations, in homes, workplaces, schools, hospitals and factories that have been built and rebuilt over time. Changes in the social, economic and environmental context of 21st century Britain present major challenges to these systems and to the built environments that depend upon them.

10 Ward (2008)

11 Department for Business, Enterprise and Regulatory Reform (2008b)

Fig 1.1: UK energy flow chart 2007



12 Oil equivalent is the amount of energy released by burning the specific amount of oil. For conversion: http://www.berr.gov.uk/whatwedo/statistics/source/notes/page18916.html

1.1 Drivers of change

While there are many drivers of current and future change in energy systems, climate change, the search for energy security and fuel poverty are by far the most influential.

Climate change is arguably the greatest challenge facing energy systems today. The Intergovernmental Panel on Climate Change (IPCC) makes it clear that human activity is changing the world's climate. Scientific evidence shows that past economic development based on use of fossil fuels has already contributed to a rise in average global temperatures and to other effects. Deep cuts, by at least a half, in global carbon dioxide and other greenhouse gas emissions are needed by 2050 to avoid some of the most dangerous impacts in the future.[13] The Stern Review on the economics of climate change argues that, as climate change effects intensify, there will be rising costs for global and national prosperity, for people's health, and for the natural environment.[14] Acting now to reduce emissions will have costs, but these will be much lower than the costs of doing nothing. Even with reduced emissions in the future the world will still experience climate change for several decades, as a result of previous carbon dioxide and other greenhouse gas emissions and the time-lags in the earth's climate system. Infrastructure systems and society will need to adapt to these inevitable but unpredictable changes as well to mitigate longer term impacts.

The UK has had domestic and international targets to reduce greenhouse gas emissions since the 1990s. Under the international Kyoto Protocol, the UK must reduce emissions by 12.5 per cent between 2008 and 2012 in comparison to 1990 levels. Following the Royal Commission on Environmental Pollution's report in 2000,[15] the 2003 Energy White Paper[16] included a longer-term target, which was reinforced in the 2007 Energy White Paper.[17] This stipulated that steps must be taken to reduce UK carbon emissions to 60 per cent by 2050. The Climate Change Bill, which is expected to receive Royal Assent in November 2008, will put into statute targets to reduce greenhouse gas emissions by at least 80 per cent by 2050. Far reaching changes in our systems of energy production and consumption will be required to achieve these reductions.

Energy security. The 2007 Energy White Paper gives security and climate change equal weight as drivers of policy. Rapid increases in oil and gas prices, heightened awareness of terrorism, geopolitical uncertainties, and the blackouts that affected several electricity networks in the summer of 2003 have all contributed to concerns about energy security. The end of UK self-sufficiency in energy has added to the perception that energy supplies are getting less secure (see Figure 1.2). UK primary fuel production almost trebled between 1970 and 2000, due to increased production of gas and oil. By contrast, consumption remained more stable, increasing by about 10 per cent over that period, reflecting a combination of improved energy efficiency alongside a growth in demand for space heating.

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13 Intergovernmental Panel on Climate Change (2007), G8 Toyako Summit Communique (2008)

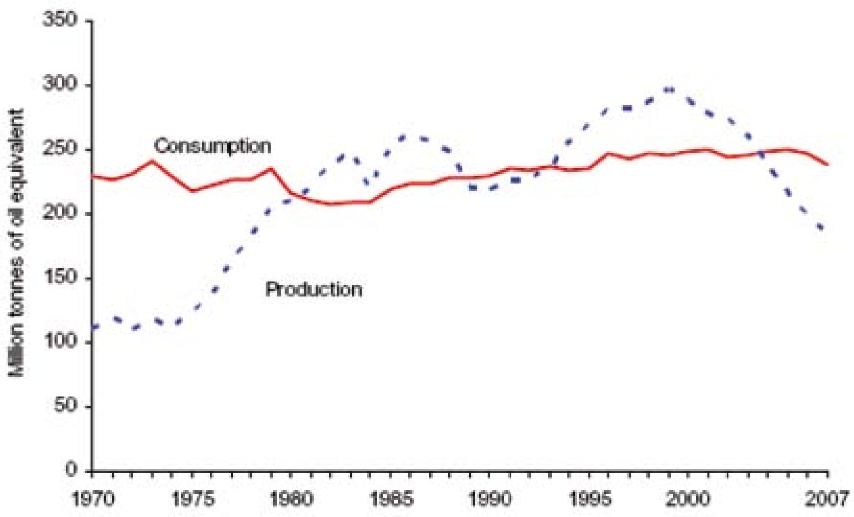
14 Stern (2006)

15 Royal Commission on Environmental Pollution (2000)

16 Department for Business, Enterprise & Regulatory Reform (2003)

17 Department for Business, Enterprise & Regulatory Reform (2007)

Figure 1.2: UK primary fuel production and gross inland consumption of primary fuels 1970 to 2007



Source: Department for Business, Enterprise & Regulatory Reform (2008a)

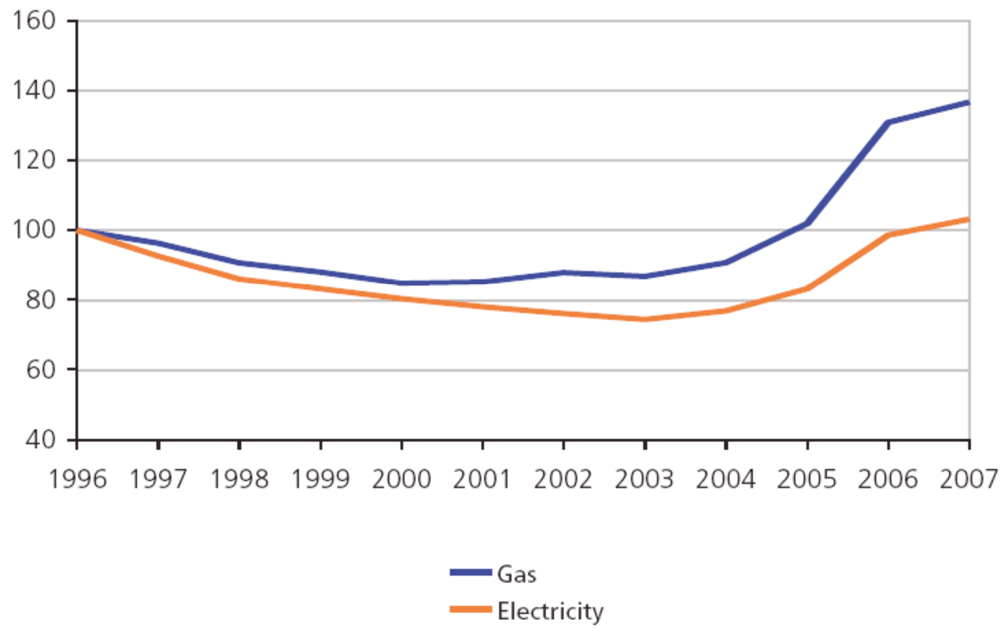
Energy systems in the future will need to be designed to manage their vulnerability to a range of different threats. Some of these threats are emphasised in current government policy, such as the risks associated with importing large quantities of natural gas and the need for investment in new electricity generation capacity as ageing capacity is closed. Whilst the history of the competitive market over the last 20 years or so shows that companies will need to invest in substantial new capacity, climate change targets mean that this capacity will have to use low-carbon technologies, some of which (e.g. carbon capture and storage (CCS)) are as yet unproven at a commercial scale. Future energy systems will also need to be able to cope with the kind of threats that have had the most impact on energy security in the past two decades. These include a lack of investment in gas storage capacity, which has contributed to high prices,[18] and threats due to civil unrest such as the 2001 fuel protests.

'***Fuel poverty***'. Whilst issues relating to energy security are often national and international in focus, the concept has applicability at a much smaller social scale. 'Fuel poverty' has long been a focus of UK energy policy. Households are said to be in fuel poverty if they spend more than 10 per cent of their income on domestic energy.

Since 2003 energy prices have risen by around 50 per cent in real terms[19] and have greatly increased the number of households in fuel poverty. See Figure 1.3. In 2006 there were 3.5 million households in fuel poverty in the UK, and this is projected to rise by 1.2 million in England alone in 2008.[20]

18 Stern (2007)
19 Fuel Poverty Advisory (2008)
20 Fuel Poverty Advisory (2008)

Figure 1.3: Retail prices of gas and electricity. (Real gas and electricity price index, 1996=100)



Source: The UK Fuel Poverty Strategy (2008)

A high proportion of households' energy consumption and expenditure has, to date been associated with heating, with space heating accounting for 58 per cent of households' energy use in 2000.[21] This, coupled with the adverse health impacts of lack of warmth, has created a focus on the relationship between fuel poverty, heating bills, and the thermal efficiency of buildings. Improving thermal efficiency is important, but there are also other factors which may contribute to energy poverty and need addressing. For example, residents in remote rural areas experience particular problems, such as reduced access to gas, making them more reliant on more expensive fuels;[22] and in the future keeping sufficiently cool in rising temperatures may become as critical to health as keeping warm in cold periods.

1.2 Decarbonisation pathways

If the targets for climate change emissions in 2050 are met, UK energy systems will have undergone a process of decarbonisation, i.e. the use of energy will produce significantly less carbon emissions. This decarbonisation of energy systems, and the relationship of that process with the built environment, is a key focus of this Report.

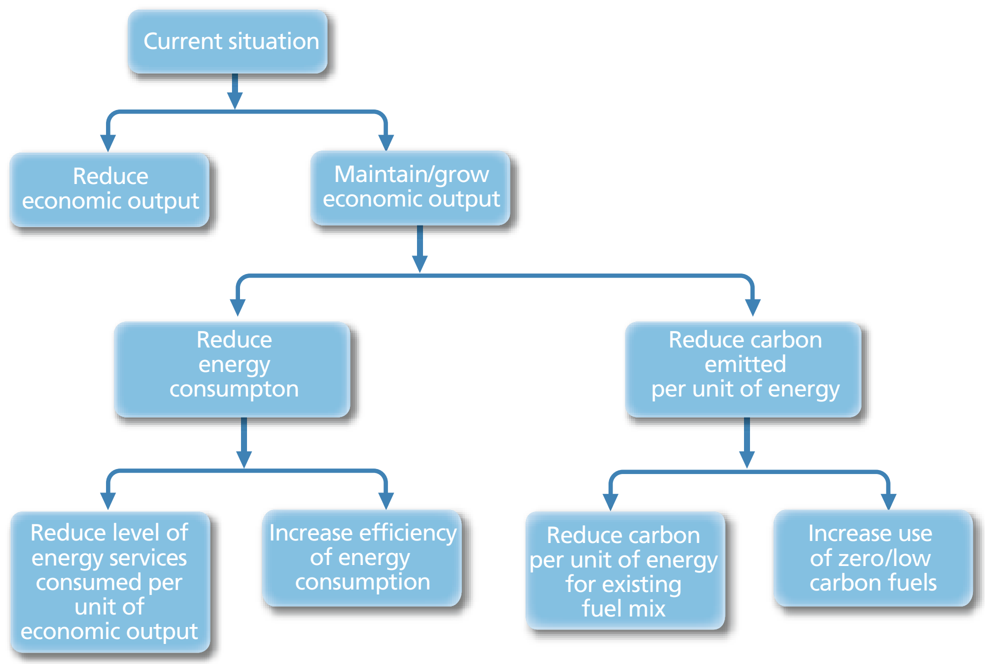
There are a number of possible pathways towards decarbonisation (see Figure 1.4). One theoretical option would be to hold constant the current energy intensity of economic activity, and the associated rate of carbon emissions, and to reduce energy consumption and hence emissions by reducing economic output. Whilst some argue for a reduction in output and consumption as a means to decarbonisation, the implications for economic welfare (as traditionally defined) are not widely seen as compatible with public and political acceptability. Given the longer term perspective of the analysis in this Report it is assumed that, other than in a relatively short-term

21 Department of Trade and Industry (2002)

22 Walker (2008)

recession, a decline in economic output is unlikely to be a significant source of decarbonisation over the medium to longer term.[23]

Figure 1.4: Pathways to decarbonisation



Ruling out a significant reduction in economic output leaves two principal routes to reducing carbon emissions:

- **Reduce the amount of energy used for a given economic output; the lower energy consumption means less carbon is emitted**, i.e. a reduction in energy intensity, or improved energy efficiency. In addition to straightforward energy saving measures such as turning down thermostats, this route includes approaches such as the use of combined heat and power (CHP) systems which make more efficient use of the energy generated (by making use of heat that would otherwise be wasted). Technologies such as advanced electric motors and light-emitting diode (LED) lighting can also contribute to energy efficiency.
- **Find ways of reducing the rate of carbon emitted per unit of energy** so that, for a given amount of energy use, carbon emissions fall. This can be achieved either by use of technologies that capture carbon, or by using sources of energy that have lower or no carbon emissions such as biofuels or solar, nuclear and wind power.

This distinction, described in more detail in Table 1.1, is used here to clarify thinking and simplify the discussion. In practice, these pathways are not mutually exclusive and will often complement each other, although in some cases there could be tensions between them. For example, CCS reduces carbon emissions but also decreases the efficiency of energy generation. Moreover peoples' motivations to engage with

23 Although for some a reduction in GDP would be a (or the main) source to reduce carbon, (see for example, Victor (2008)) this is not considered here. It is therefore assumed that the economy will continue to grow over the longer term although the scenarios considered in Chapter 3 assume different trend rates of growth over the next four or five decades .

different approaches will vary between individuals and organisations, and across time and circumstances. Factors that might provoke, encourage, or provide incentives to consumers to change their energy-related behaviours in line with one or both of these pathways are discussed in Chapter 4. Any energy system that successfully decarbonises in a growing economy is likely to have made progress through multiple routes. The challenge is to achieve decarbonisation while not threatening the goals of ensuring energy security and of reducing impacts on vulnerable social groups. We return to these issues in Chapter 7 and address the strategic choices that may be necessary in Chapter 8.

Table 1.1 Pathways to Decarbonisation	
In a growing economy, consumption of total energy will, in all probability, continue to increase.[24] In order to decarbonise it will be necessary to use less energy per unit of economic output (i.e. reduce energy intensity) and/or to emit less carbon per unit of energy consumed. Each of these two goals can in turn be pursued in two ways.	
1. Reduce energy consumption, holding both economic output and carbon emissions per unit of energy constant. For a given economic output, the lower amount of energy consumed results in less carbon emitted. This can be achieved via two pathways:	**a) A reduction in the level of energy services** holding energy efficiency constant. For example, householders and office users lower their thermostats, or car owners drive fewer miles, reducing the level of services used and hence the amount of energy consumed.
	b) An increase in the efficiency of energy consumption – via more efficient appliances, and capital and housing stock and transmission and distribution systems – means that the level of energy services can remain constant for less energy consumed. Energy consumption falls without a reduction in energy services. Less energy is wasted.

24 Although the strength of correlation between energy use and economic growth is disputed (see Ockwell (2008))

Table 1.1 Pathways to Decarbonisation *(continued)*	
2. Reduce carbon emitted per unit of energy, holding economic output and energy intensity constant. For a given economic output and energy use, carbon emissions fall. Again there are two pathways:	**a) A reduction in the amount of carbon emitted per unit of energy from the existing fuel mix**. This depends primarily upon the development and uptake of technology improvements, for example, Carbon Capture and Storage systems with fossil fuel power stations.[25]
	b) Increase use of zero or low carbon fuels changing the energy mix in favour of zero or lower carbon energies. This might mean an increase in renewable energy (within a centralised, decentralised or hybrid system), or an increase in electricity generated by nuclear power stations.

1.3 Project scope and the Foresight approach

The Project is concerned with the opportunities and challenges for the UK built environment, over the next five decades, to respond to, and shape, changing energy systems. A major theme is to determine how change in the built environment can contribute to decarbonisation and other energy policy goals. The Project is not concerned with the energy system in its own right, nor is it designed to determine specific routes to particular energy or emissions targets.

Throughout the Project we have encountered innovative examples of policies from around the world, in the areas of energy systems, of development of the built environment, and of behaviour change. However there are significant differences between the histories, infrastructures, geographies, and social systems of the UK and other countries which make it difficult to draw parallels or immediate lessons. For example, the UK has relied heavily on its own natural gas in recent years, and gas heating systems prevail in a domestic sector dominated by owner occupiers.In parts of northern Europe e.g. the Netherlands, Germany and Denmark different patterns of property ownership and a greater prevalence of apartment dwellings have contributed to a stronger CHP infrastructure. Elsewhere, e.g. France and Norway electrical heating dominates. These are major systems differences, but even seemingly minor differences in design practice can be significant. For example, windows in European buildings generally open inwards, whilst British ones typically open outwards, constraining the options for shutters and shading to help with cooling. Similarly behaviours in relation to practices such as heating, cooling, and lighting are culturally shaped and vary between countries. For these reasons, whilst the Report points as appropriate to interesting alternatives that operate elsewhere and from which lessons for the future might be developed, the focus is very much on the opportunities and challenges inherent in the UK.

25 Alternative, but related, versions of this pathway could include the purchase of 'carbon offsets' or the use of 'geo-engineering' technologies. The latter is subject to major uncertainties with respect to feasibility and desirability. Neither option reduces the amount of carbon emitted, but they compensate by attempting to reduce emissions elsewhere or to modify the climate impact of emissions

The interaction between energy systems and the built environment is explored over a 50-year period because of the different rates of change visible between them. For example, power stations have lifespans in the order of 50 years, while most buildings typically endure for much longer. Domestic stock is estimated to be replaced at a rate of less than 1 per cent per year and non-domestic at a slightly higher rate of around 1 per cent.[26] However, the rates of change can also vary within the built environment. The refurbishment, as opposed to the replacement, of buildings can change the nature of the built environment more rapidly; so can shifts in the way the built environment is used. Overlaid on the cycles of change in the infrastructure is the turn-over in energy-using appliances within buildings (see Table 1.2). Heating systems and white goods are typically replaced on 10-20 year timeframes, and the lifespans of computing and entertainment systems are shorter still. When periods of change within and between energy systems and the built environment coincide these can create opportunities to move towards decarbonised systems. When changes in different parts of both are out of phase, this can contribute to inertia in progressing energy goals.

Table 1.2: Estimates of lifetime cycles for energy system infrastructure and domestic appliances

Infrastructure/appliance	Lifetime (years)
Hydro station	75
Coal station	45
Nuclear station	30-60
'Fridge & 'fridge-freezer	13-18
Oven	19
Washing machine	12
Domestic heating boilers	10-20

Source: World Business Council for Development (2004).[27] Department of Environment Food and Rural Affairs Market transformation Programme (2008).[28]

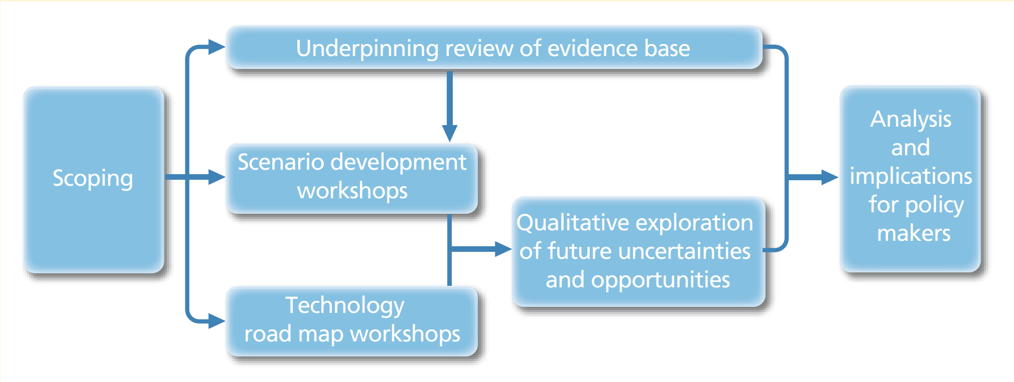
The Project used Foresight's approach to futures thinking (see Box 1.2), including the creation of four narrative scenarios, to explore the nature of possible changes to energy systems and the built environment over the next five decades. Past changes in UK energy systems were also examined to help illuminate possible developments in the future.

26 Royal Institute of British Architects (2006)
27 World Business Council for Development (2004)
28 Department for Environment, Food and Rural Affairs (2008)

Box 1.2 The Foresight approach

Foresight analyses complex issues that cut across government departments, combining robust scientific and other evidence with well-informed futures thinking, to inform and influence policy development in government. This Report is based on analysis of a wide range of evidence which is published alongside the Report at www.foresight.gov.uk. The project process is outlined below.

Project process



Sixty 'state of science' reviews, commissioned either by the Foresight Sustainable Energy Management and the Built Environment (SEMBE) Project or for the smaller 2006 Foresight project on energy, have been published in a special issue of the journal *Energy Policy*.[29]

Eight workshops, bringing together experts, stakeholders, policy makers and professionals, were held during the Project to develop understanding of key drivers of future change and possible technology trajectories, and to shape and test the scenarios. The scenarios developed for the Project are not predictions or forecasts, and do not represent a government view of the future. They are tools which informed the Project's thinking and which allow stakeholders from government and from other organisations to explore and discuss the development of their policies and strategies. A technical report on the futures work is published on the Foresight website www.foresight.gov.uk. During the course of the Project, over 200 experts from business, the third sector, academia and government contributed to develop the evidence and create the scenarios.

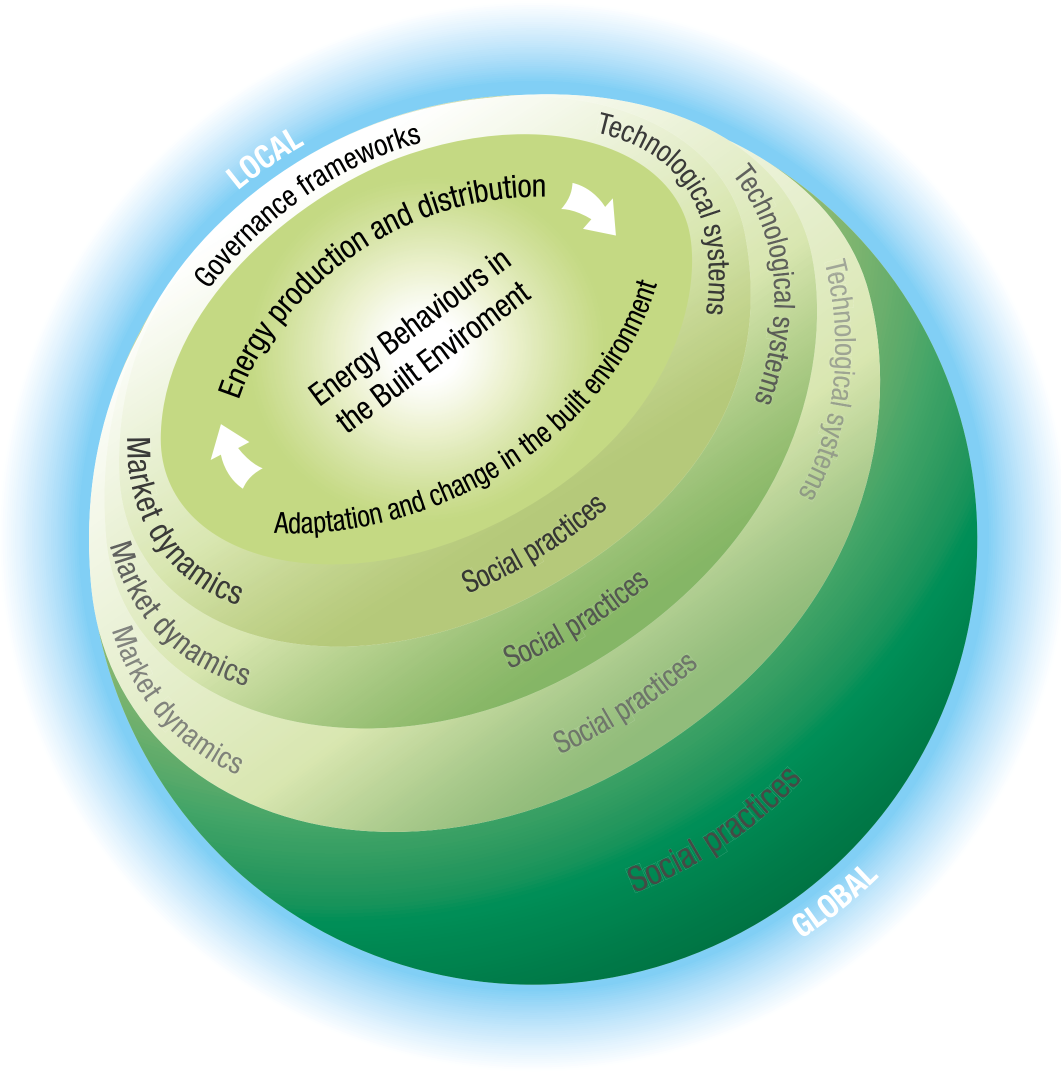
1.4 Co-evolution: the Project's framing concept

Energy use and the development of energy systems cannot be understood merely as a series of changes in technologies and infrastructures. Patterns of energy generation, distribution, and use are the outcome of interactions between technologies, infrastructures, and human behaviour. Energy consumption is the outcome of daily practices such as working, travelling, eating or shopping, with the associated social, economic, geopolitical and environmental consequences. Buildings alone do not consume energy. The role of Government in setting regulatory frameworks is also an important part of the development and use of energy infrastructures and the built environment. Regulation of energy markets, spatial planning systems and codes of building control are just three examples of such frameworks.

29 Energy Policy (2008) **Vol. 36** (12)

The term co-evolution is used in this Report to describe the interdependencies between social, political, economic and technological aspects of energy generation and use.[30] It is these aspects and their connections which determine the development of energy systems, the demands on those energy systems and, eventually, the climate impacts of our energy use (see Figure 1.5). The concept of co-evolution recognises that technological innovation must address both the social and the economic expectations of its intended users, and requires appropriate governance arrangements. A framework of co-evolution also acknowledges that carbon reduction cannot be separated from the processes of energy production and consumption, which in turn are affected by developments in infrastructure and in built environments.

Figure 1.5: A framework of co-evolution



Adopting such a co-evolution framework is necessary because it reflects the complex interconnections that actually shape energy use in the built environment. But there are also distinct benefits that come from framing the problem in this way. First, it enables an understanding of why some policies fail to achieve their objectives, identifying failures in the overly simple and one-sided view of the problem. Secondly, understanding the complex inter–relationships involved in energy systems and the built environment

30 For background and discussion of the co-evolutionary perspective on sustainable built environments see: Brand, R (2005) *Synchronizing Science and Technology with Human Behaviour*, Earthscan.

points to reasons why barriers to change – that we will term 'lock-in' and path dependencies – so often dominate over the drivers for change. Thirdly, the framework allows policies to be conceived that tackle the multiple dimensions of a problem. Finally, an understanding of the depth of inertia in a situation can help identify the scale of change that is needed and the level of action that is required to prompt that change.

Box 1.3: Co-evolution – some examples from history

The ways in which people live and work today have been shaped by the energy systems that sustain society. Innovation in these energy systems has been influenced at least in part by the development of societal norms, values and practices as well as from developments in science and technology. An historical perspective on the co-evolution of energy systems and societies illustrates the interaction between infrastructure development and lifestyles. For example, the innovation of central heating in buildings is often cited as an illustration of the importance of Roman civilisation. This innovation was likely to have been stimulated and promoted by developing expectations and desires for comfort coupled with a reduction in relative costs and an increase in incomes. What began as a luxury for the elite in Rome soon became an expectation for Roman civilisation as far north as Hadrian's Wall. The relationship between innovative energy solutions and the benefits of increased comfort relative to costs continues today. Underfloor heating, now electric, is desirable in the idealised domestic bathroom depicted in lifestyle magazines around the globe.

The history of lighting offers another example. Changes in the energy used for lighting, from animal fat through oil and gas to electricity, have been driven by a search for enhanced intensity, clarity and efficiency, hand in hand with the emergence of ever more imaginative uses, accompanied by reductions in costs. The UK norm of well-lit domestic and public spaces, irrespective of natural daylight, has grown out of changing ideas of accessibility, safety, beauty, convenience and status. In the home, we have moved in less than a century from kitchens which were unlikely to have more than a single domestic light fitting to ones which have multiple sources of light for ambience, accent and different tasks. In the future, more stringent Building Regulations are likely to contribute to further change in our expectations of lighting.

1.5 Structure of the Report

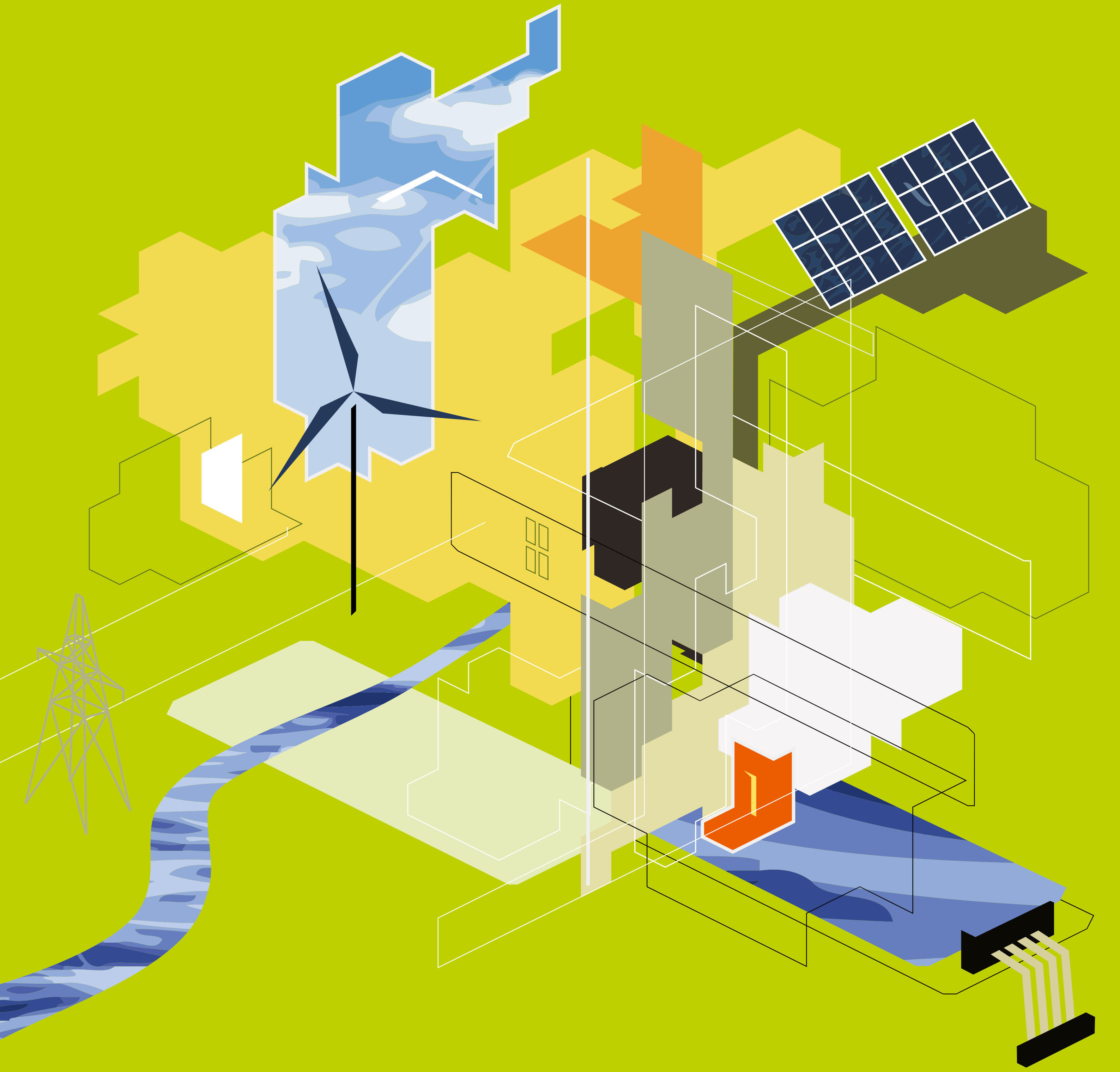
This introductory chapter has explained the Report's aims and sets out the key factors that are driving the UK into a significant period of energy transition. As we move into a period where decarbonisation of the UK's energy system must gather pace, the Report argues that it will be crucial to make the most of the potential offered by the built environment to help achieve this goal. Historic periods of energy transition, and how the ensuing changes in energy systems and in the built environment in the modern UK throw light on future uncertainties are explored in Chapter 2.

A structured exploration of future uncertainties is central to Foresight's approach. Chapter 3 describes four future scenarios which are framed by uncertainties in the wider geopolitical environment and by the scale and nature of future investments. They reflect different emphases amongst the pathways to decarbonisation, and differing dominant social norms and values. The concept of co-evolution helps to frame the analysis of issues of four key areas identified in the scenarios:

- **Human behaviours** (social, economic, political, technological) (Chapter 4) are at the heart of the co-evolution framework and decarbonisation will necessitate changes in behaviour. Discussion of energy systems and of the built environment often overlooks or underplays the importance of social dimensions, or focuses too heavily on information deficit models of behaviour. The determinants of energy behaviour and the wide range of behaviours which influence energy systems and carbon emissions are discussed, as are intervention strategies designed to alter behaviour.
- **The different scales at which energy systems operate** (Chapter 5) – from the international through to local, community and individual levels – are closely linked to the potential of the built environment to contribute to energy goals, and to the social and governance arrangements that support or hinder take up of various technologies.
- **The renewal of the built environment** (Chapter 6) may drive, or be driven by technological, behavioural and wider social change. Renewal encompasses the development of new built environments, the infilling and alteration of existing environments, and the refurbishment of existing stock.
- **Security and resilience of energy systems and the built environment** (Chapter 7) encompass a wider range of factors than typically discussed. The co-evolution framework leads us to consider not only resilience to large scale system risks and security of input supplies, but also the system's capacity to offer equity, to adapt to changing environmental conditions, and to accommodate diversity in supply and demand.

The Project's conclusions are drawn together in Chapter 8.

2 Transitions in energy systems and the built environment



2 Transitions in energy systems and the built environment

2 Transitions in energy systems and the built environment

2.0. Introduction

The need to mitigate and adapt to climate change is a huge imperative which is likely to disrupt current assumptions about energy and its place within the built environment. This chapter provides an historical perspective on how social, political and economic factors shape energy production and consumption in the built environment, and change in the built environment itself. Change over many centuries has encompassed physical changes in infrastructure systems, built structures and spatial patterns, and also changes in the way that they are used.

Over 50 years, which is the time horizon of this Project, energy systems and the built environment can both alter fundamentally. Past transitions in the UK reinforce the point that apparently stable systems can change relatively quickly as technological, political, social and economic contexts alter. There is extensive evidence that major changes in technologies, institutions and policy approaches are indeed possible over timescales as short as a few decades.[1] For example, a critical feature of the modern UK energy system – a high level of centralisation – has not always been as dominant as it is today.

However, there is also evidence that current energy systems are characterised by a phenomenon known as lock-in, a term which explains why some technologies remain dominant despite the existence of other technologies that could perform the same function more effectively.[2] (See Box 2.1). Lock-in can be particularly strong because the dominance of particular energy technologies occurs alongside institutions, regulations and behaviours that reinforce this dominance. It is not the technology itself that generates lock-in but rather the congruence of social, economic and political factors that create the presumption against change.

At the same time, the built environment is also characterised by relatively slow rates of change in physical structures. And, as we shall argue, there are strong path dependencies in the sectors that influence how the built environment changes, with organisations tending to move along established paths and reinforce currently-accepted ways of doing things. Taken together with lock-in, this might lead to the presumption that it will be difficult to shift away from business-as-usual scenarios, even over the next 50 years. However, incremental change over long periods of time can reshape the physical fabric of towns, cities and the countryside. In addition, the life within that physical fabric has the potential – not consistently realised – to radically alter the way that the built environment is used. An urban area may look relatively unchanged over the years but this cloaks the different living and working practices occurring within it.

Transitions in the UK energy system and built environment that have occurred in the past are the result of conflicting pressures to resist and promote physical change in infrastructures and built fabric, and continuing shifts in how these features are used.

1 Freeman and Louca (2001), Geels (2004)

2 Arthur (1989)

Box 2.1 What is 'lock-in'?

'Lock-in' is a concept that is now in increasingly common usage in public policy discussions. Some of the earliest uses of the term were to explain why some technologies have become dominant despite the existence of other technologies that could perform the same function more effectively.[3] Notable case studies of this phenomenon focused on the QWERTY computer keyboard[4] and the VHS format for videos. In each case, economies of scale and standardisation meant that it became increasingly difficult for alternative technologies, such as the Betamax video, to survive.

More recently, lock-in has been used to explain why broader characteristics of technological systems are difficult to change. The carbon- intensive energy systems that underpin many advanced economies have been a particular focus of debate.[5] Research shows that because these systems have met the requirements of society in the past (e.g. the desire for cheap, plentiful energy) it is hard to change them quickly once these requirements change (e.g. the desire to reduce environmental impacts). The research also notes that lock-in is not just a technical phenomenon. It is exacerbated by rules, regulations, social arrangements and institutions that are part of prevailing technological systems.

Examples of lock-in in contemporary energy policy debates include the difficulty of switching road transport away from oil. This is not only because switching might mean an alternative to the internal combustion engine – it would also mean changes in supporting infrastructures (e.g. refineries, petrol stations) and the rules that govern the use of oil based fuels (e.g. fuel and safety standards). This multi-dimensional lock-in presents significant challenges for any ambition to make a transition towards electric vehicles for example.[6]

2.1. The development of the current energy system within the changing built environment

Analysing an evolving energy system within the context of the built environment is complex. In this chapter, the UK energy system is therefore considered in terms of four successive periods characterised by:

- distinctive technological and institutional features;
- contrasting approaches to economics;
- competing policy priorities;
- spatial strategies.[7]

The nature of the built environment is also considered within this framework.

3 Arthur (1989)
4 David (1985)
5 Unruh (2000)
6 Department for Transport (2007)
7 e.g. Surrey (1996), Helm (2007), Mitchell (2007)

The four periods are:

- the period of fragmented development in the energy system to 1945, termed '**Localisation**';
- the period of energy network expansion through public ownership and centralisation from 1945 to the early 1980s, termed '**Nationalisation**';
- the period of energy market reforms through privatisation and liberalisation from the 1980s to the early 2000s, termed '**Marketisation**';
- the period since the **turn of the millennium**.

2.1.1 Localisation: developments to 1945

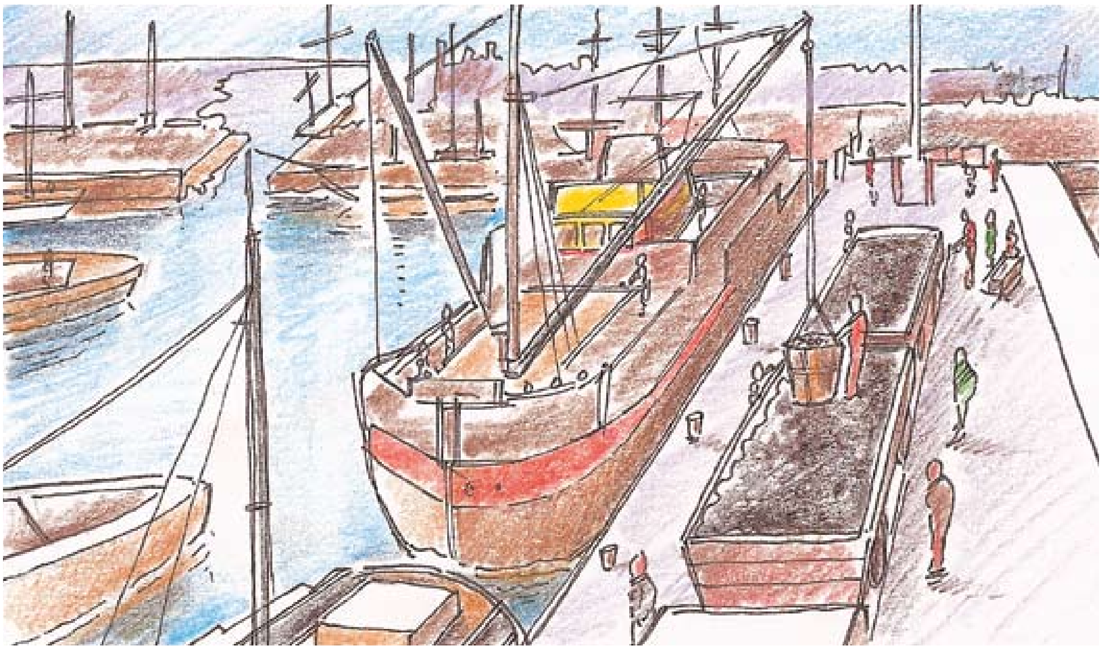
The Industrial Revolution engendered a wholesale shift in UK energy demand away from traditional wood fuel towards the plentiful supply of fossil fuel.[8] Energy sources and energy carriers that are important today, played only marginal roles in the UK energy mix in the early 20th Century. The location of fossil fuel sources was central in determining where much of the urban expansion of the early 19th century occurred. However, rapid urbanisation from the mid-nineteenth century onwards was facilitated by new technical networks, initially delivering water and gas and removing waste, but followed later by electricity, transit systems and the telephone.[9] This bundle of support services encouraged urban growth and helped overcome social, economic and environmental constraints leading to the formation of dense urban-industrial agglomerations.

The rapid urbanisation of this period was largely unregulated and characterised by major public health and environmental pollution problems. These were a major spur to the passage of legislation for the clearance and rebuilding of poor quality housing areas, investment in water supply and treatment infrastructure and the creation of pollution control measures. In effect, by the end of the 19th century, the period of completely unregulated urban development was over. This was consolidated in the period around the end of the First World War, when there was a concerted set of policies to provide 'Homes Fit for Heroes' for the returning soldiers with a drive to raise the quality and environmental standards of housing.[10]

8 Pearson and Fouquet (1998)

9 Guy et al. (1997)

10 Swenarton (1981)



Dock of the bay localisation period

In the early 20th century, the gas and electricity systems were small and localised.[11] Oil use was also comparatively low. In 1900 there were only 8,000 cars in the UK.[12] Gas manufactured from coal was well-established, but was used mainly for lighting in streets, factories and public buildings. This had an impact on how urban areas were used. The growth of street lighting during the late 19th century had facilitated the use of built-up areas, allowing social use of the streets for more of the day. However, gas was not in widespread use in homes. Whilst some households had adopted gas lighting,[13] heating and hot water needs were usually met by burning coal. Electricity was comparatively new.[14] But as electric lighting was relatively more expensive than gas lighting, there was no economic incentive for investment in this new source of power. Early customers included industrial facilities and leisure venues of the wealthy, such as the Royal Opera House. It was the first of these groups of customers that began to change the economics of electricity. Larger electrical generators and grids to distribute power from them were only developed once industrial demand began to grow. This delivered economies of scale and falling costs which could then benefit other groups of consumers such as households. 'Electric Homes' soon emerged, with extensive wiring, numerous sockets, lighting, and refrigerators and so on. The advent of the competition from electricity provided an incentive for gas companies to diversify from their early focus on street lighting to new domestic gas appliances, including cookers and refrigerators.[15] This had a major impact on how people used their homes with the emergence of new practices in heating, lighting, cleaning, cooking and washing.

11 Hughes (1983)
12 http:// www.museumoflondon.org.uk/English/Collections/OnlineResources/X20L/Themes/1/1101/
13 National Grid (2005)
14 Hughes (1983)
15 Hughes (1983)

Energy systems in this period were fragmented, each developing its own distinctive standards, technologies, degrees of municipal support, regulation and tariffs.[16] The result was a complex 'utility patchwork' based upon separate 'islands' of gas, electricity, water and phone networks, which could often not be interconnected because of their technical differences. Furthermore, regulations did not require companies to provide universal services nor oblige consumers to purchase electricity from licensed providers. If developers, for example, of a new tram system, did not like the terms offered by local electricity companies, they would often construct their own system with dedicated generators and transmission lines.[17] However, the municipal ownership of some energy companies by local authorities allowed domestic and commercial urban development to be planned alongside investment in energy infrastructure and this was a minor feature of early 20th century urban change.

From the 1920s onwards, the growing need for load management and the economies of scale offered by advances in steam turbine technology began to feed through to a move to expansion, centralisation and standardisation of the electricity supply.[18] In the UK, the national grid began to emerge from a patchwork of local companies and networks, signalled by the creation of regional electricity networks in 1926. However, it was still difficult for governments to take control of the new electricity systems and plan their development in the 'national interest'. There was a long-running battle between central government, private developers and municipal councils over control and jurisdiction.

This occurred against the background of substantial suburban expansion in the interwar period, particularly in the Midlands and the South of England. Housebuilding in this period was supported by the growth of building societies, providing finance for home ownership and starting the long shift from majority renting to majority owner-occupation within the housing sector.[19] The pattern of housebuilding out along roads and railways into the countryside required spatial expansion of the infrastructure networks, particularly for gas and electricity.

The industrial development of the period was also heavily dependent on electricity supply for production processes. This initiated the long-term shift in the centre of gravity for industry away from the north of the country. The start of the long phase of growth in transport, both private, road-based travel and public transport also began during this period. Important energy users in their own right, these transport modes also spurred further urban expansion and rendered industry more mobile in terms of its possible locations.[20] These developments set the scene for growing expectations in terms of living standards and mobility, which began to shape the built environment as architects, planners and engineers strived to meet new modernist ideals of cleanliness, comfort and convenience.

2.1.2 Nationalisation: end of the Second World War until the early 1980s

The post-war era saw the increasing entrenchment of national energy systems to address the problems caused by the fragmented, unreliable, and uneven supply of energy services. Electricity supply in the UK was nationalised in 1947 after World War Two, largely as a political programme to maintain the coal industry and support

16 Dimcock (1933)
17 Patterson (1999)
18 Hughes (1989)
19 Boddy (1980)
20 Hall (2002)

manufacturing industry. Nationalisation imposed universal technical standards across the UK, marking the end of the protracted battle between local authorities and national government.[21] Similarly, nationalisation of the gas industry a year later amalgamated over 1000 companies into 12 regional gas boards.[22]

These shifts led to the emergence of more homogeneous, standardised energy networks, integrating regional economies and urban systems into more functional wholes. The merging of diverse utility fragments into single national networks provided the framework for the massive urbanisation of the period and the elaboration of modern metropolitan economic and social life. Such energy infrastructure, although now taken largely for granted, made possible 'the existence of the modern city and the means for its continued operation',[23] through a continuous flow of energy. The modern conveniences available only to wealthy home-owners before the war became a more common experience with, for example, ownership of televisions jumping from 0.25 per cent in 1945 to 85 per cent in 1965, and of refrigerators from 2 per cent to 46 per cent over the same period.[24]

Edge of town nationalisation period

Wider environmental concerns began to become more significant in this era. Smog due to the use of coal in urban areas became increasingly severe. The infamous smog of 1952 that caused several thousand deaths in London led to action in the form of the 1956 Clean Air Act. This introduced special zones in towns and cities where only 'smokeless' fuel could be burned. In addition, some factories and power plants were moved from urban centres.

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21 Patterson (1999)

22 National Grid (2005)

23 Tarr and Dupey (1988)

24 www.makingthemodernworld.org.uk

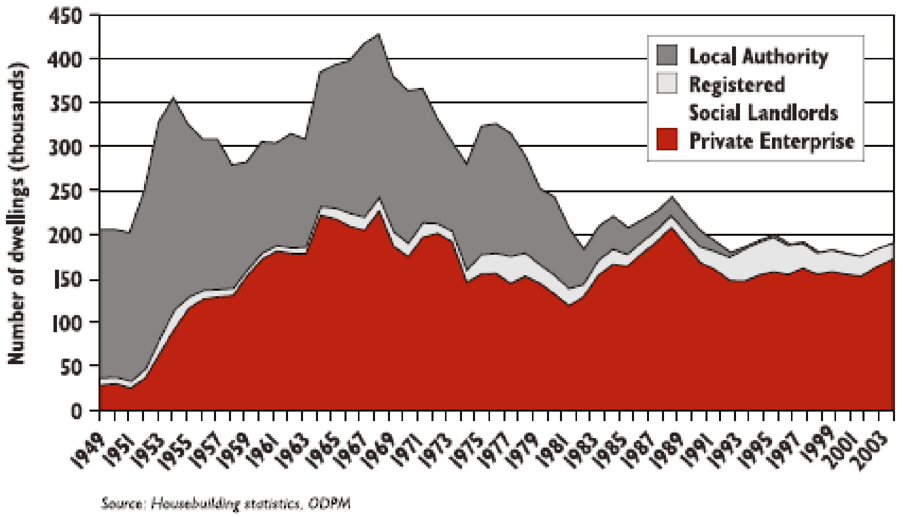
Continuing innovation and progressively larger power plants helped to meet growth in demand, which grew 17-fold in the 20 years after World War II.[25] As plants were made larger, the cost per unit of capacity fell,[26] so that investment in the energy network focused on developing the quality and quantity of energy provision to guarantee the standards of supply needed to support urbanisation and regional economic equalisation. Critical to this was a diversification away from coal, both for electricity generation and more widely. The UK's first civil nuclear power plant opened in Calder Hall in 1956 and the use of oil and gas increased rapidly, a trend that was reinforced by the discovery of oil and gas in the North Sea in the 1960s.[27] The availability of domestic natural gas led to a decision to convert the UK gas infrastructure away from coal-derived gas, leading to a rapid national programme to modify household appliances such as ovens. The continuing shift within industry away from coal towards other energy sources contributed to the improvement in air quality after 1956.

The emphasis on a centralised planning approach during this period also affected the built environment.[28] In 1947 the Town and Country Planning Act was passed introducing comprehensive planning for all urban areas and control of all new urban development. During the years up to 1979 (and the advent of the Conservative government under Margaret Thatcher), the planning system evolved and became an embedded part of local government activity. Development plans took different guises (structure plans, local plans, action area plans, etc.) but all represented an attempt to provide coordinated guidance to where development of different types should take place and how settlement patterns should grow and change. There was considerable greenfield development, which included several phases of New Town development across the country, where a New Town Development Corporation managed land acquisition and development of whole new settlements according to a Master Plan. There were also substantial programmes of council housebuilding, sometimes accompanied by demolition of older properties.

However, at times, the planning system struggled to cope with the amount of new development that was occurring in all sectors: housebuilding, commercial, retail and industrial. Housebuilding went through a long post-war boom from just over 200,000 completions per annum in 1949 to a peak of about 425,000 per annum in 1968.[29] See Figure 2.1. Speculative housebuilding for the owner-occupied market was a considerable proportion of this total, reflecting population growth and rising real incomes during this period. A less positive consequence of this focus on housing supply was little consideration of energy demand-side management, with building stock often poorly insulated and energy efficiency generally a low priority. Although not a primary focus of this Report, it is interesting to note that these changes also coincided with the growth of demand for transport. Personal car ownership and use grew steadily. In 1951, only 25 per cent of households had access to a car, but this figure had risen to 50 per cent by 1969.[30] Growth in car travel further fuelled the growth of urban areas, the spread of residential areas and the movement of industry, commerce and retail activities to urban periphery locations.

25 Sherry (1984)
26 Casten (1995)
27 Kemp (2008)
28 Rydin (2003)
29 Barker Review (2006)
30 Department for Transport (2007)

Figure 2.1: Housebuilding: permanent dwellings complete, (by tenure, United Kingdom) 1949 – 2005



Source: Housebuilding – permanent dwellings completed, by tenure, UK historical calendar year series, Department for Communities and Local Government (2008)

The discovery of new UK energy resources did not insulate the UK economy from rapid oil price rises in 1973 as a result of the Yom Kippur war and again in 1979 as a result of the Iranian revolution. One consequence was a new focus on demand-side energy conservation and a growing but marginal interest in new approaches to sustainable architectural design. Oil prices did not fall significantly again until 1986, with the recession following the oil price crisis of 1973 triggering a property crash and temporary downturn in new development. However, once the economy had recovered, there began a period of long-term increases in property prices – both residential and commercial – that was only punctuated temporarily by downturns within this period. Property price rises spurred new development and redevelopment in urban areas. Housebuilders built out their land banks in pursuit of high profits, while financial institutions invested in prime new commercial property for long-term asset growth, mostly with little mind to the energy efficiency innovations of the early seventies.

In the 1970s and 1980s, new environmental issues affected the energy sector. The accidents at Three Mile Island in 1979 and Chernobyl in 1986 had a severe effect on confidence in nuclear technology. Orders for new plant disappeared as a result of safety concerns, but also due to increasing costs and over-investment caused by incorrect assumptions about growth in demand. Demand did not grow as foreseen because of the 1970s' oil shocks and associated economic difficulties. By the end of this period, environmental concerns were also having an effect in terms of increasing public resistance to urban and suburban growth. In sum, by the late 1970s the relationship between energy and the built environment had become increasingly complicated and contested, wrapped up in competing policy priorities and driven by a spectrum of anxieties.

2.1.3 Marketisation: early 1980s to around the turn of the millennium

During the 1970s, the supply-side logic of energy system development came under increasing challenge. The energy crisis highlighted the vulnerability of a mainly supply-side approach, while the growing strain on public expenditure exposed the financial costs. On the social side, there was rising concern about the impact of energy costs on the fuel poor,[31] while environmentalists were becoming more vocal on the failure to pursue energy conservation and efficiency measures seriously, and on the environmental cost of large infrastructure investments. A growing perception that the nationalised, vertically integrated gas and electricity industries were poorly run and hence inefficient and poorly equipped to meet contemporary challenges helped signal the end of the era of nationalisation and a shift from the early 1980s from the planning approach to the market approach.[32] The objectives became privatisation, liberalisation and competition. State-owned, vertically integrated gas and electricity monopolies were sold off, sometimes as integrated companies (e.g. British Gas), and sometimes in parts (e.g. the Central Electricity Generating Board and regional electricity companies). Over time, the potentially competitive parts of the gas and electricity industries were separated from the network monopolies, allowing competition to set prices and quantities in wholesale and retail markets. Arguably, this model worked well in the UK. Energy networks were well established, there was excess capacity in electricity generation, and there were few worries about the price and availability of oil. Another defining feature of the UK energy system in the 1990s was the availability of cheap natural gas from the North Sea which resulted in a (largely unintended) by-product that the UK's CO_2 emissions fell significantly. Moreover, as a result of these favourable factors, and tough price regulation of monopoly elements, energy prices for consumers fell throughout the 1990s and into the early 2000s.

Glass palace marketisation period

Deregulation and marketisation also affected the planning of the built environment. Planning was led by market pressures, rather than working to contain or influence them, and regulation over many aspects of urban development was curtailed. Public sector land was sold to private sector developers by local authorities and public sector

31 Boardman (1991)

32 Helm (2007)

bodies. The Urban Development Corporations took a mechanism from the New Towns programme and used it to foster market-led development. Housebuilding rose from 1982 to 1988 and commercial and industrial property development was equally buoyant. In London massive office development was prompted by the deregulation of the City of London, while Enterprise Zones and a belief in property-led regeneration encouraged investment in industrial and retail development. Office specifications spiralled, with the pursuit of prime assets marked by ever more energy intensive air-conditioning and electrical systems that were mimicked from Reading to Edinburgh irrespective of climate need.[33] Much urban development was out-of-town, although there was an attempt to redevelop inner city brownfield sites also. Energy efficiency in new development was not a priority. Low-density urban growth often took place in locations that required use of the car.

Similarly, energy efficiency in households still had a low priority. This was partly due to low real energy prices, and partly due to the view (expressed through the regulatory system) that the primary objective of energy policy was to keep prices low.[34] Competition was seen as the primary way to do this, and to protect the interests of both domestic and business consumers. It was not until a change of government in 1997 – and developments such as the Utilities Act of 2000 – that the regulator was required to include social and environmental considerations in decision-making.

Throughout this period, research and innovation had an increasingly low priority.[35] The 'dash for gas' was based on largely foreign gas turbine technology developed in the United States and elsewhere in Europe. Public and private R&D budgets were cut dramatically and many of the research establishments of the former state-owned companies were closed.[36] This led to cuts in renewable energy research – reversing a trend of increasing spending which had started after the 1973 oil price rises. Research efforts on the home tended to focus on producing ever more technically sophisticated 'smart-homes', full of energy expensive 'infotainment' systems that harnessed communication technologies to integrate and extend domestic technical systems.

In the late 1980s, this property-led boom came to an end. This was followed by a renewed emphasis on market development being led by the planning system rather than the other way round. This shift set the scene for a wide-ranging rethink of the connections between energy, urban development and environmental concerns.

2.1.4 Since the turn of the millennium

A combination of excess capacity, low fossil fuel prices and the inherited networks resulting from past investment had allowed the early market period in the 1980s to deliver cheap energy. However, since the turn of this century there has been a marked shift in UK energy fundamentals that arguably heralds a 'New Energy Paradigm', suggesting that a new model for delivering UK energy policy might be required.[37] The UK is now a net importer of energy, new investment in the energy infrastructure is becoming pressing, and there is greater fear of terrorism. Energy security, a major issue in the 1970s, is once again to the fore and now coupled to the constraint of climate

33 Guy (1998)
34 Helm (2007)
35 Stern (2006), Jamasb et al. (2007)
36 Helm (2007)
37 Helm (2007)

change. This is at a time when energy prices for petrol, gas and electricity have been rising, when oil prices look set to remain high by historical standards for the foreseeable future, leading to concerns about fuel poverty.

There has also been a change in approach to the built environment, seeking to overcome the contrast between a pro-development and a pro-planning approach. Since the late 1990s, the planning policy climate has been favourable to new development but sought to frame it within a revitalised planning system – the Local Development Framework (LDF). This is a tool to implement spatial planning, which is characterised by being proactive and coordinated in delivering new development. The Barker Review argued for a new era of housebuilding in order to meet demographic demand.[38] This could offer new opportunities to reshape the energy system through physical change in the built environment.

Energy efficiency of buildings[39] has undergone regular revision, including further strengthening in 2006 to make new homes more thermally efficient, raising standards by 40 per cent compared with 2002. Looking further ahead, policy packages, such as *Building a Greener Future*,[40] seek to achieve this by promoting zero-carbon development in the residential sector by 2016, with the non-domestic sector following by 2019. New experiments in sustainable urbanism are in progress, whether small scale efforts in micro-generation, larger eco-development such as One Gallion[41] in London or European exemplars of eco-towns such as Amersfoort in the Netherlands.[42]

However, changing the built environment and its associated energy use is an approach that is challenged by downturns in the housebuilding sector, property markets and the economy more generally.

Thus energy systems, urban growth patterns and changing social practices can powerfully interlock to produce recognisable periods of development in the built environment. Equally, how these eras come to break down under new pressures and demands, leading to new phases of development, can be identified. Our analysis indicates that the UK is at just such a potential transition point with regard to energy systems and the built environment. Possible trajectories through this transition using future scenarios will be explored in Chapter 3. Next the key features of the current situation on energy and the built environment are set out.

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38 Barker (2004)

39 Regulated by Part L – Consumption of Fuel and Power – of the Building Code

40 Department for Communities and Local Government (2007a)

41 http://www.onegallions.com

42 PRP Architects, URBED and Design for Homes (2008)

2.2. Today's environment and issues for the future

2.2.1 Energy supply and demand in the UK

The UK has become increasingly dependent on the generation of energy through advanced technological means to service every facet of our lives (Figure 1.1 in Chapter 1). Table 2.1 summarises the UK energy balance in 2007. [43]

Table 2.1: Summary UK energy balance 2007.

	Energy supplied basis : million tonnes of oil equivalent						
	Primary Fuel Availability						
Source	Coal & manu-factured fuels	Oil & petro-leum products	Natural gas	Renewables & waste	Electricity	Heat	Total
1 Indigenous Production	10.67	84.21	72.13	3.98	14.93	0.00	185.91
2 Imports	28.93	88.40	29.07	0.38	0.74	0.00	147.51
3 Exports	-0.58	-87.86	-10.59	0.00	-0.29	0.00	-99.33
4 Marine bunkers	0.00	-2.51	0.00	0.00	0.00	0.00	-2.51
5 Stock change	1.87	1.94	0.47	0.00	0.00	0.00	4.29
6 Primary supply	40.89	84.18	91.07	4.35	15.38	0.00	235.87
7 Statistical difference	0.08	-0.21	0.13	0.00	0.13	0.00	0.13
8 Primary demand	40.81	84.39	90.94	4.35	15.25	0.00	235.74
9 Transfers and transformation	-36.98	-0.70	-32.16	-3.49	18.83	1.19	-53.31
10 Energy industry use	0.89	4.55	6.41	0.00	2.40	0.06	14.31
11 Losses	0.22	0.00	1.04	0.00	2.27	0.00	3.52
12 Final consumption	2.73	79.14	51.34	0.87	29.40	1.13	164.60
13 Non energy use	0.00	8.83	0.90	0.00	0.00	0.00	9.73

Source: Department for Business, Enterprise and Regulatory Reform (2008)

43 Department for Business, Enterprise and Regulatory Reform (2008)

Table 2.1: Summary UK energy balance 2007. *(continued)*

14 Final energy consumption	2.73	70.31	50.44	0.87	29.40	1.13	154.87
Source:							
14a Industry	2.03	6.83	11.76	0.26	10.12	0.69	31.69
14b Transport	0.00	59.10	0.00	0.00	0.71	0.00	59.81
14c Domestic	0.68	2.88	30.09	0.43	9.89	0.05	44.02
14d Other final consumers	0.01	1.50	8.59	0.18	8.68	0.39	19.35

Source: Department for Business, Enterprise and Regulatory Reform (2008)

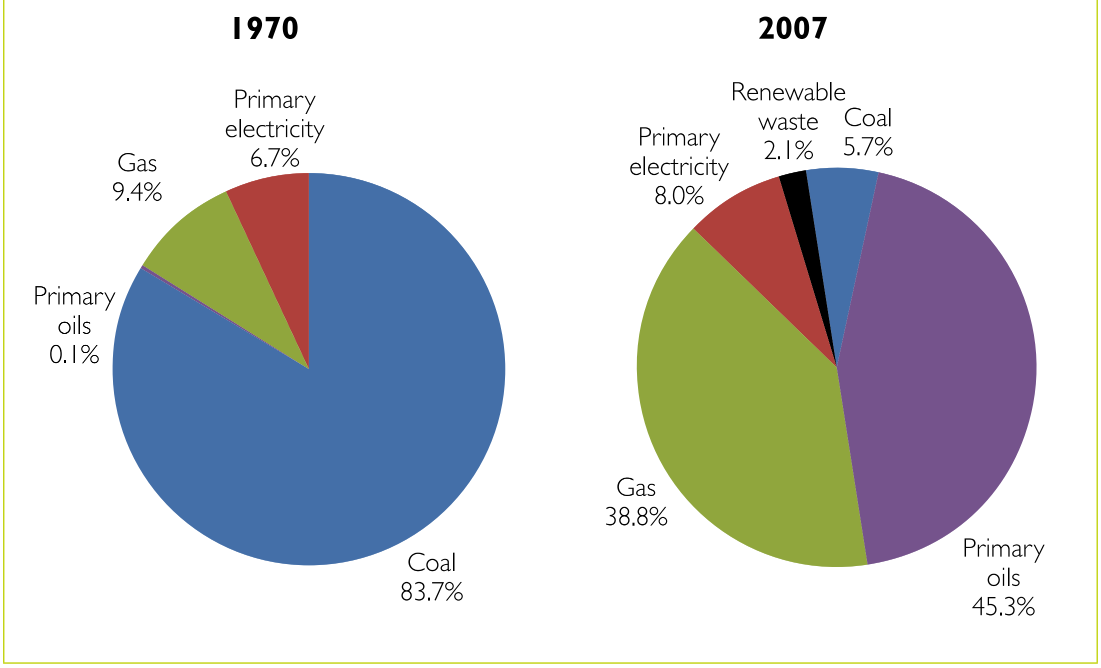
UK primary fuel production is dominated by oil and gas accounting for 39 per cent and 45 per cent respectively in 2007 with renewable energy sources accounting for only 2 per cent. The UK has been a net importer of crude oil and natural gas since 2005 and 2004 respectively.[44] Oil and petroleum products and natural gas also dominate primary fuel demand accounting for 36 per cent and 39 per cent respectively.[45] Primary electricity accounts for about 6 per cent with renewable sources only currently accounting for less than 2 per cent of primary demand. Coal still accounts for about 17 per cent of primary fuel demand. Apart from in 2002 imports have exceeded indigenous production since 2001.[46]

The UK is still heavily dependent on the use of petroleum; 45 per cent of final energy consumption in 2007, but mainly for transport. Natural gas accounts for just over 30 per cent of final energy consumption and is particularly important in domestic heating. Electricity accounts for just under 20 per cent of final energy consumption.

The mix of energy and fuel types in today's systems is illustrated in Figures 2.2, 2.3 and 2.4 and is contrasted with that of 1970.

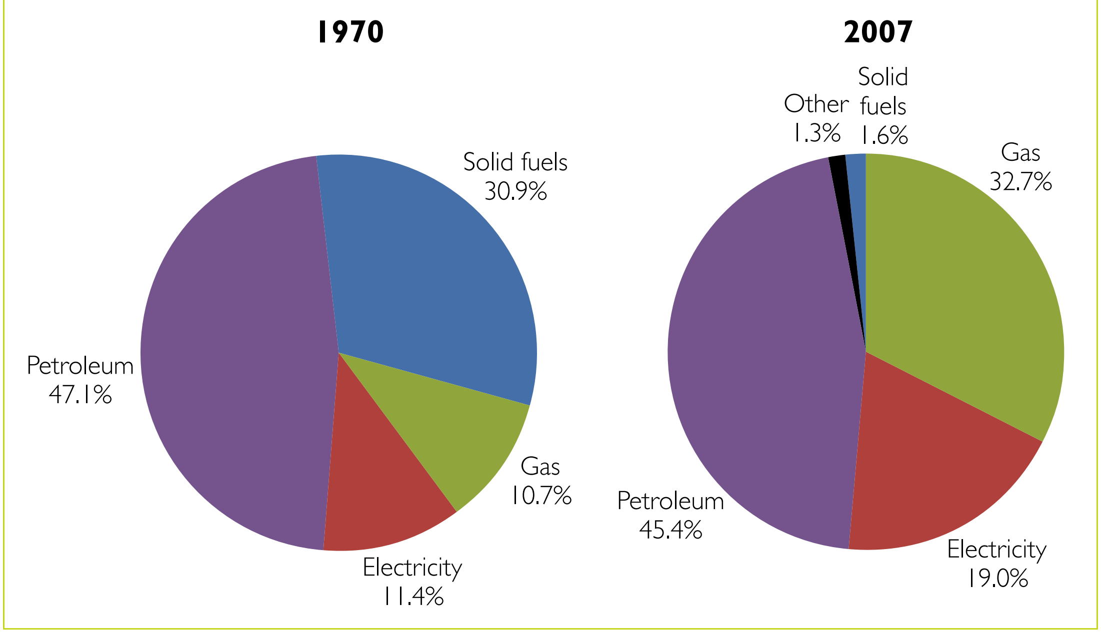
44 Department for Business, Enterprise and Regulatory Reform (2008)
45 Department for Business, Enterprise and Regulatory Reform (2008)
46 Department for Business, Enterprise and Regulatory Reform (2008)

Figure 2.2: Production of primary fuels.



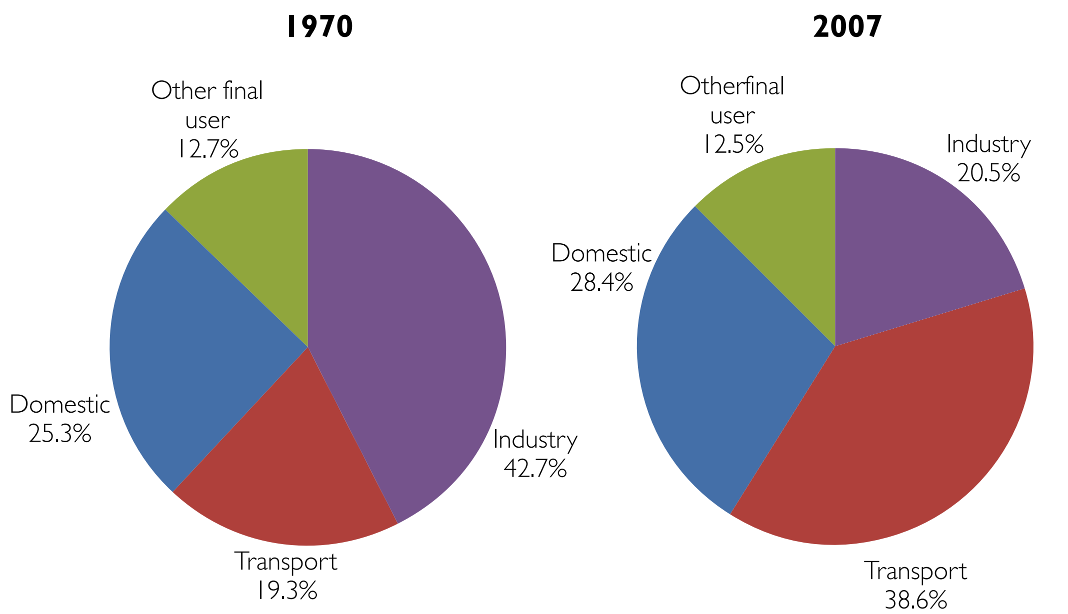
Source: Department for Business, Enterprise & Regulatory Reform (2008)

Figure 2.3: Final energy consumption by type of fuel.



Source: Department for Business, Enterprise & Regulatory Reform (2008)

Figure 2.4: Final energy consumption by final user.



Source: Department for Business, Enterprise & Regulatory Reform (2008)

Electricity in the UK is generated from various primary resources, both stock (gas, coal, uranium) and renewable (wind, tidal, hydroelectric, and solar). In 2007, renewable energy sources contributed only 5 per cent of UK electricity,[47] with gas and coal accounting for 36 per cent and 41 per cent respectively, and nuclear power for 17 per cent. All but a very small amount of this electricity is generated centrally in large power stations and distributed through the National Grid. In 2007, CHP plants supplied a little over 7 per cent of the total electricity generated in the UK.[48] Decentralisation of electricity and of energy systems more widely is discussed further in Chapter 5.

Total energy demand reflects both the pattern and volume of activities for which energy is needed, and the technical and economic efficiency with which it is used. Energy demand depends on a mix of economic factors and other social and cultural factors which are discussed in Chapter 4; whereas, energy efficiency depends upon technological, behavioural and cost changes. Since 1980 there have been overall improvements in energy efficiency for the industrial and service sectors and a lack of change in the household sector.[49]

In the UK a major use of energy within the built environment is for heating. Gas currently meets more than two-thirds of this demand through the nationwide gas grid. Heating is a particularly important part of energy use within homes and hence a major contributor to carbon emissions from the domestic sector. Over a quarter of the UK's total carbon emissions come from homes.[50] In 2005, 53 per cent of these domestic carbon emissions were from heating space, with another 20 per cent from water heating, 22 per cent from lights and appliances, and 5 per cent from cooking.[51]

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47 Department for Business, Enterprise and Regulatory Reform (2008)
48 Department for Business, Enterprise and Regulatory Reform (2008)
49 Department for Business, Enterprise and Regulatory Reform (2007b)
50 http://www.tyndall.ac.uk/events/past_events/dti_210301_full_report.shtml
51 Communities and Local Government (2007b)

These data show that bold action to improve the thermal energy efficiency of our homes and the efficiency of the appliances used in them must be a high priority in combating the impacts of climate change (see Chapter 6). But lowering energy consumption is not simply a matter of technological innovation to improve energy efficiency. The behaviour of people, households and communities ultimately determines energy demand. The co-evolution framework draws attention to the importance of 'energy behaviour' which is discussed in Chapter 4.

From the perspective of decarbonisation, energy use in the non-domestic sector is also critically important. Accurate data on energy use in the non-domestic stock are not available but estimates suggest that electricity consumption amounted to about 95 Gwh in 2004 and gas consumption to about 85 Gwh.[52] It appears that electricity use in this sector per unit of floorspace has not grown over time, while gas use per unit of floorspace has actually reduced. Energy in the non-domestic sector is discussed in Chapter 6.

2.2.2 The UK Built Environment

About 50 per cent of energy per annum is consumed in the built environment,[53] so an appreciation of how it functions is essential for identifying how energy systems can evolve. Not only does the domestic sector account for a large part of UK energy consumption and hence carbon emissions, it occupies more land than the non domestic sector and sets the character of large parts of urban, suburban and rural areas. Culturally, we have strong affinities with our homes.

In March 2006, there were 26.4 million dwellings in the UK,[54] but there were also an estimated 1.4 million non-domestic properties in England and Wales in 2004.[55] These comprised 17 per cent offices, 19 per cent retail units, 25 per cent warehousing and 38 per cent factories by area. In addition, the built environment is more than the sum of stocks of buildings. The arrangement of different land uses, the connections between them and the design of the spaces around buildings creates a complex environment which draws together the disparate elements of the built stock. Taken together, this built environment accounts for around 11-12 per cent of the land area of the UK.[56]

The UK's built environments are old. Patterns of land use, open space and infrastructure have been laid down over centuries of incremental development. The built stock itself is also relatively old (see Figures 2.5 and 2.6). By 2050, 65-70 per cent of the dwelling stock in existence is likely to have been built before 2000. The non-domestic stock is somewhat more modern than the housing stock. Nevertheless, just over half of all commercial and industrial properties were built before 1940 and only 9 per cent after 1990.[57] Just over a quarter of commercial building space by area was built before 1940 and only 15 per cent since 1990.[58]

52 Figures for the UK, Communities & Local Government and UK Green Building Council (2007)

53 Ward (2008)

54 Communities and Local Government (2008)

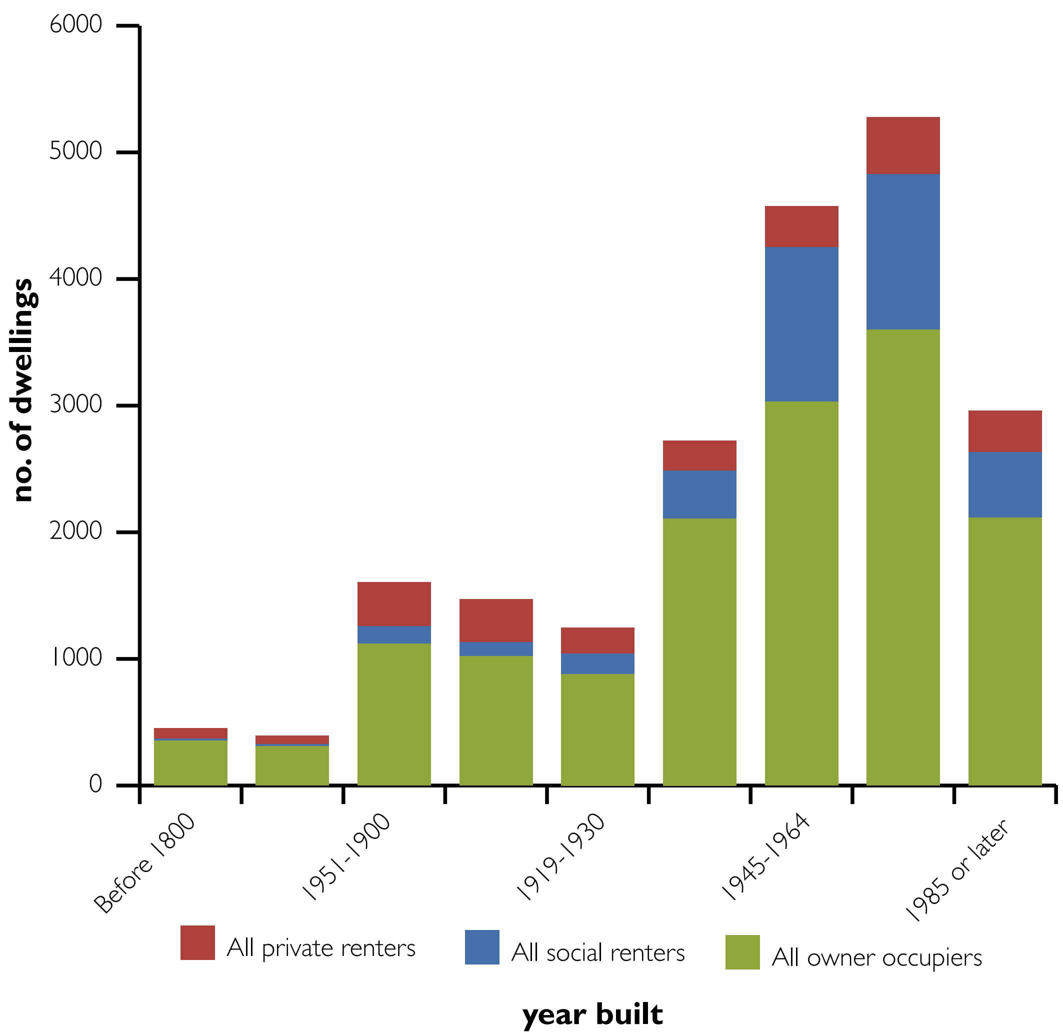
55 Properties are defined in terms of hereditaments, the taxable unit for industrial and commercial property. Communities and Local Government (2005b)

56 http://www.defra.gov.uk/environment/statistics/land/kf/ldkf08.htm

57 Office of the Deputy Prime Minister (2005)

58 Retail property is disproportionately older with about 40% of the floorspace built almost 70 years ago; about 30% of office floorspace and a quarter of industrial floorspace is this old.

Figure 2.5: Age of dwellings (in England) by type of ownership.



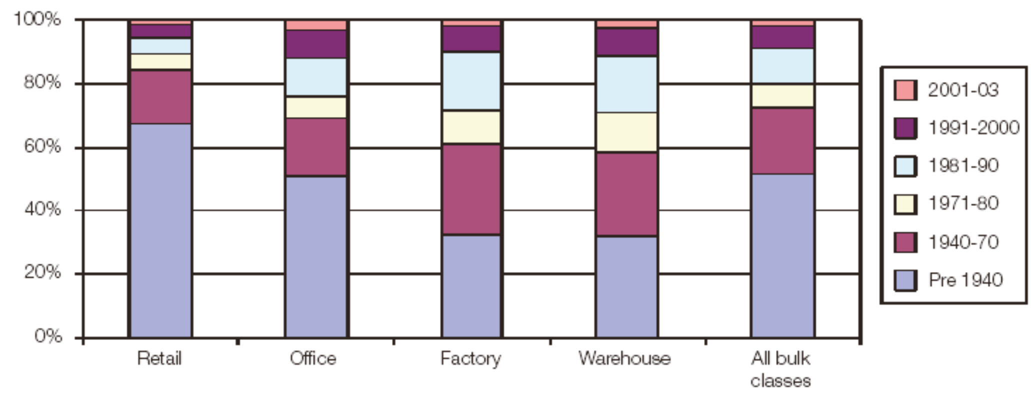
Source: Communities and Local Government (2007c)

The significance of these age distributions is that the majority of buildings in the UK were not designed or constructed with current energy efficiency standards in mind, although some will have been refurbished and retrofitted. Data for the domestic stock suggests that only a third of all dwellings with a loft have adequate insulation.[59]

There are so many older buildings, both domestic and non-domestic, with poor energy efficiency standards, that any attempt to reduce carbon emissions from the built environment must tackle the issue of retrofitting existing buildings and decarbonising the energy they use. (See Chapter 6).

59 Relates to loft insulation of 150mm or more. Communities and Local Government (2006)

Figure 2.6: Age profile hereditaments on the non-domestic sector by bulk class.



Source: Communities and Local Governments (2005a)

New construction of buildings offers the opportunity to implement much higher standards of energy efficiency. In 2006, there were orders for almost £3 billion of non-domestic buildings in England, and £1.8 billion of new housing orders.[60] However, the long-term trend since the late 1960s has been one of declining house-building rates. In 2001 only 175,000 dwellings were built, the lowest level with the Second World War.[61]

Government policy, in recent years, has supported more house building, with targets of three million new homes by 2020[62] and between 2001 and 2006, new build completions increased by 24 per cent to about 165,000 per annum. However, the very recent reduction in housebuilding rates during 2008 emphasises that actual rates of construction are strongly influenced by the growth of the economy and market forces.

While the primary focus of this Report is on how energy systems in the built environment can mitigate climate change through reduced carbon emissions, no study on energy systems which looks ahead to 2050 can fail to consider resilience[63] and adaptation[64] to climate change. Changing patterns of rainfall, temperature (particularly peak temperatures), soil moisture, wind speeds and sea-level rise will all affect built-up areas and their infrastructure.[65] About 10 per cent of new dwellings are currently being built on floodplains,[66] which raises serious questions about their ability to cope with the consequences of climate change. There are also complex interfaces with the demand for energy, for example, for heating and cooling and for water treatment and distribution. Some of these issues are explored in Chapter 7.

60 Department for Business, Enterprise and Regulatory Reform (2007a)

61 Barker Review (2006)

62 Communities and Local Government (2007b)

63 Resilience: The capacity of human and natural systems to deal with surprises or changes including climate change, severe weather events or terrorism. An increasing policy priority for the UK and other countries.

64 Adaptation: Change in human or natural systems in response to climate change or other pressures. It is the complementary approach to mitigation.

65 University College London Environment Institute (2008)

66 Communities and Local Government (2007d)

2.3. Society, energy and the built environment

This brief account of energy systems and the built environment should not be considered in isolation from changing social trends in the UK. For example, demographic change will put new pressures on both energy use and the built environment. The UK population is expected to increase to 67 million by 2020[67] and net migration to the UK is projected to continue. The number of those aged over 85 will increase by 50 per cent by 2020 and is an important part of the projected growth in one-person households. There are currently about 25 million households in England,[68] 31 per cent of which consist of one person. This figure is projected to increase to 38 per cent or nearly 10 million one-person households in 2026. Such a shift in household size would have significant implications for how energy is used in homes.

Both energy use and the quality of the housing stock have strong links to social deprivation. In 2006 37 per cent of all housing was defined as 'non-decent' according to current standards.[69] At times the planning system has had a significant role in seeking to improve such conditions within the built environment. There were 6.5 million households in fuel poverty in 1996. In 2006 the figure was about 3.5 million households – of which 2.75 million were particularly vulnerable households.[70] Fuel price increases mean that the figure is projected to increase by at least 1.2 million by 2008.[71] Age Concern asserts that one in five pensioners live in fuel poverty.

Set against this deprivation has been an increase in expectations of material comfort over the past century. Desired temperature levels within the home have increased from 12°C in 1970 to 18°C in 2002,[72] with consequent impacts on energy consumption. Our expectations of mobility have also changed, again with implications for higher energy use.[73] In general, people currently aspire to greater freedom of work, movement, social life and education.

Society's ability to respond technologically to these pressures needs to be seen in the context of these social aspirations (see Chapter 4). The paths that our energy systems and the UK built environment might take over the next five decades are uncertain. Next, four alternative future scenarios are used to examine the opportunities and challenges that lie ahead.

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67 Cabinet Office (2008)

68 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. Communities and Local Government (2008)

69 There are four criteria that make up the Decent Home Standard. These are; it meets the current statutory minimum standard for housing; it is in a reasonable state of repair; it has reasonably modern facilities and services; and; it provides a reasonable degree of thermal comfort. Communities and Local Government: Housing and planning: Key Facts

70 i.e. those with children, the elderly, those with disabilities, or the long-term sick

71 Fuel Poverty Advisory Group (2008)

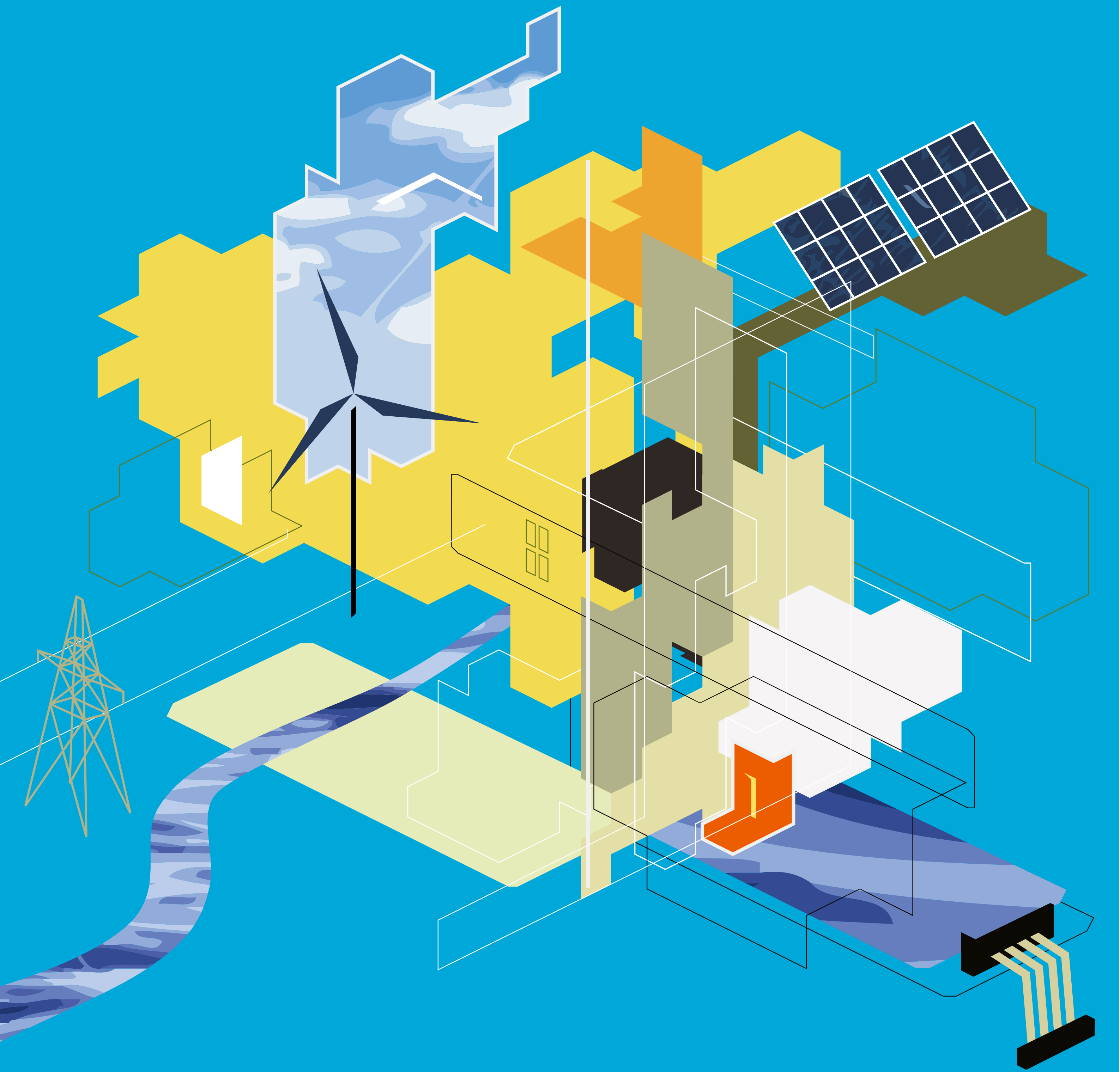
72 Utley and Shorrock (2006) in Loveday et al. (2008)

73 Foresight (2006)

Key messages

- Looking back over the last two centuries the UK has experienced both a centralised and decentralised energy system and therefore there is no reason to assume that a centralised system should prevail over the coming decades in meeting the twin challenges of energy security and climate change.
- Evidence from past eras shows that energy systems could be radically altered within the timescale of the next 50 years.
- Creating a secure and sustainable low carbon energy system in the future requires change in energy markets, regulation and energy technologies.
- Lock-in which explains why technologies may remain dominant despite the existence of others that may be more effective (see Box 2.1) is a key consideration in meeting the challenge of decarbonisation.
- The Project's framing concept of co-evolution recognises that technological innovation requires both socio-economic viability and governance arrangements.
- The UK built environment is evolving through a mix of new build, and renovation and development of the existing built environment. Given the longevity of a large part of the building stock, the renewal of the built environment is likely to be critical in reducing carbon emissions.
- Action to improve the thermal energy efficiency of homes and the efficiency of the appliances used in them must be a high priority.

3 Exploring the future



3 Exploring the future

Having taken a historical perspective in the preceding chapter, Chapter 3 takes a look forward at possible future worlds. It does this through four scenarios, developed for this Project.

The analysis of the scenarios draws out different aspects of social behaviour, energy systems and the built environment, and explores how they interplay in the context of decarbonisation and energy security.

3 Exploring the future

3.0 Introduction

The principal aim of this Project is to explore how the UK built environment could evolve, over the next five decades, to secure sustainable, low-carbon energy systems that meet the needs of society, the requirements of the economy, and the expectations of individuals. The high costs of providing or adapting the infrastructure of energy systems combined with the low turnover in the built stock mean that decisions made now will necessarily be long term in outlook. Achieving a transition in the built environment to sustainable energy systems is likely to require multiple changes in, for example, planning and building regulation and social behaviour, as well as action from business, government and consumers. Any exploration of the future is by its very definition uncertain. Forecasting techniques for specific trends can be useful in the shorter term but have limited value in helping to deal with uncertainty over longer time horizons. Systematically exploring possible futures, over the next five decades, with the aim of making current policies robust and resilient to future change needs to be a key part of the policy making process. Four hypothetical scenarios of the future were therefore developed for the Project. They were used to stimulate thinking about alternative ways in which energy systems and the built environment could evolve. They have also been designed to act as a tool for policymakers and other stakeholders to use in the development of strategic policy-making.

The scenarios are neither predictions nor forecasts or comprehensive critiques. They are framed by uncertainties in the wider geopolitical environment, and by the scale and nature of future investments. Different aspects of the pathways to decarbonisation and differing social practices are reflected across the four different worlds.

3.1 Climate change effects and the scenarios

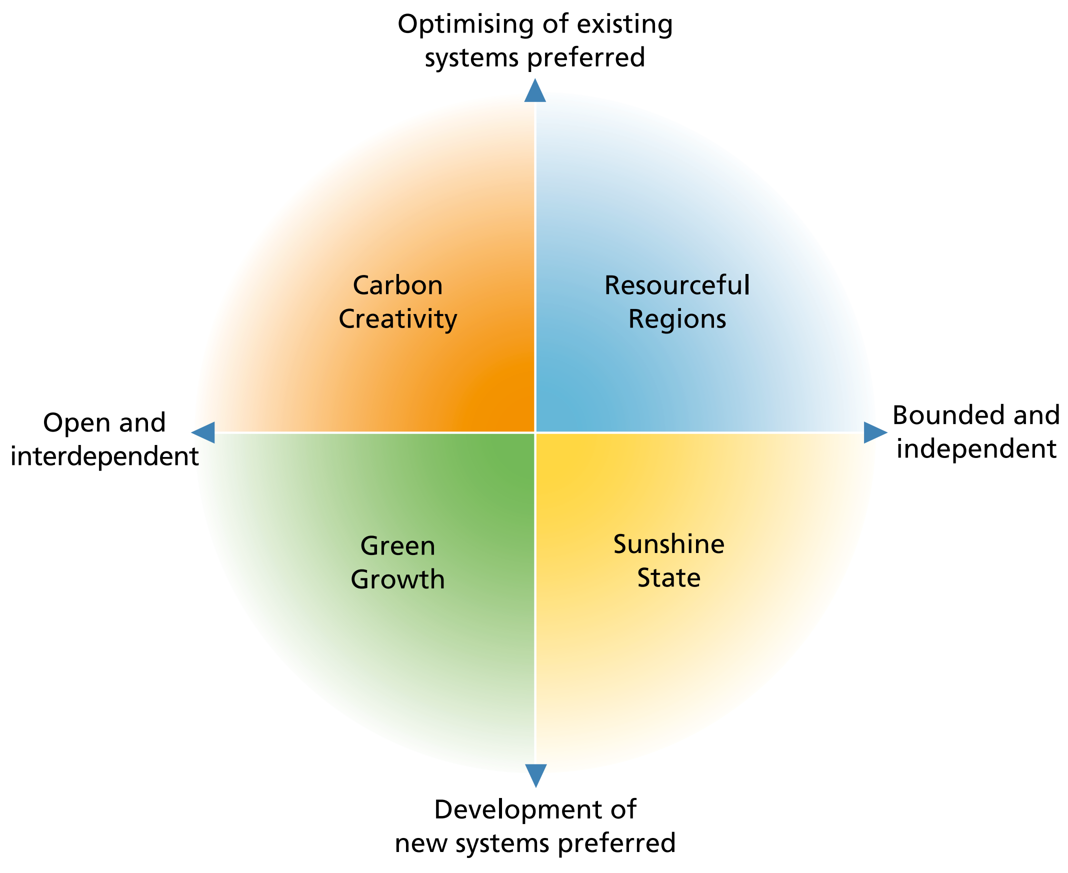
The impacts of climate change will be a critical issue for the UK over the Project's timeframe of five decades. It was therefore decided to make the scale, nature and impact of climate change consistent across all four scenarios. Over the 50 year period in question, whilst there is uncertainty over any detailed effects climate change will have, the nature and scale of any changes will have already been largely pre-determined by human activities in the preceding decades. The UK Climate Impacts Programme 02 Gateway Scenarios suggest that the UK will continue to get warmer with hotter, drier summers and milder, wetter winters. The number of very hot summer days is expected to increase and the number of very cold winter days is expected to decrease.[1] Sea levels will continue to rise. All four scenarios were therefore built around this trajectory. Patterns of behaviours over the next 50 years, from the demand for energy services through to political action on energy issues, will influence climate trajectories in the longer term. Those post-2060 paths are not, however, the focus for the Project's scenarios.

1 UK Climate Impacts Programme (2002)

3.2 The scenarios

The four scenarios are framed by two key axes of uncertainty focussed on infrastructure and the economy, which were identified through the analysis of seven major clusters of forces, trends and drivers for change. A summary on how the scenarios were created is shown in Box 3.1. First, uncertainty associated with the **innovation investment** – ranging from investment in innovations that enable optimisation of existing systems and infrastructure to investment in innovations at the other extreme, that lead to the introduction of novel systems and ideas and organisations. The second uncertainty is concerned with the **wider political and economic dimension** ranging from the extent to which the environment is one of open, interdependent relationships or, at the other extreme, one where states or regions are more bounded and relatively independent. Figure 3.1 illustrates the axes of the Project scenarios.

Figure 3.1: 2x2 axes of Project scenarios



The scenario axes provided a framework in which four different narratives were written, drawing on the evidence in the science review papers commissioned for the Project and on extensive discussions, at eight workshops with participants from industry, policy and academic communities. Energy systems and the built environment were key areas for exploration. Information and ideas about people, buildings and the economy from these two sources were incorporated and through iteration developed into robust and plausible stories. A summary description of each scenario is outlined below together with a scenario vignette. Full narratives of the scenarios are at Appendix I.

Box 3.1: Creating the scenarios

The Sustainable Energy Management and the Built Environment (SEMBE) Project scenarios were developed using the 'deductive' method of scenario development.[2] This method starts with an analysis of the underlying drivers of change, which are then prioritised in terms of their impact and uncertainty. The two most significant uncertainties are then used as scenario 'axes', creating a 2x2 matrix. The scenarios are then derived deductively through exploring the different quadrants of the matrix.

In the SEMBE Project, the underlying drivers of change were identified through an analysis of relevant existing futures work. Twenty-seven futures studies were examined and seven major clusters of drivers were identified: climate change and the environment, demographic change, infrastructure, technology and materials, public attitudes, the economy, and the political framework.[3] An initial set of scenarios based on these seven clusters were developed. They were then tested, modified and refined through a series of stakeholder and expert workshops. The development process for the scenarios also included: the development of a set of technology roadmaps considered plausible in the context of each scenario; the exploration of potential policy implications in each; and a validation process, which included 'benchmarking' to ensure internal consistency. In total, the Project held 8 futures-related workshops involving approximately 175 experts and stakeholders.

3.2.1 Resourceful Regions

This is a world in which political trust has diminished on a world scale, although bilateral agreements and trade continues. Most UK energy comes from fossil fuels with innovation being focused on the optimisation of existing systems. They are used more efficiently than in the past, but the focus of attention is less on the global impact of climate change and more on energy security and the cost of fuel. Electricity networks have become more intelligent and adaptive to allow power to be used as efficiently as possible. The key distinguishing feature is that English sub-regions have a high degree of autonomy, matching Scotland and Wales. In situations of resource scarcity, regional trade in fuel and water carries considerable leverage; water is now widely understood to have an energy cost. This has meant a resurgence of industrial activities such as deep and open-cast coal mining in areas where they had previously died out. Some regions do deals with overseas countries on energy supplies. Regional deals for permitting new power station developments have meant that nuclear power still plays a role but many regions have also invested in appropriate renewable technologies for their area.

The countryside is used more intensively than in the past, for food production, mining and other activities. Within built up areas, retrofitting rather than new build is the preferred approach. Any new buildings are increasingly built in a local vernacular style, and there is considerable emphasis on urban green space to tackle overheating. People in this Britain like to think they are self-reliant, and are proud of being British, even though the country is closer to breaking up than any other time in the previous century. Their living conditions vary widely as regions have their own economic structures and differing levels of economic success. But acceptance of the situation is underpinned by strong regional identities and the effectiveness of most regional government's moves to support vulnerable groups and public services such as public transport.

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2 Ringland (2006)

3 Foresight Powering our lives: futures report (2008)

Figure 3.2: On the dock of the bay – 2050

On the dock of the bay – 2050

On the dock of the bay

It is perhaps appropriate that the Bute Docks in Cardiff, once the busiest coal port in the world, now looks out over Cardiff's tidal-powered energy station. The project has been many years in the making and there has been much dispute about its impact on the earlier Cardiff Bay development – more oriented towards leisure and housing – of the late 20th Century. But in the end, the City Council and the Welsh Administration agreed that energy needs meant that they should utilise the resource that was almost on their doorstep.

The plant powers the local electric tram network, around Cardiff and across much of South Wales. The hydrogen to power the City's buses comes from the re-purposed gasometer overlooking the bay, once thought ugly, now a symbol of the City's relative levels of energy independence. The dragon on its side can be seen in England on brighter days – a constant reminder of a more heralded but now, in the face of environmental damage, unstable Avon-Welsh agreement over the location of the energy station.

The fact that Wales has got tidal power to work ranks as one of the Administration's finest achievements. Many other similar schemes around the world have proved to be less successful. One of the features of the scheme is a research and development centre, affiliated to the University of Wales at Cardiff, and based in the old customs building, overlooking the bay. This building and its surrounding outhouses have been hugely re-purposed for the benefit of the local community – exhibitions by Welsh artists are often on display (a source of considerable local pride). There are frequent school trips to the facility, in order to help children understand energy, where it comes from and how existing energy systems can be modernised.

3.2.2 Sunshine State

International solidarity has fallen by the wayside in response to climate change and expensive energy. Instead the Government has fostered an emphasis on localism to respond to energy problems supported by a shift in social values after a period of outages and fuel shortages. A Sunshine Index is the main metric of progress, not Gross Domestic Product. Home insulation and other energy efficiency measures are universal following strong regulation. Retrofitting is sometimes done alongside adaptation work to help buildings cope with warmer and wetter conditions. Green roofs and parks are common as part of comprehensive local sustainable drainage systems to counter flooding. There are more local shopping streets and other community resources, partly because of planning decisions intended to promote local autonomy and partly because of municipal enterprise. New build commonly uses off-site construction methods, often from overseas.

People are active energy users and know about the energy use of everything they own. They know their neighbours, who are important to them economically as well as socially; people travel less widely. Many belong to local 'time banks' (where people use their time, rather than currency, as a form of transaction) or use local currencies. Innovation has led not only to the introduction of novel technologies but also new organisations, ideas and approaches. There has been considerable expansion of renewables including solar energy and biomass. Bulk electricity storage has become more practical alongside virtual storage, and costs for solar power have come down radically. Gasification, pyrolysis and other creative ways of using biomass and waste to generate energy have been developed successfully. A new cohort of energy and environment professionals has grown up to address earlier skills shortages and government has been actively involved through nationalisation of the grid and municipally-owned energy schemes. Energy markets are also closely regulated and reserve powers of rationing energy and water exist.

Figure 3.3: Edge of Town – 2050

Edge of town – 2050

The edge of town

Out of town supermarkets have long since closed, in a world in which energy was scarce and its use discouraged. But retail sites on the edge of town, or in town, have gone through successive mutations. The first – and most obvious – iteration was to become primarily a distribution hub for goods rather than a shopping destination for consumers, with the retailers effectively using them as distribution warehouses, a model which substantially reduced energy costs.

The second stage added people to this mix. People still need to travel, but they now tend to travel more slowly and to stay longer. The supermarket sites had sufficient space, in the car park and elsewhere, to build sophisticated and desirable self-contained 'living units' for students, key workers, and other visitors. These units have access to communal power sources – usually self-powered from solar strips and wind turbines on the roof, energy storage and rain water collection reservoirs. A shared canteen is supplied from the warehouse. Advances in ICT and telecommunications allow the residents to be fully networked and integrated into their respective communities, both physically and virtually. Sound insulation, separating the living units from the work of the warehouse, has been a prerequisite for success.

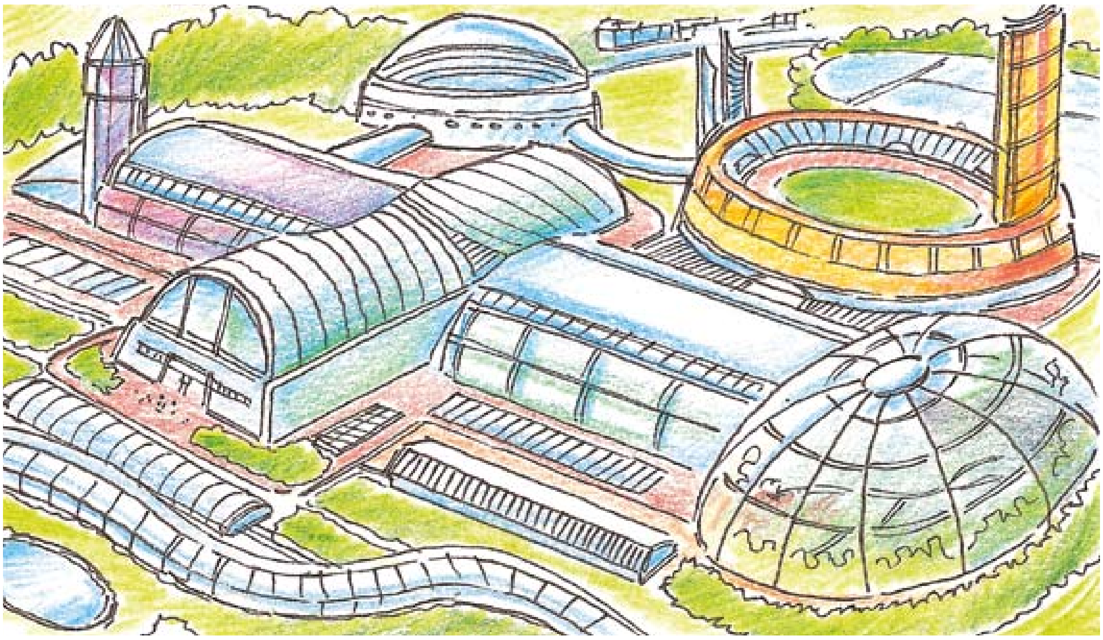
In many places it's a comfortable walk to the town and business centres. But there are usually car-sharing clubs based at the site, and sufficient density and demand to ensure that the local bus and tram connections work well.

3.2.3 Green Growth

In this world, fossil fuel depletion and climate change are serious concerns and novel technologies and systems are regarded as the way to deal with them. Social values emphasise universalism and benevolence. There is an emphasis on decoupling economic growth from carbon emissions and a substantial carbon tax to drive change. By 2050 the building industry reflects these developments although it took time to achieve a step-change within the UK. Strong planning powers and public procurement focussed on carbon reduction led to much penetration by overseas companies in the early years. However there are now many highly energy-efficient new houses and other buildings. New designs, particularly for offices and shops, had to take on board the banning of all air conditioning. There is less emphasis on retrofitting old property and, as a result, these have fallen considerably in value.

People take responsibility for their energy use supported by energy avatars and have become much more active consumers. Most energy comes from renewable sources including big projects such as the Severn Barrage, offshore wind farms, and solar energy farms in Africa. Strong planning powers were used for the UK schemes. There is some local renewable energy, including energy-from-waste schemes, partly to offset the inherent instability of electricity supplies transmitted across thousands of kilometres. In response to such insecurities, energy use is managed automatically, for example, by turning off freezers and washing machines at times of peak demand.

Figure 3.4: The glass palace – 2050



The glass palace – 2050

The glass palace

One hundred and ninety years after the original building was moved to the site, the Crystal Palace has been rebuilt and re-opened in the Park, on the same site, as a symbolic showpiece of the commitment to energy and service innovation. It was built by an international team of architects, engineers and energy companies from the UK, Europe and China. The building combined the London bio-dome with exhibition space showcasing the latest developments in renewable energy and conservation, a sports hall and a concert hall. New research facilities – linked to Kew Gardens and to the global Eden Project – have also been sited here.

Even such a prestigious project has had to fight its way through the rigorous planning, procurement and building management process. No new building can be commissioned without a government-approved maintenance and management contract with a MUSCO (a multi-utility service company) which will ensure that energy, water and resource management, together with maintenance, complies with current performance standards, including the capacity for remote monitoring and management. In the water-stressed capital, a new building of this size has to be able to pay its way by putting an equivalent amount of resources to the amount it consumes back into the resource network. Rainwater capture and use of renewable energy were part of the original design, although it took several redesigns to release enough resources to local buildings to 'fund' the incoming water demand.

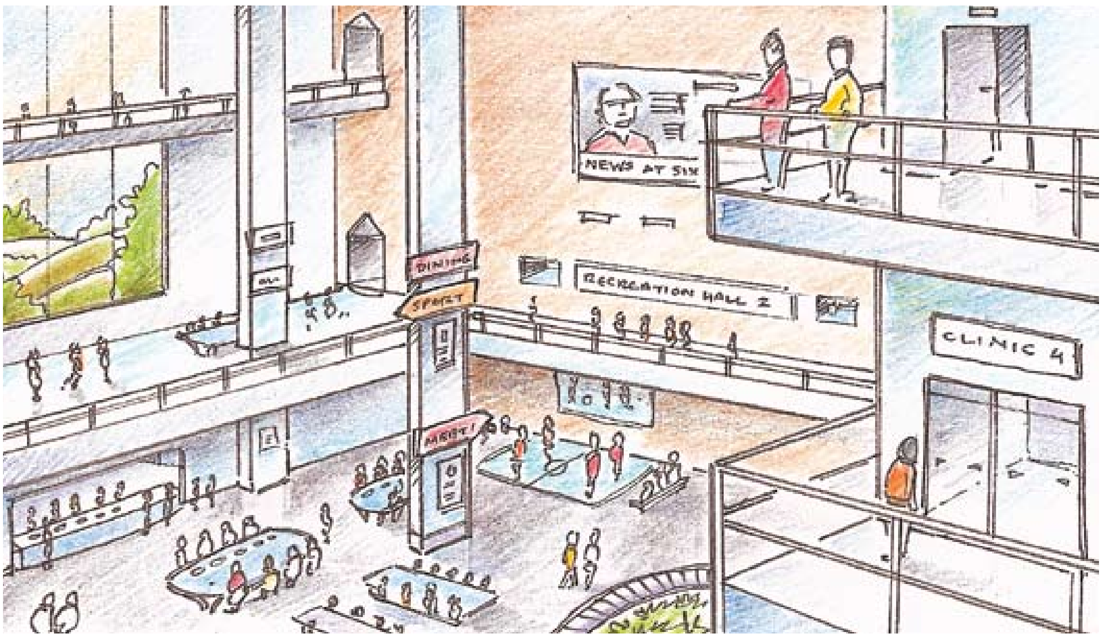
The sports hall floor has been constructed using smart materials which can be adjusted to suit the particular event that's taking place, while the pathway from the refurbished integrated transport hub has been built from recycled self-healing 'stone' – an artificial surface which is designed to regenerate after wear.

3.2.4 Carbon Creativity

Decarbonisation is a major theme in this world, prompted by a carbon market in which all goods and services carry a carbon price. However, it has been possible to combine this with a continued reliance on fossil fuels due to considerable investment in CCS. Renewables are small in scale and volume and little renewable power is connected to the grid. The economy faltered for a while in the transition to this new technology and carbon-driven economy but has now recovered although there is general acceptance that there will not be a return to high levels of growth. People in this world are highly aware of energy in the form of embodied carbon in everything they produce. They are also conscious that energy is expensive. On a more positive note, there has been a boom in carbon consultancy, in which there are EU-recognised qualifications and London is the centre of world carbon trading. Europe also plays a major role in regulating energy markets.

Energy costs and regulation have driven considerable retrofitting and renewal of the existing built stock, both domestic and commercial. The construction industry responded well to poor standards and practices in the early days and the quality of work now delivers considerable carbon savings. High-density, mixed-use developments are popular because of their community feel as well as their energy efficiency and proximity to transport nodes. They feature optimisation of existing technology for capturing energy, especially from solar power, and for using it effectively, for example advanced glazing. Following a steep learning curve, local planning has ensured that these new developments deliver on all these fronts as well as being adapted for climate impacts.

Figure 3.5: The clinic by the park – 2050



The clinic by the park – 2050

Figure 3.5: The clinic by the park – 2050

The clinic by the park

The conversion of one of the PFI hospitals built in the early 21st Century into a mixed-use health/home/living complex made sense when one considered how many people worked there – and the transport and energy infrastructure which went with it. The carbon market – and better health monitoring – meant that there was more demand for local rather than centralised health services. At the same time more of the hospital's own staff needed to be able to live close to work to make it an affordable proposition.

While much of the living accommodation had to be converted to meet new building standards, one of the most intriguing features of the new developments was the integration of shared space and facilities. Much of this benefited from the facilities already in place within the hospital, with some needing to be developed from scratch, albeit by adapting existing space within the former hospital buildings (given the high carbon costs of demolition and new build there was a premium on renovation whenever it was an option). As well as shared cleaning facilities there were also shared canteen facilities which were welcomed by many as a way of having a social life close to home. Other resources simply reduced the need to travel for entertainment, such as the virtual reality internet, where people can engage in team sports such as football, cricket and netball without leaving their houses.

Although a planned shared social space was repurposed – some users found it too reminiscent of student life, others failed to treat it with the necessary respect – a club space which was bookable for different interests (with members on the site and in the locality) was used by many groups, from religious, cultural and environmental interest groups, to the home-carbon-traders group, the book club and continuing education.

3.3 Looking across the scenarios

In this section different issues, such as scales of energy systems and social behaviour are compared and contrasted across the scenarios to gain a better understanding of some of their interrelationships.

Decarbonisation is present in all the scenario worlds to a greater (**Green Growth** and **Carbon Creativity**) or lesser (**Sunshine State** and **Resourceful Regions**) extent. The **Resourceful Regions** and **Sunshine State** scenarios describe inward looking worlds that are responding primarily to concerns about energy supply rather than concerns about carbon emissions and their impact on climate change. By contrast, the **Green Growth** and **Carbon Creativity** scenarios describe future worlds which are actively responding to concerns about carbon reduction. In **Carbon Creativity**, carbon accounting runs through all products and services because of the carbon market. Decarbonisation is an explicit policy here, but worked out through the CCS technology. This also allows for the possibility of business as usual (*circa* 2008) but without the same level of carbon emissions.

Currently, popular discussions about energy and climate change often confound energy efficiency and carbon efficiency. The differences in the focus in these scenarios demonstrate that these issues, whilst interrelated, are not synonymous. The relative priority given to each could lead to quite different pathways but collectively these scenarios indicate the potential to decarbonise UK society.

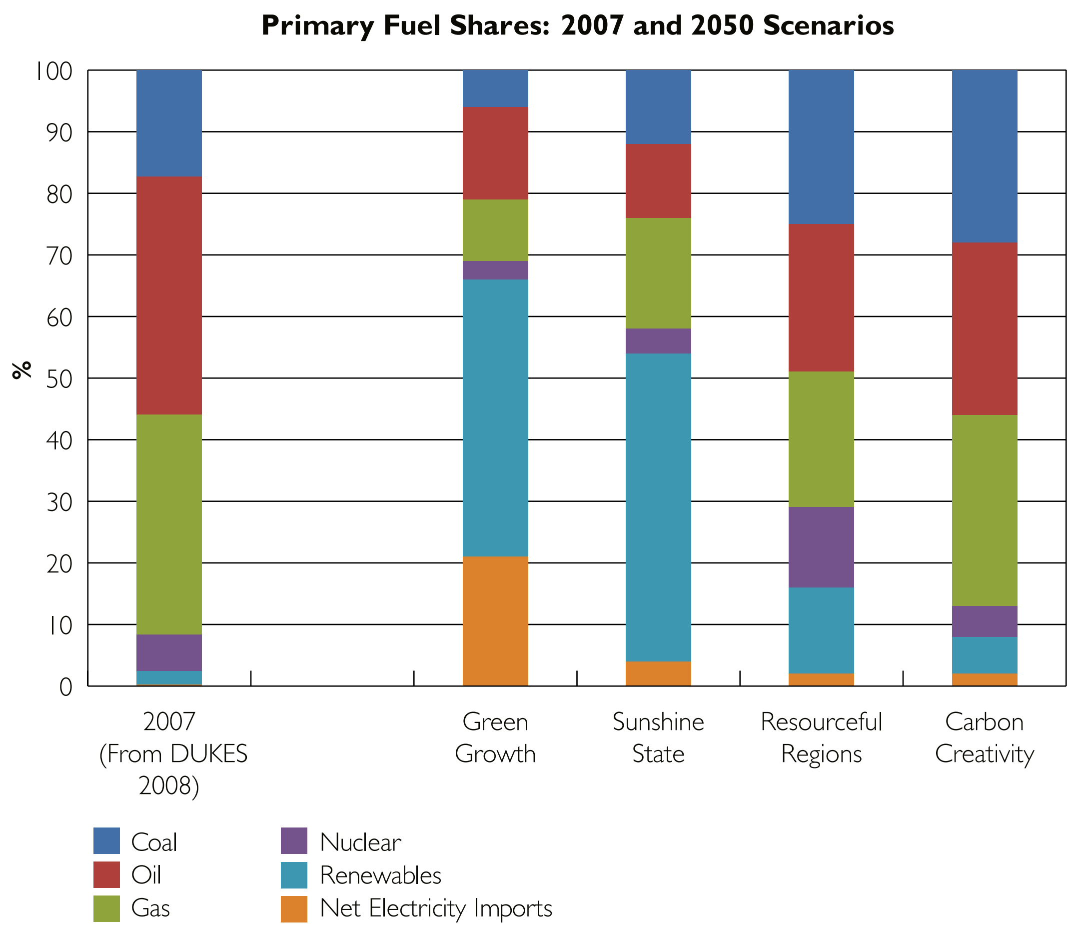
Resourceful Regions also allows for considerable diversity and flexibility in responses to scarcity of resources, including energy. It allows change to occur at different paces and in diverse ways across the country. This pattern highlights what is a feature in all scenarios but more hidden in the other three; i.e. the spatial patterning of differentiated change across the country. Thus, while the scenarios suggest different directions the country as a whole could take, **Resourceful Regions** provides a reminder that there will always be scope for variation between localities. Indeed this can be a key driver for change.

The mix of fuels used to supply energy (primary fuel shares), and to generate electricity (generation fuel shares) were estimated, relative to 2007 data, for each scenario in 2050 (see Figures 3.6 and 3.7). The figures for 2007 are based on data from DUKES 2008.[4] The scenarios' figures are based on the Project team's assumptions about the primary fuel and generation fuel shares reflected in the narrative of each of scenario. These projections show that all four scenarios envisage a significant change in the energy mix. In **Green Growth** there is a significant reduction in the total share of fossil fuels which are being replaced by renewables and electricity imports. **Sunshine State** also sees a sizable increase in the share of renewables but with less electricity imports and with fossil fuels maintaining a greater share, particularly gas. **Resourceful Regions** and **Carbon Creativity**, do not however, experience a significant growth in renewables. Instead fossil fuels still dominate particularly in **Carbon Creativity**, but with a sizeable increase in nuclear power in **Resourceful Regions**.

Various interventions, described in the scenarios, to address the four different pathways to decarbonisation are highlighted in Table 3.1. Three of these pathways are discussed extensively in later chapters in this Report because they are particularly relevant to the built environment i.e. reduced energy consumption, energy efficiency and fuel switching. The fourth pathway reduces carbon emissions or the climate impact of emissions, for example by CCS, afforestation or geoengineering. There is less emphasis on this pathway in later chapters because many of these options would not be deployed within the built environment.

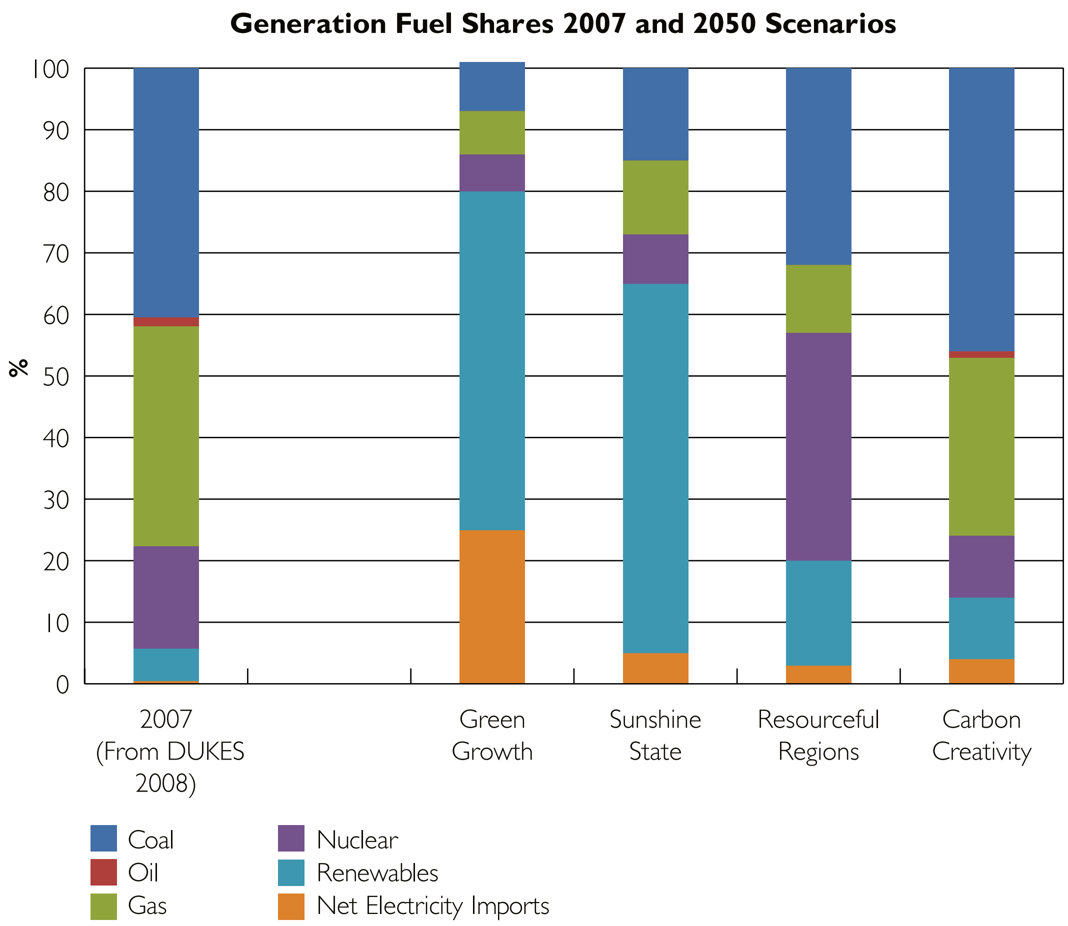
4 Department for Business, Enterprise & Regulatory Reform (2008)

Figure 3.6: Primary Fuel Shares: 2007* and the Project scenarios.



2007*: Source: Department for Business, Enterprise & Regulatory Reform (2008)

Figure 3.7: Electricity Generation Fuel Shares: 2007* and the Project scenarios.



2007*: Source: Department for Business, Enterprise & Regulatory Reform (2008)

Four issues which were considered to be key to the Project were identified from the scenario narratives and developed in later chapters. They are social and behavioural dimensions (Chapter 4); the spectrum of energy scales (Chapter 5); the renewal of the built environment (Chapter 6); and the security and resilience of future systems (Chapter 7). Each of these is considered in turn below.

Table 3.1: Interventions for pathways to decarbonisation illustrated in the Project scenarios

Interventions to:	Resourceful Regions	Sunshine State	Green Growth	Carbon Creativity
Reduce energy consumption	Campaigns such as turning down radiators and exploiting local resources. Local regulation constraining energy consumption.	Multi-utilities regulated so that their primary aim is to reduce consumption. Public/private partnerships to stimulate capacity for retrofitting. Local ownership/ management.	Regulation including banning air conditioning and heat dumping. Energy avatars. Technologies that obviate need to travel.	High prices.
Increase energy efficiency	Intelligent demand management. Regional government investment in energy storage. Retrofitting existing buildings, with regional incentives and advertising campaigns aimed at commercial properties.	Legislation to secure public control of utilities and energy grids. Home insulation. Targeted demolition.	New generation of zero-emission housing and off-site construction techniques plus demolition of obsolete stock. Regulation of construction and development activity for energy service management. Smart, centralised, power systems. Variable road pricing. Pay as you go car clubs	Regulation and economic pressures drive retrofitting of novel insulation. Investment in CHP. New development incorporates heat pumps.

Table 3.1: Interventions for pathways to decarbonisation illustrated in the Project scenarios *(continued)*				
Interventions to:	**Resourceful Regions**	**Sunshine State**	**Green Growth**	**Carbon Creativity**
Capture and store carbon emissions from the atmosphere		Afforestation programmes established as a means of carbon offsetting.		Investment in CCS as a result of high carbon price.
Increase use of low carbon fuels	Significant investment in new nuclear power.	Community funding of electric buses. Local hydrogen production schemes. Development of solar technologies. Local CHP and other schemes, based on biomass and waste.	Severn tidal barrage; electricity from hydroelectric power in the Pyrenees and Saharan solar arrays.	Some investment in new nuclear power. Carbon market and multi-national agreements. Service sector in carbon reduction. New built development incorporates local PV and other low-carbon options as well as design for climate adaptation.

3.3.1 Social and behavioural dimensions

Each of the scenarios was designed to have distinctive social values which reflect different social practices.[5] The purpose of this distinction was to explore the impact of social values, priorities and visions which are fundamental to the implementation of policy pathways in energy systems and the built environment. Development of the scenarios reveals tensions and trade-offs, for example, between different social practices, and between different scales of energy systems, depending on the relative priority given to energy security, energy saving and carbon saving because they produce quite different energy systems.

5 Values are '…desirable goals, varying in importance, that serve as guiding principles in people's lives'. Schwartz and Sagiv (1995)

Sunshine State illustrates change in social values as it is characterised by rethinking the value of economic growth, and developing lifestyles that are often associated with living and working locally. Rather than developing around a concern with energy or carbon alone, this scenario embraces a broad set of environmental values, including many other aspects of 'green thinking' concerning self-sufficiency and changes in lifestyle.

The scenarios also explore some of the potential impacts of different energy-related behaviours. In **Sunshine State** and **Green Growth**, the introduction and implementation of energy avatar systems,[6] smart metering and highly visible displays of energy consumption reflect people's willingness to engage with reducing energy consumption. In **Sunshine State**, the close relationships within communities is a key factor in driving and maintaining changed behaviour, alongside high energy costs. In **Resourceful Regions**, energy behaviour is less based on the adoption of specific technologies and more focused on changing expectations of comfort and resource use in line with regional priorities. While in **Carbon Creativity**, people's patterns of purchasing products and services are motivated by the need to reduce carbon rather than energy, driven by the extensive impacts of a carbon market.

Such changes in behaviour partly respond to the new patterns of social values discussed above but can also be traced to the impacts of specific interventions in each scenario. The various interventions which are introduced to alter behaviours to achieve decarbonisation in the Project scenarios are highlighted in Table 3.1.

Public participation and community engagement are reflected in different forms in the four scenarios. They enable, for example, the development of new social institutions to manage resources at local or community level in **Sunshine State,** and in **Green Growth,** a social movement aimed at reducing energy consumption develops. This latter phenomenon also influences the introduction of regulation which prohibits mechanisms of cooling buildings that entail the dumping of heat externally. Social support for strong regulation is important in both these scenarios.

Issues of social equity characterise all four scenarios but are tackled differently. For example, the provision of social safety nets, such as skills retraining are a feature of **Green Growth**, European Union regulation of energy utilities to prevent exclusion of the poor is present in **Carbon Creativity** and using the tax from wasteful energy consumption to fund energy improvements in poorer households is a feature in **Resourceful Regions**.

3.3.2 The characteristics of the energy systems

Consumers of energy are seen as undertaking a more active role in relation to energy systems across all four scenarios. This requires active support from government and energy suppliers, for example, in terms of the information provided and the incentives offered. It also requires a shift in social values and information technology often plays a vital role in facilitating change.

6 An energy avatar is an electronic, usually graphics-based, version of the user. In the context of energy, avatars could be used within households to provide immediate and interactive information about energy service and suggestions on how to reduce consumption.

The scenarios suggest prominent roles for regional and local governance of energy systems, in **Resourceful Regions** and **Sunshine State** in contrast to **Green Growth** where governance is primarily national. The scenarios also hold out the possibility of governance capacity being enhanced at different scales at the same time within a strong central framework, for example, with local power systems to support a slightly unstable central grid.

In each of the Project's scenarios, different scales of centralised and decentralised energy systems are visible. They all include energy systems at a number of different scales but some scenarios are considerably more decentralised than the current largely centralised system. Public engagement is present in two of the scenarios (**Green Growth** and **Sunshine State**) as supporting the establishment of community level structures. The spectrum of energy scales is discussed in detail in Chapter 5.

3.3.3 Renewal of the built environment

The renewal of the built environment is an important feature of all of the Project's scenarios. Renewal encompasses the development of new built environments, the infilling and alteration of existing environments, and the refurbishment of existing stock. All scenarios, for example, see a need for a significant degree of retrofitting of the existing building stock. Where this does not occur, the dynamics of property markets are likely to devalue energy inefficient buildings. Even though there are strong arguments against wholesale demolition programmes, there is a role for limited demolition of the most energy inefficient properties, both domestic and non-domestic, for example; **Sunshine State** (demolition of poorly constructed houses and commercial property from 1950s and 1960s) and **Green Growth** (demolition of a low-demand housing estate). Table 3.1 shows that in all the scenarios the built environment is the focus for the more efficient use of energy.

Importantly, all of the scenarios reflect a need for a radical step-change in the construction industry in terms of delivering new development appropriate to the future challenges of climate change and energy security. Achievement of such a step change is likely to require substantial policy support at local government and local planning level. Renewal of the built environment, new construction activity and the implications for energy systems is the focus of Chapter 6.

3.3.4 Security and resilience of energy systems and the built environment

Different dimensions of security are apparent in different scenarios, although the assumptions regarding future impacts arising from climate change mean that energy systems and the built environment need in all cases to be designed and planned so that they are resilient to these impacts. For example in the **Green Growth** scenario there is a reaction against heat dumping in urban areas as building occupants try to cool down their buildings in response to a warmer environment. Extreme weather contingency planning to deal with the impacts of heatwaves and flooding is a theme in the world of **Carbon Creativity**. Some of today's designs and technologies for both the built stock and urban spaces need to be sufficiently flexible to allow for changing requirements and for learning to occur over the next five decades.

Some of the scenarios reflect possible trade-offs on how much security is achieved and how much society is willing to pay. In all of the scenarios, continuity of energy supply cannot be assumed. In each scenario, society has adapted to periods of outages, both technologically and in terms of ways of living and working. In the **Green Growth** scenario, smart power systems are present as a means to manage fluctuations in energy supply; businesses and local communities invest in local energy production to offset outages as in **Resourceful Regions** where fuel cells and batteries are used to bridge outages.

Security and resilience of energy systems and the built environment is the focus of Chapter 7. In Chapter 7 the discussion examines not only resilience to large scale system risks and security of input supplies, but also the system's capacity to offer equity, to adapt to changing environmental conditions, and to accommodate diversity in supply and demand.

3.4 Using the scenarios

In Chapter 2 it was emphasised that while there is considerable potential for change in energy systems in the built environment to occur by 2050, there may also be barriers to achieving that change in the form of lock-in, path dependencies or institutional inertia. Our scenarios illustrate some of the interventions that might bring about change and they therefore give some insight as to how lock-in may be overcome.

First, it is clear that financial incentives have a significant role to play. In **Carbon Creativity** the costing of carbon into all prices leads to considerable change. In other cases – **Resourceful Regions** and **Sunshine State** – the cost of energy performs a similar function. Change in these scenarios has been driven by the assumption that these financial incentives are at a sufficient scale to have significant impact.

Second, financial incentives are supported in the scenarios by other factors. Strong regulation, underpinned by social acceptance, led to changes in construction practice and the built environment in **Green Growth** and **Sunshine State**. Institutional innovation – at a variety of scales from the local in **Sunshine State** to the global in **Green Growth** – is also important in providing new ways in which cooperation over energy production and use can be generated. **Resourceful Regions** and **Sunshine State** show that the local level can be highly productive in creating institutional arrangements which are effective in leading to change: social capital within communities or competition between strongly identified regions are alternative bases for such institutions.

Finally, it is noteworthy that innovative use of information and community technology often supports change, from the intelligent electricity networks of **Resourceful Regions**, to its use in integrating local communities in **Sunshine State** and the energy avatars in **Green Growth** and virtual reality internet in **Carbon Creativity**. It appears that ICT has a flexibility that can support other measures to overcome lock-in.

The scenarios provide a tool that can be used to inform policy development. One such approach called 'wind tunnelling' is to envisage how a policy decision taken now might play out in the different future worlds (see Box 3.2). There are also other approaches.[7] A wind tunnelling exercise was conducted using the Project scenarios in workshops with three groups: experts, stakeholders and policy makers. Participants worked with a number of possible, illustrative policy options, including fiscal, regulatory and planning options, investment and technology prioritisation, governance arrangements, educative measures, and capacity building initiatives. The outcomes reported here are a synthesis of broad principles to inform policy making in the broad area of sustainable energy and the built environment, based on participants' views.

Box 3.2: Wind tunnelling

Wind tunnelling is a process of applying scenarios to policy or strategic options[8] to determine whether they are robust against a range of possible future changes. Participants in a wind tunnelling workshop are presented with the scenarios, then asked to imagine themselves as different actors in the future worlds and to assess the effectiveness of the various present-day policies under consideration. The impact of policies is evaluated, typically on a five-point scale from highly negative to highly positive, yielding an assessment table, as shown in the table below.

Wind tunnelling evaluation

	Resourceful Regions	Sunshine State	Green Growth	Carbon Creativity
Policy 1	✓	–	–	✓✓
Policy 2	×	××	–	–
Policy 3	✓	–	✓✓	××

Policies that are positive (✓) or neutral (–) in all scenarios (such as Policy 1) are considered to be robust and therefore good candidates for implementation. Those that are negative (×) or neutral in all scenarios (such as Policy 2) can be discarded. Policies that are a mixture of negative and positive across the scenarios (such as Policy 3) can be examined further to determine if there are ways to modify them so that the negative impacts can be mitigated.

3.4.1 Understanding the systems

This section illustrates how these scenarios could be used in the development of policy and strategy. This section explores the main issues identified from these workshops which, in turn, reflect the views of those who attended.

An important set of issues that emerged from the wind tunnelling workshops concerned the need to have an in-depth understanding of sustainable energy management systems as a prerequisite for implementation. In particular, participants highlighted the need to understand at what level of governance policy interventions would be most effective, how and when lock-in could occur, and the need for field trials.

7 See Appendix II

8 Van der Heijden (2004)

As later chapters of this Report will show, the systems involved in sustainable energy management are complex and interconnected. Participants therefore took the view that different policy interventions to encourage sustainable energy management would work most effectively at different levels. For example, changing energy regulations to encourage the development of energy service providers was a policy that many participants felt would work most effectively if implemented at a national level. By contrast, policies involving 'greening' dense urban areas would likely be achieved in a more effective and innovative manner if responsibility for implementation was devolved to more localised or regional delivery bodies.

Another issue highlighted by participants was the need to understand how and when systems could become locked-in. This was viewed as being crucial, especially where the lock in is likely to lead to poor outcomes. Some participants considered that a market-based approach would be the best way to allow future systems to evolve whereas other participants took the view that market-based mechanisms alone could not break out of an undesirable lock-in, so there would be a place for strong, active intervention.

Participants also noted that effective field trials are a prerequisite for successful policy interventions or technical innovation and some felt that government should fund such trials for new or innovative technologies. Government would also need to ensure that the appropriate regulations and institutions are in place to support new innovations.

3.4.2 Incentives and enablers

A second set of issues that were raised by participants in the wind tunnelling workshops concern the importance of understanding how behaviours and values are shaped and shifted over time – a theme that is discussed in more detail in Chapter 4. Many of the policy interventions discussed would require some form of behaviour change, so an understanding of the potential incentives and enablers for change would be crucial. Particular areas that participants believed would be important to understand were: age-related value changes, behaviours in the planning and construction sectors, the impact of design on the built environment, and costs.

Values and attitudes can change over time. Workshop participants thought that this property could offer an opportunity to identify specific points or life stages at which individuals are particularly amenable to changing their lifestyles or life choices, such as in relation to the environment. Attending school, starting work, having children or retiring could be opportunities for changing habitual energy-related behaviours.

In addition to the behaviour of individuals, participants also identified the impact of regulation on the behaviour of professionals in the planning and construction sectors as an issue that underpins many policy options. They noted that there were a range of structural impediments in regulation on planning and construction that discouraged innovation. Effective restructuring of these regulations would be important in encouraging innovation directed at effective sustainable energy management.

The impact of the design of the built environment was raised in discussions on a number of the hypothetical policies. Higher density urban developments are potentially an effective way of reducing energy consumption and carbon emissions, so ensuring that these are desirable places to live was seen as critical to attracting residents in the future. However, participants felt that people are often put off such developments because they associate high density living with high-rise living and tower blocks.

Understanding how to make high density developments attractive and how to frame the discussion about high density living in such a way that avoided negative associations would likely be key to the success of any such developments in the future.

Another significant potential barrier to the implementation of many technologies is their relative cost. Participants believed that the biggest barrier to the implementation of CCS technology is the cost of installing it compared to the savings generated from the fall in carbon emissions. Similarly, for individuals, one of the barriers to developing more pro-environmental behaviour is the perceived cost of making 'green' choices. In both of these cases, an increase in the price of carbon and the pricing of other externalities should make the green choice more attractive. However, participants thought that getting the prices right was unlikely to be sufficient on its own (a point recognised in the Stern Review). For example, CCS technology has yet to be demonstrated at scale – and therefore needs more specific government support to reduce risks before a carbon price serves to encourage deployment.

3.4.3 Recognising the starting position

In developing policies for sustainable energy management and the built environment out to 2050, participants thought that it was important to consider the current situation in the UK. Two important issues were raised at the workshops: the need for retrofitting, and developing the skills base.

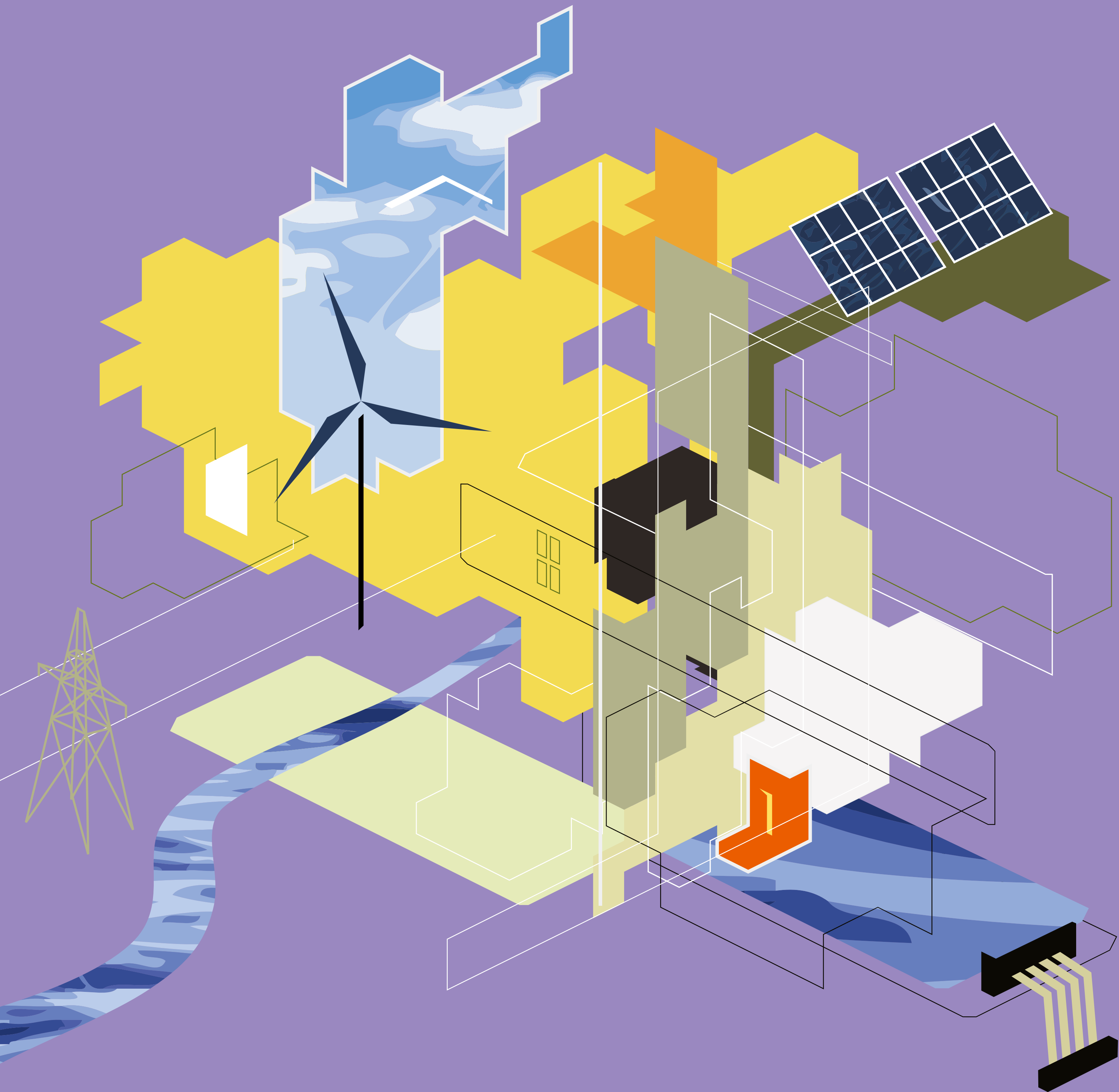
More than half of existing infrastructure will still be in place in 2050, although the precise proportion will vary depending on the level of investment in new buildings and systems. Participants considered that it was important to recognise this aspect, with policies addressing effective retrofitting and upgrading programmes, as well as regulation for new developments. Some participants expressed concern that the focus on improving energy efficiency could be on new build at the expense of improving existing stock.

A number of the hypothetical policy options discussed at the workshops would require an effective skills base for implementation. Participants highlighted the need to bring together the differing skills sets traditionally associated with energy systems, buildings and the environment more broadly. Providing skills and training for those in the construction industries (particularly those in SMEs), for example, was considered a critical success factor for many of the policy options. Participants thought that the lack of skills in the UK building industry for delivering sustainable building design could present a potential blockage to a range of policy goals. Many felt that market mechanisms alone would be insufficient to correct this failure, with there being a need for some form of more centralised state intervention. As it would likely take years to develop new skills bases, it was seen by many participants as a priority for policymakers.

Key messages

- The scenarios indicate that very different energy systems and built environments are possible depending on how various drivers develop; e.g. energy security and carbon emission priorities, social and economic values, public attitudes and behavioural norms, and governance arrangements.
- Relative priorities for energy security and reducing carbon have a significant impact on the scenarios: changes in their relative priorities could lead to quite different pathways.
- Energy systems are intertwined with social values and behaviours. Energy-related behaviours, the nature of public participation, and issues of social equity appear in all the scenarios, creating different tensions and trade-offs.
- Across all scenarios consumers of energy are seen as taking a more active role in relation to energy systems. The style of engagement differs but it requires a shift in social values, as well as support from government and energy suppliers.
- All the scenarios project a need for renewal of the built environment, which becomes the focus for the more efficient use of energy. This would necessitate a radical step-change in the construction industry.
- In all of the scenarios, continuity of energy supply can not be assumed: society has to adapt to periods of outages. There are trade-offs between the level of security and the amount society is willing to pay.
- These scenarios can be used as a tool for policy-makers to investigate the robustness and potential future impact of decisions they are currently facing.
- Four key issues highlighted in the scenarios are considered in Chapters 4-7.

4 Behaviours, values and interventions for change



4 Behaviours, values and interventions for change

4 Behaviours, values and interventions for change

4.0 Introduction

Policy makers and others seeking to shape the transition to a decarbonised economy must consider the impact of human behaviour. People, rather than buildings, consume energy services. Securing future energy supplies whilst mitigating the impact of climate change through decarbonisation will necessitate substantial changes in various aspects of human behaviour, although those changes may follow quite different paths, as the scenarios in Chapter 3 illustrate. An understanding of the determinants of behavioural change is therefore critical.

The term 'energy behaviours' is commonly used to refer to consumption behaviours that result in a demand for energy. However, the concept is broader and encompasses behaviours of individuals and communities relating to both the consumption and production of energy, and also to political actions[1] which may encourage or resist policy actions. The behaviour of organisational actors, including energy companies, land developers, and building managers, will also be critical and is considered in more detail in Chapters 5 (scales of energy systems) and 6 (new and existing buildings and future decarbonisation). 'Energy behaviours' have to be considered in the context of other forces that will influence the UK built environment and the form and use of energy-related infrastructure during the next five decades. These forces include social change, (e.g. the composition of households), the ageing demographic profile, shifts in values and lifestyles, as well as the introduction of new technologies in homes, in workplaces, and in construction, and an evolving UK economy.

This chapter begins by explaining the complexity of individuals' energy consumption behaviours and the factors that influence them. It then draws attention to the need to look beyond consumption behaviour to the role of individuals and communities in energy production, and to the way in which social values and norms influence and shape the policy environment. Frameworks for analysing individual behaviours and for categorising potential interventions to shift behaviour are considered in the context of energy behaviours. Finally, the scope for future policy interventions to influence behaviours and accelerate the pace of decarbonisation is assessed.

4.1 Energy Consumption

Energy consumption behaviours are primarily motivated by human needs and aspirations for services such as warmth, light, and leisure facilities. In economic terms, energy demand is a *derived* demand, like the demand for many goods and commodities; consumers want to cook a meal, not to consume gas. The energy consumed as a result of these behaviours is typically quite invisible to the user.[2] This contributes to poor understanding by users of the energy implications of their actions. The disconnect between people's daily activities and the energy that powers them suggests that policies which aim to influence energy demand will need to take greater account of energy-consuming behaviour in the design of interventions.

1 Devine-Wright (2005)

2 Burgess and Nye (2008)

Noting this key point, the terms 'energy demand' and 'energy consumption' are nonetheless used for convenience in this Report. Energy demand can be either 'direct' or 'indirect'. Direct energy demand arises from the consumption of services, such as heating, lighting, and ICT. However, consumption of other goods and services implicitly drives demand for energy further up the supply chain. In every commodity and service, there is an embedded amount of 'indirect energy' (and hence 'indirect carbon'), for example, in the manufacture and transport of food.

Behaviours that drive consumption of direct energy are diverse. They encompass activities such as the everyday use of lights and appliances to one-off decisions with long term consequences such as installing new heating systems, increasing levels of insulation, or moving house. Whereas 'everyday use' behaviours are largely repetitive and habitual in nature,[3] longer term purchase-related behaviours which are 'one-off', are likely to be more deliberate, reasoned or planned. These differences between habitual and deliberate behaviours offer different scope for policy interventions to provoke change (see section 4.3.2).

Both habitual behaviours and one-off decisions are strongly shaped by several influences, as well as economic factors. The ownership status of buildings is an important example. Decisions taken in the workplace, or by a tenant in rented accommodation, will involve a different set of socio-economic influences from those taken in the context of an owner-occupied dwelling. The implications of these different contexts for policy interventions relating to energy-efficiency of homes and commercial properties are analysed in Chapter 6.

Income and relative prices are important economic factors that drive the demand for energy in any context, whether commercial or domestic. But energy consumption is also driven by other social and cultural factors, which economists tend to refer to as 'tastes'. These include the symbolic and emotional meanings associated with buildings, technologies, and energy consuming practices of living and working. In this sense, buildings and energy systems are socially constructed. The meanings associated with each help to create and maintain a sense of identity, social status, sense of belonging and a sense of place. Domestic environments represent more than their physical attributes; they provide a sense of home, where people feel safe, secure and in control.[4] In a similar way, commercial buildings signal corporate identity and aspiration. Thus how people make choices about consuming services such as heat, light and ICT will be shaped in part by their given set of 'tastes', as well as by levels of income and prices.

'Tastes' and energy consuming practices are also in turn socially determined and are dynamic, varying significantly over time. For example, contemporary notions of comfort and convenience are strongly influenced by changing social and cultural practices, such as how we wash, clean and cook.[5] Energy demand in the future, therefore, will be influenced by shifts in personal preferences, shared – and sometimes contested – socio-cultural norms and values, and changing regulatory contexts, as well as by varying levels of real income and relative prices.

The importance of social and cultural factors in shaping energy consuming behaviours has policy implications for interventions designed to change those behaviours. The evidence we have reviewed in this project strongly suggests that interventions are likely

3 Shove (2003), Burgess and Nye (2008)
4 Moore (2000)
5 Shove (2003)

to fail if they are based on a partial understanding of all the factors shaping behaviour. For example, promoting a new technology as energy saving will not of itself stimulate widespread take up if the service it provides does not match what is desired, both practically and symbolically as well as in terms of cost-effectiveness. Low energy lighting technologies, which do not always match the design aspirations of consumers, are a case in point.

Psychological aspects of decision making and consumer choices have received greater attention from economists in recent decades, with the notion of 'bounded rationality' being developed to explain why consumers may not make the seemingly 'rational' cost/benefit-based choice. The new area of behavioural economics seeks to factor psychological insights into economic models – for example, seeking to explain why, when faced with too much choice, the result may be inaction.[6] In our view, these developments in economics may help policy makers develop more effective policy instruments to encourage different energy-consuming behaviours in future, if they can be incorporated into mainstream government economic thinking.

It is arguable whether policy-making should broaden its focus to encompass 'indirect energy' as well as direct energy. At present, the issues of indirect energy and indirect carbon are less commonly researched[7] and so less well understood[8] so they are given limited consideration in this Report. However, there are other dimensions of energy behaviour, beyond energy consumption, that need consideration and these are discussed in the next section.

4.2 Looking beyond consumption: broadening the concept of energy behaviour

Although the term 'energy behaviour' is commonly used to refer to consumption behaviours that result in a demand for energy, the behaviours that influence the nature of the energy system are in fact far broader in scope. They extend to a range of political actions, which may encourage or resist policy actions. This includes voting and responding to consultations as well as lobbying, signing petitions and protesting. These behaviours can shape the prevailing social and political climate and influence the future direction of development. Energy behaviours also include energy generation by producers, and actions taken by individuals and communities on the supply of energy at different scales. The behaviours of national and international energy producers are considered in Chapter 5. This chapter focuses on individual and community scale actions and the importance of social values in shaping them.

The term 'co-provision' has been used to describe the situation[9] when households or firms not only consume but also produce heat or power, through technologies such as solar PV panels or small-scale CHP plants. None of the future scenarios developed in this Project envisaged a major expansion of individually driven household generation. However, there are already instances of individuals acting as part of a larger collective, through community-based initiatives for example, to generate energy.[10] Some community initiatives focus upon energy demand as well as supply, such as the Transition Towns movement, which seeks to encourage and enable communities to

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6 Ariely (2008)

7 Although more research is being undertaken in this area, for example Jackson and Papathanasopoulou (2008)

8 Steg (2008)

9 van Vliet, B et al. (1999)

10 Walker (2008)

reduce carbon emissions through concerted local action.[11] In other initiatives, individuals purchase shares in energy cooperatives to raise capital funding for the development of low carbon energy technologies, for example the Westmill Wind Farm in Oxfordshire which is 100 per cent community owned.[12]

Theories of behaviour[13] recognise that people's actions are rooted in social values, and that the influence of values on behaviour is mediated by more specific processes, for example beliefs, norms, identity processes and intentions to act.[14] These influence the choices that people and organisations make.[15] Variation in social values might lead to different outcomes for energy systems, as they influence the ways in which economic and other benefits and costs are assessed and valued. For example, the relative balance between individual and collective values is likely to influence whether medium-scale neighbourhood or community-level technologies and systems[16] for energy generation and distribution are prioritised in the future. Developments at this scale will depend upon concerted cooperative actions by different individuals and organisations in a particular locality.[17] In one of the Project's future scenarios, **Sunshine State** (see Chapter 3) a community approach, relatively uncommon in the UK today, becomes increasingly prevalent. In **Resourceful Regions** there is also local development of energy systems but in this scenario it is implemented through regulation and the formal structures of local or regional government. The scale of energy systems is discussed further in Chapter 5.

Another characteristic seen to vary across the scenarios is the extent to which highly innovative systems arise. A transition towards highly innovative energy systems will depend not only on the economic drivers but also, in part, upon the prevalence of values which stress openness to change rather than tradition. For example, decentralised energy systems that might be considered disruptive to today's predominantly centralised arrangements or to today's environment are less likely to be embraced where social values emphasise conservatism.

Despite the significance of the social values that drive choices in energy systems in the context of the built environment, they are often left implicit and their impact may not be really identified as part of the decision-making process. We conclude that policy makers need to give greater recognition to the dynamic nature of values over time, and give more conscious consideration to their potential impact. A key rationale for the development of future scenarios as a policy tool is to stimulate consideration of these important contextual factors. The scenarios in Chapter 3 have been developed for this purpose and illustrate a variety of futures that might unfold as different values influence future energy systems and built environments in different ways.

The remaining sections of this chapter consider ways in which policy makers can take the complex and dynamic social and cultural factors into account when designing interventions to bring about change in people's individual or collective energy behaviours.

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11 see the following website: http://www.transitiontowns.org/TransitionNetwork/TransitionCommunities

12 http://www.westmill.coop/westmill_home.asp

13 e.g. Ajzen (1991), Stern et al. (1999)

14 Research across cultures has indicated a stable, universal structure to social values that forms a motivational continuum manifesting four higher-order dimensions. These dimensions in turn reflect oppositions in the motivational goals of the structure: between self-enhancement and self-transcendence, and between tradition and openness to change.

15 Recognising that people and organisations involved in energy and the built environment are diverse, encompassing householders, landlords, SMEs, large organisations, communities and so on.

16 Walker (2008)

17 Walker (2008)

4.3 Intervening for behaviour change

4.3.1 The complexities of behaviour change and the range of interventions

Since the mid-1990s, policy thinking has incorporated a belief that a change in people's behaviour will be necessary to address environmental and other challenges successfully, and that policy interventions will be needed to influence the changes. The Government Social Research network recently published a Knowledge Review exploring the general area of behaviour change. The review provides an overview of theories and models of behavioral change. It considers issues to be addressed when using such models in the design of interventions which aim to change behaviour.[18] This material is not yet in widespread use however, and the way in which behavioural change is commonly understood can be problematic.

For example, it is often assumed that change can be achieved through awareness raising or the provision of information. But campaigns based upon this assumption in the past, have typically had little success in altering behaviours despite considerable expense, for example the 'Are You Doing Your Bit?' campaign.[19] Similarly, it is often assumed that if the financial costs and benefits are readily apparent, then a behavioural change will follow. Yet the energy area provides numerous examples of seemingly cost-effective measures that are not taken up. For example, the installation of domestic insulation for those on low-incomes has not been popular, despite the incentive or subsidy offered, and relatively few households have made the effort to reap the potential benefits of good loft-insulation (see Box 4.1). In practice, the broad spectrum of energy behaviours are determined by a range of psychological, socio-cultural, economic, institutional and technological factors. Evidence suggests that provision of information alone is unlikely to achieve significant or enduring behavioural change, except when the behaviour being encouraged is relatively convenient and cheap in terms of time, money, effort and social disapproval.[20]

Box 4.1 Case study – Domestic insulation

The Department for the Environment, Food and Rural Affairs commissioned a study on household energy efficiency in 2006 to identify any 'perception gap' in the knowledge of the costs and benefits of domestic insulation – the difference between the actual costs and benefits of installing cavity wall or loft insulation and respondents' perceptions of those costs and benefits

Many respondents' perceptions of the costs of domestic insulation were £500-£1000 higher than actual costs. The survey found that up-front costs were a much more important determinant in take-up decisions than benefits. A sizeable majority of respondents had very pessimistic expectations of installation times. The average disruption cost for loft insulation was estimated to be £47 for loft insulation and £68 for cavity wall insulation. Installer accreditation was found to be highly influential in the take-up decision with its implicit value calculated to be £400 for loft insulation and £580 for cavity wall insulation.[21]

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18 http://www.gsr.gov.uk/resources/behaviour_change_review.asp

19 £3.4 million in 1998–99, £7.0 million in 1999—2000 and £9.3 million in 2000–01. Hansard *HC Deb 19 September 2002 vol 390 cc294-5W*

20 Steg (2008)

21 Oxera (2006)

Categorising behaviours: The Department for the Environment, Food and Rural Affairs has produced a broad framework for describing pro-environmental behaviours which is helpful in analysing the complexity of energy behaviours and informing the development of policy interventions (see Box 4.2). The different dimensions of energy behaviour in this framework are broad-brush descriptions at the level of the national population, and as such are inevitably imprecise.

Box 4.2 Department for the Environment, Food and Rural Affairs: Framework of pro-environmental behaviours:

Behaviours can be classified along different dimensions. They include:

- willingness/unwillingness to act;
- ability/inability to act;
- high/low impact upon CO_2;
- and common/uncommon behaviour.

For example, installing **microgeneration technology** is a behaviour characterised by:

- relatively low levels of willingness to act (approx 30 per cent of the population);
- low levels of ability to act (7 per cent);
- medium level of CO_2 impacts;
- being uncommon (currently less than 1 per cent of the UK population has done so).[22]

By contrast, **better energy management** is a behaviour characterised by:[23]

- willingness (80 per cent) to act;
- high levels of ability to act (100 per cent);
- medium level of CO_2 impact;
- medium level of commonality.

The model includes some energy behaviours pertinent to this Report, such as installing insulation products, installing domestic microgeneration through renewables, and better management of energy.[24] As part of the framework, other energy behaviours have been researched, including a switch to green tariffs, and purchase of more energy-efficient appliances.[25]

Categorising 'the public': The dimensions of behaviour are complemented by a segmentation model that subdivides 'the public' into seven distinct groups on the basis of findings from market research. The groups are distinguished on the basis of environmental indicators such as ecological worldview; socio-demographics; lifestyle; attitudes towards past and current behaviours; motivations and barriers; knowledge and engagement. The resulting groups have been labelled:

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22 Department for Environment Food and Rural Affairs Attitudes and Behaviour Survey (2007)

23 Better energy management includes: more efficient use of appliances for space and water heating; reducing the temperature that homes are heated to; cutting down on the use of air conditioning; and turning off appliances when not in use.
Department for Environment Food and Rural Affairs (2007b)
Department for Environment Food and Rural Affairs (2007c)

24 Department for Environment, Food and Rural Affairs (2008)

25 Brook Lyndhurst for Department for Environment, Food and Rural Affairs (2007)

- 'positive greens';
- 'waste watchers';
- 'concerned consumers';
- 'sideline supporters';
- 'cautious participants';
- 'stalled starters';
- 'honestly disengaged'.

This subdivision informs a social marketing approach to behavioural change, which assumes that different forms of intervention are needed, appropriately tailored to the characteristics of each group.

Categorising interventions: Interventions designed to change individuals' behaviours can, in turn, be categorised in different ways to aid analysis. Psychologists distinguish between informational (making people aware of facts), normative (factoring in the influence of social norms on target audiences) and structural (tackling the wider regulatory, economic or technological factors) types of intervention.[26] Environmental economists sometimes distinguish between, 'command and control' (mandatory obligations or restrictions), 'market-based interventions' (incentives vis taxes, subsidies, traded permits etc) and 'other institutional' approaches.[27] The Department for the Environment, Food and Rural Affairs has used an overarching framework for behavioural change – the '4Es model' developed by the Sustainable Consumption Roundtable – to inform its Environmental Behaviours Strategy.[28] This model involves four strands of intervention: engaging, encouraging, enabling and exemplifying (see Box 4.3). The four strands are not mutually exclusive, and might be used to reinforce each other to maximise the likelihood of enduring behavioural change.

Box 4.3 '4Es model' for environmental behaviour change

Engaging – involves measures that provide opportunities for the public to participate in debate, through community and social networks, and marketing.

Encouraging – involves measures that provide fiscal, legislative or accredited rankings, to reward certain behaviours and discourage others.

Enabling – refers to methods that provide core infrastructure, creating a supportive framework for action. This includes measures such as setting standards for product or building labelling as well as amending building regulations or setting new standards such as the Code for Sustainable Homes.

Exemplifying – refers to measures that demonstrate Government commitment and leadership, providing a role model for change and challenging existing social norms.

There are several ways in which policy interventions under the broad headings of the '4Es model' may be used to stimulate the four pathways to decarbonisation identified in Chapter 1:

26 Steg (2008)
27 e.g. Perman et al. (2003)
28 Department for Environment, Food and Rural Affairs (2006)

- reducing energy consumption;
- promoting efficient use of energy;
- reducing carbon emissions per unit of energy;
- encouraging a switch in fuel types.

However, when the four approaches to intervention are coupled with the various behaviours and motivations associated with the possible pathways to decarbonisation, there is scope for confusion and mixed messages. For example, carbon emission technologies such as CCS may decrease the energy efficiency of a system; changing fuels might increase energy cost; energy efficiency might result in increased energy consumption through rebound effects (where financial savings from an energy efficiency measure are either directly ploughed back into a higher level of energy service or used to purchase additional energy-using)[29 30]. Psychological research on ambivalence indicates that campaigns for behaviour change may backfire in some circumstances.[31] Also, the acceptance of policies designed to 'encourage' change is often determined by their perceived effectiveness, for example whether they are believed to be likely to help remedy the problem in question[32] and what impacts there might be upon other social problems, notably fuel poverty. Furthermore, as discussed in section 4.1, individual behaviours occur in a wider socio-cultural context and the success of particular policy interventions will be influenced by prevailing norms and values. This is illustrated by the different interventions that shape the four different future scenarios described in Chapter 3 (see Table 3.1).

Given the complexity of energy behaviour described above, we conclude that no single, simple, intervention strategy is likely to prove successful in isolation. The achievement of enduring behavioural change is likely to require:

- systematic, concerted action;
- employment of a range of tools and strategies;
- sustained implementation over time;[33]
- tailoring to specific groups or sectors, rather than 'the public' or 'industry' as a whole.

In considering how interventions might be deployed to achieve change along the different pathways to decarbonisation, it is helpful to look separately at those targeted on energy savings and those targeted on carbon reductions. Changes in behaviour motivated by energy goals may or may not be associated with changes directed towards carbon goals, and vice versa. Current energy policies directed towards consumers generally emphasise energy efficiency and energy saving goals, although polices to support local scale renewables and microgeneration are oriented towards

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29 Examples of rebound effects might include turning up the thermostat when insulation has been improved, or spending savings from improved insulation on a plasma TV or a patio heater. Evidence suggests that direct rebound effects are typically less than 30 per cent for households. Much less is known about indirect effects. In some cases, particularly where energy efficiency significantly decreases the cost of production of energy-intensive goods, rebounds may be larger.

30 Sorrell (2007)

31 Government Office for Science Tackling Obesities: Future Choices – Lifestyle Change Evidence Review. "…people who have high ambivalence towards an issue scrutinise information, take note of overly simplistic messages, and identify flaws – and may then form more negative attitudes to recommended behaviours".

32 Steg (2008)

33 Gardner and Stern (2002)

carbon reductions. Regulation in the built environment has until recently emphasised energy efficiency, although new 'zero carbon' regulations are shifting the emphasis to carbon efficiency and fuel mix in new developments. Policies aimed at altering the behaviour of large energy suppliers have both energy efficiency and carbon reduction dimensions.

4.3.2 Interventions focussed on improving energy efficiency and reducing energy consumption:

Interventions to encourage and enable energy efficiency behaviours have received considerable attention because they contribute to decarbonisation and also help to address fuel poverty, without implying acceptance of reduced levels of energy-services. In 2005 the UK Government published an Energy Efficiency Innovation review [34] which examined how a step-change in energy efficiency in domestic, business, and public sectors could be delivered cost effectively, and how energy efficiency improvement could be embedded into decision making across the economy. The review considered a range of instruments for making improvements in energy efficiency in addition to those expected from the policies in place at the time. Additional instruments put forward included tighter product standards, bigger obligations on utilities to invest in energy saving, tighter building regulations, and more support for R,D&D in energy efficient technologies.

Enabling action at the household level has included tighter building regulations for insulation, glazing and boiler installation. Provided that regulations are properly implemented and monitored for compliance,[35] this approach ensures that household consumers can use less energy to achieve the same level of energy services. [36] Interventions like this, designed to improve the efficiency of the infrastructure, have a long-term impact and obviate the need for conscious change in habitual behaviour by the consumer. But they do need consumers to opt for the energy efficient products and buildings. The requirement to label white goods with energy efficiency ratings has had some success[37] in influencing both manufacturers and purchase decisions. A similar idea informs the Energy Performance Certificates for buildings but it is less clear what the impact will be given that very different social and economic dimensions influence choices of dwelling and commercial location, compared to the factors influencing purchase of appliances.

Subsidies and grants have been deployed to reduce the relative price of loft insulation, cavity wall insulation, more efficient boilers and other goods, providing some incentive for consumers to install them. But the challenge remains to design interventions based on more than a simple economic analysis and which adequately factor in the 'taste' and wider social components of behaviours and choices. The high value placed on installer accreditation (see Box 4.1) offers an example of the aspects of consumer decision making that may need to be considered when designing incentives for action. Subsidies and grants could also provide incentives to companies to install equipment that is more efficient, or to build factories and offices that reach certain efficiency standards, though again factors beyond the immediate economics may need to be considered. The scope

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34 HM Treasury; Department for Environment, Food and Rural Affairs; Carbon Trust; Energy Saving Trust (2005) http://www.hm-treasury.gov.uk/4030.htm

35 Communities and Local Government (2008)

36 Some measures work on both fronts. Smart meters, for example, might be imposed on households as part of a command and control type policy but because of the increased information, this should enhance consumers' awareness of the relative costs and benefits so that their response to economic incentives would be greater.

37 Winward et al. (1998)

to upgrade the energy efficiency of the built infrastructure through these and other measures is considered in more detail in Chapter 6.

Whilst interventions to improve energy efficiency are typically directed at consumers as individuals, other interventions seek to encourage collective actions to use energy more efficiently, notably through public or voluntary sector initiatives, such as Community Action for Energy[38] and initiatives led by Global Action Plan.[39] These aim to facilitate information-sharing and cooperative actions between different consumers, whether individual householders or organisations working in partnership.

An alternative approach to targeting individuals or local communities is intervention to require and enable energy utility companies to address energy efficiency on behalf of their customers. A mechanism adopted by several European countries is the Tradable White Certificates scheme, whereby energy companies are required to undertake energy efficiency measures for the final user. In Great Britain, under the Energy Efficiency Commitment, electricity and gas suppliers were required to achieve targets for the promotion of improvements in domestic energy efficiency. This has been superseded by the Carbon Emissions Reductions Target which shifts the focus more explicitly to carbon savings.

At a more macro level, direct command and control intervention could potentially apply to electricity production. For example, power producers might be 'forced' in future to produce electricity using a certain level of efficiency per unit of power generated. Certain levels of energy efficiency might be imposed on particular manufacturing processes, although some argue that this would be less efficient than alternative policies, such as the use of cap and trade systems.

Interventions for direct energy saving also typically emphasise encouragement and enabling approaches, including targeted information campaigns to shift habitual behaviours, such as persuading individuals to use less energy and save money, by lowering thermostat levels or switching off lights and radiators in rooms that are not commonly used. Energy saving could also, at least in theory, be encouraged by approaches such as energy taxes to increase the relative price of energy, with the intention of providing incentives for consumers to buy less energy. However, relatively low estimates of the price elasticity of aggregate UK energy demand[40] suggest that higher prices will have only a limited impact, although recent protest behaviour by consumers and hauliers in response to rising petrol and diesel prices suggests that large price changes might alter behaviour. However, such behaviour also implies that inducing large increases in energy prices would not, under present conditions, be politically acceptable. Also, an approach based on increasing prices would present challenges for the objective of fighting fuel poverty.

Even when people are motivated to reduce consumption, a complicating factor is the invisibility of the energy that powers the services consumed. People tend to rely on trial-and-error when using appliances and often hold inaccurate beliefs about how appliances work and the energy they consume. For example, the larger the appliance, the more energy it is believed to use.[41] Some interventions attempt to increase the visibility of energy consumption by providing information to energy users about the volume, cost and environmental impacts of their consumption, such as via smart

38 http: //www. energysavingtrust.org.uk/café/welcome/

39 Global Action Plan is an NGO that specialises in implementing community initiatives and projects

40 see for example Hunt et al. (2003)

41 Schuitema et al. (2005)

meters or visual displays. Research has indicated that feedback can reduce energy consumption by up to 20 per cent, though many studies claim more modest savings.[42] There are good arguments for promoting this visibility. However, smart meters are limited unless they are connected to energy markets and other sources of real-time information. Only then can they provide a full range of services such as time of day pricing (so that consumers can choose to operate appliances when prices are low), carbon emissions and even remote control (e.g. to switch on appliances automatically when prices fall below a selected threshold). Such fully functional smart meters could help accelerate the pace of change in energy consumption patterns.

When the focus of intervention is on energy saving and energy efficiency, there is an implicit message about the importance of 'economic' savings. The issue of 'decarbonisation' becomes secondary or even invisible. These interventions beg the question of whether energy efficiency and saving is inherently desirable or whether, as the name implies, renewable sources might offer potential for future profligacy. Arguments for energy efficiency and energy savings may stand more chance of success when incomes are under pressure and/or when energy prices are high, but risk being unstable as a motivation for sustained behaviour change unless there is an accompanying shift in wider values. If, as this Report argues, it is the case that energy efficiency and energy savings have a crucial contribution to make to the transition over the next five decades for reasons that transcend short-term economic expediency, then interventions may need to go beyond encouraging and enabling energy efficiency and savings and start to engage people in more sophisticated discussion of the role of energy systems in the built environment. That in turn may help develop more appropriate strategies for enabling and encouraging change, whether the change leads to more energy conscious decisions and habits on the part of individuals, or to a willingness to transfer greater responsibility for management of energy efficiency to others – be it energy or building service companies or community based organisations.

Despite the limitations of a focus on energy efficiency and saving, focussing on changing behaviours for carbon efficiency or for fuel switching is more challenging in the short term.

4.3.3 Interventions focussed on carbon emissions and changing the fuel mix

There have so far been few consumer-oriented interventions focussing directly on carbon emissions or fuel switching, although the Carbon Emission Reduction Targets directed at utility companies, is designed to impact on company behaviour and encourage them to focus on reducing carbon emissions from the energy they supply (see Chapter 5). Standards and limits for carbon emitted might, in theory, be set at every level from the household right through to power generation, although problems of policing and compliance would exist at the more disaggregated level. Future prospects for enabling consumers to factor carbon considerations into their decision-taking include the idea of carbon labelling. However, carbon labelling is seen as complex and problematic,[43] and is only likely to induce behavioural change if it is perceived by customers to be credible and trustworthy.

A major issue for future consideration concerns personal and household carbon allowances and trading, such as those recommended recently by Parliament's

42 Darby (2001), cited in Burgess and Nye (2008)

43 Burgess and Nye (2008)

Environmental Audit Committee,[44] which would send price signals to individuals and households to conduct more carbon efficient lifestyles. On a larger scale, there is potential for government-set emission limits for power production, which would 'force' electricity producers to install cleaner technology such as CCS or to switch fuels. Even more radical would be overriding the commercial interests of the energy markets and insisting on carbon-intensive primary fuels being replaced by nuclear or renewable energy. It is likely that some form of public sector intervention and/or financial assistance will be required. Measures which distort or override markets would be harder to implement in future scenarios where market-based approaches are the norm.

The kinds of behaviour change needed to influence the mix of fuels used in the UK are wide ranging. A shift away from gas would require changes in most domestic and much commercial heating, and shift the cooking practices of many. The scale of change would be costly. It might be justified by a large change in relative prices of fuels, or possibly delivered though a programme of managed change as was effected in the 1960s in the switch from town to natural gas. Shifting the mix of fuels involved in electricity generation tends to be seen as an issue for large-scale generators. Where interventions seek to enable individuals to engage with the issue of fuel mix, it is typically at the level of home or commercial buildings being offered grants or subsidies to install micro-generation (e.g. through the Local Carbon Buildings Programme). Government regulation of the proportion of biofuels supplementing petroleum is another measure which indirectly forces consumers to consume less fossil fuels, but the global carbon impact of such measures is a contentious matter.[45]

As with interventions to encourage greater energy efficiency, some interventions to encourage the switching of fuel types have targeted collectives or communities. However, they have been unevenly supported by public bodies across the UK, despite favourable outcomes.[46] For example, in Scotland, there are several initiatives to provide information, support and financial grants to community groups who wish to set up local renewable energy initiatives such as Scottish Community and Householder Renewables Initiative, run by the Energy Saving Trust and the Highlands and Islands Community Energy Company.[47] A similar initiative was piloted in England between 2002 and 2007 by the Countryside Agency and supported by the Department for the Environment, Food and Rural Affairs and the Department for Trade and Industry but was recently discontinued.

Another key, essentially market-based, instrument to provide incentives for fuel switching in the UK is the Renewables Obligation (RO). This requires suppliers to source an annually increasing percentage of their sales of electricity from renewable energy. For each megawatt hour of renewable generated, a tradable certificate called a Renewables Obligation Certificate (ROC) is issued. The aim is to use the market and price mechanism to ensure that firms choose to use more renewable energy. Despite the availability of support from the RO and predecessor mechanisms, the rate of deployment of renewables in the UK has been slow compared to some other countries, particularly Denmark and Germany. The proportion of UK electricity coming from renewables has risen from 2 per cent in 1990 to around 5 per cent at present. Within this, RO-eligible renewables have increased almost threefold since the

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44 House of Commons Environmental Audit Committee (2008)

45 Renewable Fuels Agency (2008)

46 Walker et al. (2008)

47 www.hie.co.uk/community-energy.html

RO was introduced in early 2002, giving about 3.0GW of new capacity, with about another 9.5GW being granted planning consent.[48] The RO has been criticised for being ineffective and more financially risky for investors than the alternative 'feed-in tariff' mechanism which is in operation in Germany and some other EU countries.[49] Feed-in tariffs give renewable generators a fixed, premium price for all electricity they generate. They can also be applied to renewable heat production. It has recently been announced that a feed-in tariff for small scale renewables will be introduced in the UK – with a possibility that a similar scheme for renewable heat will also be implemented.

The prevailing market based instrument for reducing carbon is a 'cap and trade' system for power producers and manufacturing firms such as the current European Union Emissions Trading Scheme (EU-ETS). For firms and public sector organisations not covered by EU-ETS, a new trading scheme known as the Carbon Reduction Commitment is being implemented. If implemented successfully, such schemes could send market signals that would result in a reduction in carbon emissions. A fully efficient carbon trading system would put a market price on carbon that would provide incentives to both power producers and producers of goods and services to use less carbon-intensive processes. It could be widened to cover large and small producers.

Carbon taxes, as opposed to energy taxes discussed in 4.3.2 above, would change the relative prices of the fuels according to their carbon content or emissions. This would provide incentives to both household consumers and primary energy producers to reduce their demand for the more carbon intensive fuels, but may not necessarily alter the level of energy services used or the overall demand for energy.

The interventions discussed in the two sections above fall within the 'enabling' and 'encouraging' category. However, there is a clear need for 'exemplification' from government and the wider public sector. We develop this point in Chapters 6 and 8.

4.4 A complex environment

Tackling the human dimension of energy systems and the built environment in the future will be highly challenging, and no single, simple, intervention strategy is likely to prove successful in isolation. The evidence base compiled for this Project[50] makes clear that behaviours associated with energy consumption and energy production are shaped by and arise from social, psychological, economic and political processes, and values. Sustained change requires systematic intervention tackling the variety of influences. This is becoming increasingly well recognised, as the work done by the Department for the Environment, Food and Rural Affairs in developing models of behaviour and social marketing frameworks illustrates.

The process of transitioning to a decarbonised energy system will be helped by behaviour changes that lead to energy savings, whether through direct reductions in consumption or through improved energy efficiencies. However, development of policies to improve energy efficiency will need to be accompanied by a transition to behaviours that enable an energy system based on a different fuel mix, with more renewable and low-carbon fuels, or to behaviours compatible with a world where CCS, or as yet unproven geo-engineering processes, permit the continued use of fossil-fuels without the release of emissions. The fact that there is not a single pathway

48 Department for Business, Enterprise and Regulatory Reform (2008)

49 Mitchell et al. (2006)

50 Energy Policy (2008) Special Issue, 36 (12).

through the transition to decarbonisation, that different routes require different and not always compatible behaviour changes, and that people's motivations in respect of energy efficiency and of reduced carbon emissions may well differ, creates a complex environment for the development of policies to effect behaviour change. Importantly, using arguments and messages for energy efficiency as a proxy for discussion of carbon reductions risks confusing matters further, and will become harder to sustain as decarbonised energy supplies grow.

Changing the day-to-day habits of a nation is challenging and will require sustained attention to social values and socio-economic dimensions. Interventions to shift the environment in which energy users make decisions and live their day-to-day lives are attractive options as the number of actors that need to be influenced is relatively small, although even here there are many small companies and individual decision makers involved. The insights from this chapter on energy behaviours and values inform the next two chapters on scales of energy systems (Chapter 5) and on new and existing buildings and future decarbonisation (Chapter 6).

Key messages

- Decarbonisation, whatever paths it follows, will necessitate substantial changes in behaviour, although those changes may follow quite different routes.
- Energy behaviour encompasses energy demand by consumers, energy generation by producers, and social and political actions regarding the supply of energy at different scales: individual and local, regional and national.
- No single, simple intervention strategy for changing behaviours is likely to prove successful in isolation.
- Government should give more attention to communicating clearly about carbon, and avoid using energy efficiency as a proxy.
- Increasing the visibility of energy consumption is important, i.e. by providing information to energy users about the volume, cost and environmental impacts of their consumption, e.g. via smart meters backed up by IT systems to make them 'super smart'.
- Interventions to reduce energy consumption and improve energy efficiency over the next five decades will need to go beyond 'encouraging' and 'enabling'. Government needs to stimulate 'engagement' with a more sophisticated understanding of the role of energy and the built environment leading people either to take conscious decisions to reduce their energy consumption, or to transfer greater responsibility for management of their energy efficiency to innovative multi-utility service companies or community-based organisations.
- Such a transfer of responsibility to energy service organisations will need appropriate regulatory and market incentives from government for the creation of these bodies.

5 Scales of energy systems

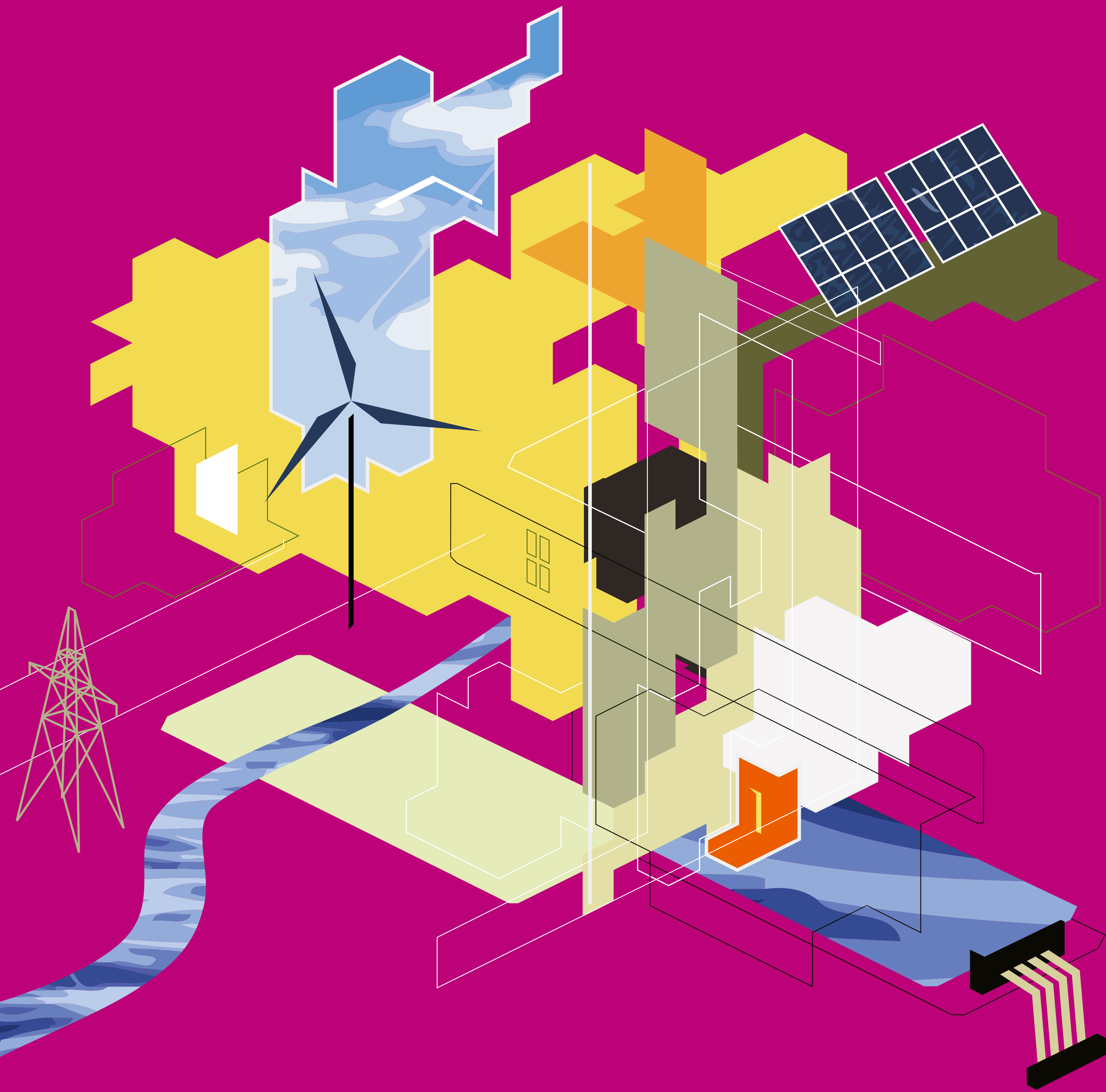
5.0 Introduction

5.1 What is 'decentralised energy'?

5.2 Scale and the current energy system

5.3 Drivers for changes in scale

5.4 Public engagement and the scale of energy systems



5 Scales of energy systems

In this chapter we discuss how energy systems comprise several scales.

These scales encompass not only the technologies that are so readily identifiable but the regulatory frameworks and institutions that are part of the overall picture.

5 Scales of energy systems

5.0 Introduction

The scale of future energy systems in the UK will have a significant impact on the evolution of the built environment. Yet, as we have seen in Chapter 4, the scale at which energy systems emerge is closely connected with social and economic values and behaviours and the nature of governance at local and national levels. Today's centralised energy system has a particular relationship with the built environment through the way people understand and use energy services. Electricity is centrally generated in remote power plants; the majority of heating systems are fuelled by gas which is centrally distributed; and petrol for vehicles is refined and distributed through a few large depots. Electricity generation within the built environment is rare, while district heating networks are virtually absent.

A key issue for decision makers is whether the strongly centralised approach to energy provision that developed in the post-war period can continue to meet the needs of the economy and society over the coming decades. The current pattern of mainly large-scale power plants and centralised delivery infrastructures for electricity, gas and oil may be sufficiently flexible to meet the dual challenges of energy security and climate change, but this is by no means certain. Meeting these challenges could require a significant shift so that energy systems are located at a range of scales within the built environment. Indeed, some government policies such as those to increase the role of renewables imply that such a shift needs to start soon.

This chapter explores the scope for deploying energy systems that are both centralised and decentralised. Since there is considerable confusion over the meaning of the term 'decentralised', the chapter first sets out some definitions and explores the range of scales that this term encompasses. The chapter then considers some of the critical drivers for future energy systems and what they might mean for system scale. The chapter also focuses in some detail on the relationship between citizen engagement with the provision of energy services at different scales.

5.1 What is 'decentralised energy'?

The defining characteristic of decentralised energy is that energy is generated close to the place where it is used, so that transmission of electricity, heat and other energy carriers is minimised. A broad technical definition, offered by the former DTI and the energy regulator Ofgem, includes distributed electricity, usually defined as power generation that is connected to the low voltage distribution network at 132kV and below.[1] It also includes CHP technologies that are similarly connected, and decentralised applications of technologies that provide heat, such as biomass, solar thermal and heat pumps.

In addition to this technical definition, decentralisation has organisational, regulatory, governance and social components. It might mean that the ownership of energy infrastructure is in the hands of businesses, individuals, community groups and local authorities as well as energy companies. This would contrast with the centralised ownership that exists today where multinationals dominate in most parts of the energy

1 For example, Department of Trade and Industry (2006c)

system (e.g. oil extraction and supply, electricity generation, household appliances and power plant equipment). In addition, markets and regulations could be decentralised so that different regional or local priorities are reflected in devolved policy for energy systems. Rather than the current dominance of national and international policy, a decentralised future might be one in which the policies of local authorities and local or regional trading systems are more important.

As these definitions suggest, decentralised energy is a wide-ranging category that encompasses energy systems at different scales. Each can involve different technologies, institutions, policy and behavioural issues. Decentralised energy can mean a solar hot water panel on a house, a CHP system for a block of flats, or a larger power plant in a city centre or a rural area. It can also mean new roles for building occupants, not only as consumers of power, but as 'co-providers',[2] blurring the distinction between producer and consumer. Co-provision suggests new behavioural practices, for example householders checking the levels of heat or power produced by their own systems using 'smart' metering technology[3] and scrutinising tariff levels to decide whether to directly use their energy or to sell it to utilities by exporting it back into the grid. Decentralised energy also suggests new organisational structures involving community ownership to different degrees and in different ways, including cooperatives, development trusts and community charities. These implicate different forms of community – both of locality and of interest.[4]

These different dimensions are explored in Table 5.1. Each row of the table represents a different scale at which energy systems can be deployed – from international to household. The columns distinguish between the technical, governance and regulatory characteristics of energy systems at these different scales. The cells of the Table provide some brief illustrative examples of the technologies, institutions and regulations that might apply at each scale. An energy system in the future might combine centralised and decentralised elements. For example, a hybrid energy system could include centralised power plants, a mixed transport system fuelled by oil and locally produced electricity, and significant heat and power generation in towns and cities. Institutionally, hybrid organisations could become more prevalent, with large-scale windfarms being co-owned by multi-national companies and communities, when one or more turbines are 'gifted' to the community as a way of ensuring local benefit.[5] Here the ability to influence investment choices and behaviour by citizens and firms would be shared between international, national and local institutions.

2 Van Vliet and Chappells (1999)
3 Keirsted (2008)
4 Walker (2008)
5 Centre for Sustainable Energy et al. (2007)

Table 5.1: The spectrum of energy system scales

	Geography	Example Technologies	Example Institutions	Example Regulations and Incentives
Centralised	International	Gas pipeline linking Norway and the UK	International Energy Agency; European Union	EU Emissions Trading Scheme
	National	Central power plants; centralised electricity and gas grids	Central government; Ofgem (the energy regulator)	Electricity market rules (known as BETTA); Renewables Obligation
Decentralised	Regional/City	City-scale heat and power systems (e.g. Mitte CHP plant in central Berlin)	London Climate Change Agency; Regional Development Agencies	Regional spatial strategies; financing for South West 'Wave Hub'
	Town/Neigh-bourhood	CHP schemes (e.g. Elephant and Castle regeneration area).	Local authorities	'Merton rule'[6] to encourage renewables; local grants
	Building	Building insulation; efficient appliances; microgeneration (e.g. solar hot water and micro-CHP)	Community organisations; building owners and managers	Low carbon buildings programme; Going for Green

6 The 'Merton Rule' is named after one of the first London Boroughs to implement a planning requirement that all major developments use on-site renewable energy generation to supply 10 per cent of their energy requirements.

5.2 Scale and the current energy system

As we saw in Chapter 2, decentralised energy has been important in the past in the UK. But the nation's current energy supply is highly centralised. Two thirds of UK heating demand is met by the centralised natural gas supplies.[7] The 2006 Energy Review estimated that less than 10 per cent of heat demand is met by off-grid heat generation, in other words by sources other than gas or electricity. The same review stated that less than 10 per cent of the UK's electricity is supplied from renewable energy or CHP plants connected to the electricity distribution network.[8]

The potential advantages of decentralised energy for meeting current and future challenges have led to extensive discussion and research in the policy, business and academic communities. The focus of much of this activity has been on electricity. Heat has only been analysed in detail by government relatively recently. An important sign that these advantages were being taken seriously was the government-industry Embedded Generation Working Group, which reported in 2001 on a range of issues on network access.[9] This was followed by a series of other committees and reviews such as a call for evidence on barriers and incentives for decentralised energy in 2006.[10]

Despite this significant activity, there have been only marginal changes in the contribution of decentralised energy in the UK. The deployment of CHP plants grew relatively quickly in the 1990s, but their total capacity has levelled off at about 5.5GW.[11] Most of the heat that they generate is for industrial processes rather than to heat buildings. Investment in microgeneration is growing slowly, despite the availability of government grants. The number of installations remains at about 100,000. The contribution of renewable electricity is limited, having increased from 2 per cent of UK electricity in 1990 to 5 per cent in 2006.[12] However, not all of this is decentralised since it includes output from relatively large hydro stations.

There are many reasons for this limited progress.[13] CHP investment has slowed due to a rise in the relative costs of gas and the absences of the local utilities that normally install district heating networks in other northern European countries. For micro-generation, the need for planning permission (which has now been removed), the hassle factor, high up front costs and a stop-start grant programme have all mitigated against investment. Larger scale renewables face significant planning barriers and long waits for grid connection.

7 Department of Trade and Industry (2007)
8 Department of Trade and Industry (2006c)
9 Embedded Generation Working Group (2001)
10 Department of Trade and Industry (2006a)
11 Department for Business, Enterprise and Regulatory Reform (2007)
12 Department for Business, Enterprise and Regulatory Reform (2007)
13 Wolfe (2008), Woodman and Baker (2008)

5.3 Drivers for changes in scale

As the scenarios presented earlier in this Report demonstrate, future changes in energy systems and the built environment could have a variety of impacts on the scale of energy systems. In some scenarios, the current centralised energy system prevails, meaning that there is little energy generation embedded within the built environment. In others, the built environment changes to absorb significant energy generation. Table 5.2 summarises the scale of energy systems in 2050 within each of the four scenarios. Within the table, darker shading is used to denote scales which are particularly prominent in a given scenario.

Table 5.2 Scale in the Project Scenarios

	Geography	**Resourceful Regions**	**Sunshine State**	**Green Growth**	**Carbon Creativity**
Centralised	International				
	National				
Decentralised	Region/City				
	Town/ neigh-bourhood				
	Building				

Key: Black shading denotes a major contribution from technologies, institutions and/or regulations; dark grey denotes a significant contribution; light grey denotes a modest contribution; white denotes little or no contribution.

How might these changes in scale come about? As this Report has already noted, there are a number of critical drivers of energy systems and the built environment, many of which will have implications for the scale of energy systems in the future. In this section, five drivers are analysed to understand better their impact on energy system scale. We have already identified climate change and energy security as important drivers in Chapter 1. In this section, technology trends, governance of energy markets and social change have been added as additional drivers of particular importance to scales of energy systems.

5.3.1 Climate change

As discussed in Chapter 1, climate change has been emphasised as the major priority for UK energy policy since the 2003 Energy White Paper.[14] There are a number of reasons why decentralisation might help to meet the UK's ambitious targets for reductions in greenhouse gas emissions. Increasing the efficiency of energy use through CHP implies locating more electricity generation capacity near to the end user,

14 Department of Trade and Industry (2003)

something in which the UK lags behind many other northern European countries.[15] Many renewable energy options such as solar (photovoltaic and thermal), biomass (for heat and power) and wind can be deployed on a small scale, either close to or within urban areas. Such options can help to reduce carbon emissions from buildings alongside behavioural changes, discussed in Chapter 4, and efficient end-use technologies. Substantial investment programmes would be needed to upgrade the performance of existing buildings in this way.[16]

However, a low-carbon energy system can continue to be centralised too. Future scenarios to explore how the UK can cut its emissions by 60 per cent by 2050 (compared with 1990 levels) have shown that there are different ways this can be achieved. For example, the Royal Commission on Environmental Pollution elaborated both centralised and decentralised scenarios,[17] as did subsequent exercises by independent research bodies.[18] It is possible that the current centralised energy system can be adapted to help meet stringent climate change targets. Low carbon supply options such as nuclear, CCS, and centralised renewable energy such as offshore wind could be deployed in large volume to do so. It is an open question whether such centralised scenarios would leave room for more decentralised governance structures and service-based business models that could foster significant demand-side cuts in energy use.

As this Report has already noted in Chapter 1, the costs of meeting climate change targets will be significant, but are expected to be much lower than the costs of inaction. When considering alternative pathways for the 'decarbonisation' of the UK, it is inherently difficult to predict which pathway might be more or less costly than the others. Some voices within the debate on scales of energy systems have claimed that decentralised systems could be cheaper than centralised ones.[19] Whilst there are economic benefits to be gained from siting energy generation closer to centres of demand, the costs of transition from our current centralised system are sometimes underplayed. A significant change of direction in energy system development will often look more expensive to governments and investors whose financial models are designed to optimise the current system. For example, a new wind farm in the North Sea looks expensive at present partly because it requires new infrastructure. However, if it were considered as part of broader change in the UK electricity system to include many offshore wind farms, the costs of system change would be shared amongst many projects – and would be much smaller for individual investors.

5.3.2 Energy security

Whilst energy security has always been an important goal of energy policies, it has become more salient in the UK in the past few years. As Chapter 7 will outline in more detail, this is due to a combination of factors including the UK's status as an energy importer, high fossil fuel prices, geopolitical events (especially the Iraq war) and the blackouts in electricity systems in summer 2003.

15 Hinnells (2008), Roberts (2008)
16 Power (2008)
17 Royal Commission on Environmental Pollution (2000)
18 For example, Tyndall Centre for Climate Change Research (2005)
19 Greenpeace (2006)

One dimension of energy security that has been prominent in recent government statements on energy policy is the need for timely investment in new power plant infrastructure. The 2007 Energy White Paper states that 30-35GW of new power plant capacity will be required within the next 20 years due to the expected retirement of existing plant.[20] This implies that almost half the current power plant stock will be replaced. As noted in Chapter 2, there will also be a need to replace other energy infrastructure such as electricity transmission lines.

Whilst meeting this need for new capacity will be a major challenge for decision makers in government, industry, wider civil society and energy companies, it also offers new opportunities. Infrastructure could be replaced on a 'like for like' basis, with a preference for low or zero carbon technology. This would mean little change for today's towns and cities. Alternatively, investment could be made at a variety of different scales, including much more decentralisation. This could include measures to manage and reduce demand more actively than in the past, and a different geographical coverage, for example allowing connection of substantial offshore wind farms. One possible advantage of this more diverse approach to scale is that it might introduce more flexibility into investment patterns, and counter the inherent irreversibility of many energy system investments.[21]

There is no clear answer to the question of whether centralised or decentralised energy systems are more secure. For some analysts, more decentralised systems could be less prone to security risks because they can contain more redundancy. In other words, they are likely to contain many more power and heat-producing plants, more grid interconnections and more technological variety.[22] However, managing such systems will be more challenging, and is likely to require new models for control and co-ordination. Whilst centralised systems may not need more sophisticated incentive and control technologies or changes in governance, these could be vulnerable if they do not include multiple energy sources, supply routes and adequate energy storage.

In all cases, costs will be an important consideration. As the more detailed discussion of security in Chapter 7 notes, it is often a trade-off between the inclusion of more redundancy within energy systems and society's willingness to pay for this.[23] For example, centralised gas supplies can be made more secure if governments mandate the construction of strategic (but non commercial) storage facilities. By contrast, decentralised power grids might still need to rely on centralised power infrastructure to help balance supply and demand patterns within (and between) local areas.

5.3.3 Trends in technology.

The architecture of future energy systems will depend on the availability of technologies and the political, market and regulatory frameworks that are adopted. This includes technologies for energy supply and generation (e.g. solar thermal for hot water, wave power, or CCS), for end use (e.g. LED lighting); for network management with new information, communication and control systems; and for storage, for example using hydrogen. One of the reasons that decentralised energy is on the agenda again in the UK is that there are more decentralised technologies available and their costs have reduced. As noted earlier, their deployment has been very slow to date.[24]

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20 Department of Trade and Industry (2007)
21 Fielder (1996)
22 Coaffee (2008)
23 NERA (2002)
24 Roberts (2008)

Most investment in energy supply is still centralised. But the technologies to operate complex networks and markets with large amounts of decentralisation have improved significantly as a result of developments in information technology.[25]

A key issue is the integration of decentralised technologies with the built environment. As we note in Chapter 6, buildings in the UK will need widespread retrofitting to improve their energy and emissions performance, especially to help them adapt as the climate changes.[26] Retrofitting this building stock with micro-generation or perhaps with larger 'community-scale' energy supply technologies will be an important target alongside measures to reduce energy demand through energy efficiency and other means. Different technologies will be appropriate for different locations. A relatively large but still decentralised power plant to generate heat and power for a large number of houses and other buildings would make the most sense in densely populated areas. This form of decentralisation is more efficient than deployment at the household scale. However, such projects would have implications for urban design. Space would be needed for new generation and heat network infrastructure. Retrofit has an important social dimension, particularly at the larger 'community scale'. Changes to familiar built environments may be opposed by local residents if public engagement is poorly managed. Public acceptance of disruption to homes and gardens, and the switch from building to neighbourhood-scale heat and power systems will be contingent upon levels of trust in the institutions implementing change.

At the household level, geography and local circumstances also matter. A micro wind turbine is much more likely to generate significant amounts of electricity if it is deployed in rural areas with good wind resources.[27] Some micro-combined heat and power technologies produce too much heat for apartments and are better suited to poorly-insulated detached houses. As energy performance is improved in both existing and new buildings, some energy generation technologies will become less attractive because the demand for heat might be too low.[28]

Enabling technologies such as information, communication and control are vital to the security of decentralised systems. Another related set of supporting technologies for energy storage could influence the direction of the energy system in the future.[29] Storage of electricity or heat is possible using a variety of technologies at a range of scales. In some cases, such as domestic hot water tanks, it is already widespread although combination boilers may reduce their prevalence. Other forms of storage such as electric batteries in plug in hybrid vehicles could be important in the future. There is also the option of 'virtual storage', which uses control systems to manage loads as well as energy sources in electricity systems.[30]

Storage could open up possibilities for future energy systems. For example, the electricity system could integrate more intermittent renewable energy, which could be centralised or decentralised. Solar heat collected in summer could perhaps be stored for months at a time until it is needed in winter. However, many storage technologies are limited by a combination of factors such as cost, storage capacity and durability.[31] Whilst incremental developments are envisaged for the future which will help to

25 Bouffard and Kirschen (2008)

26 Smith and Levermore (2008)

27 Watson et al. (2006)

28 Pitts (2008)

29 Baker (2008)

30 Hemmi (2003)

31 Baker (2008)

improve the attractiveness of storage technologies, it is difficult to foresee radical breakthroughs in the short to medium term.

5.3.4 The governance of energy markets.

Part of the reason why investment has continued to focus on centralised technologies, particularly in electricity, is the structure of electricity and gas markets and the way in which they are regulated. Whilst the liberalisation of electricity and gas markets since the late 1980s has opened them up to competition, there is a widespread recognition, not least in government, that the current system includes many barriers to decentralised options. Some of these are due to market rules, which are designed to suit large-scale power plants. Some are due to the regulatory approach to monopoly networks which has been concerned with cost reductions rather than innovation. Many government policy statements talk in terms of levelling the playing field for decentralised investments such as CHP and small scale renewables.[32] Some changes to assist decentralised electricity generation have been included in the current regulations for electricity distribution networks by the regulator, Ofgem. These provide some economic incentives for network operators to connect distributed electricity generators. However, the accompanying incentives to encourage research and demonstration of new network technologies have only produced modest results so far.[33]

Other bodies have called for more fundamental reform of regulatory systems, for example, a change to the energy regulator's duties so that they place more emphasis on government environmental and social targets.[34] As noted in Chapter 2, this is partly informed by the observation that the UK is locked-in to centralised systems and their associated institutions, rules and regulations.[35] For example, domestic micro-generators cannot sell their power to the main electricity wholesale market and take advantage of time-of-day pricing. Demand-side investors enjoy less favourable tax treatment than those on the supply side.[36] The implication is that action beyond the removal of barriers or the 'levelling of playing fields' might be required to open up the possibility of widespread decentralised investments.

Other regulatory developments also have implications for decentralised energy. Some of the most interesting and potentially radical regulations cut across traditional divisions within energy systems. New obligations on energy suppliers could lead to a more integrated approach to investments in energy supply and demand. Meanwhile, building regulations have been strengthened to mandate zero carbon homes by 2016. This is likely to focus developers' minds on the energy performance of buildings, including the integration of low-carbon supply options, much more than in the past.[37] Whilst many of these regulations are national, they have been pushed and reinforced by a series of EU Directives on buildings and energy services.[38]

The increasing obligations on energy suppliers in the UK to encourage carbon-saving measures within households are in line with the EU's 2006 Directive on energy services. These obligations could be met through a combination of traditional efficiency

32 Department of Trade and Industry (2006a, 2006b)
33 Woodman and Baker (2008)
34 Helm (2007), Sustainable Development Commission (2007)
35 Wolfe (2008), Woodman and Baker (2008)
36 Watson et al. (2006)
37 Boardman (2007)
38 Ekins and Lees (2008)

measures and micro-generation. The current phase of these regulations (known as the Carbon Emissions Reduction Target or CERT) is not expected to lead to large numbers of new micro-generators. However, CERT will be succeeded in 2011 by a more ambitious obligation that could cap carbon emissions from the energy supplied to households.[39] This could provide strong incentives for suppliers to change their business model towards the provision of services, using a combination of energy supply investments at a variety of scales, and demand-side measures such as loft insulation.

Looking beyond current policy proposals, changes in governance could have a critical impact on the scale of energy systems in the future. As some of the scenarios in this Report illustrate, there is significant scope for sub-national institutions (e.g. local authorities and regional bodies) to play a greater role. Whilst there are some notable examples of energy system development led by local authorities (e.g. in Woking and London), these stand out as the exception rather than the rule. New powers and greater guidance to local authorities from central government in areas such as planning, finance and regulation may be required for other areas to follow suit.[40]

5.3.5 Broader social change

Decentralised energy has been consistently advocated by environmentalists since the 1970s as a means of addressing social issues such as self-sufficiency and empowerment, alongside issues such as environmental impact and energy security.[41]

In the UK, only in the past ten years has mainstream energy policy begun to support the diffusion of smaller-scale energy technologies and increased energy self-sufficiency. This has occurred at two scales – community and household, amidst a growing political consensus that a more pluralistic approach to public service provision is necessary in the 21st Century,[42] with citizens and communities called to take more responsibility for climate change and energy supply.

This political change has occurred against a backdrop of signs of increased societal support for decentralisation. A database constructed in 2005 identified over 500 ongoing or completed community-scale renewable energy projects set up across the UK.[43] These were diverse, often set up in response to local as well as global environmental, social and economic challenges, and with different degrees of local participation and benefit.[44] The Transition Towns network, which includes groups in many towns across the UK, provides a clear example of decentralisation in the political and social sense, signalling a trend that could develop alongside more technical decentralisation over the next decades.

Since 2000, support schemes and funding programmes have been set up by the government to develop community implementation of renewable energy,[45] in order to realise a range of other potential benefits. Such benefits include the economic regeneration of urban and rural areas, social cohesion, enhanced public understanding

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39 The exact form of this obligation will not be clear until late 2008. See http://www.defra.gov.uk/Environment/climatechange/uk/household/supplier/index.htm

40 Local Government Association (2007)

41 For example, Lovins (1977), Willis (2006)

42 Halpern et al. (2004)

43 Walker et al. (2007b)

44 Walker and Devine-Wright (2008)

45 Walker et al. (2007a)

and support for renewable energy, and the triggering of behavioural change.[46] In Scotland, the emergence of Community Energy Companies has signalled policy support for the view that a shift towards decentralised energy can bring socio-economic benefits in marginalised communities.

However, despite the diversity of these potential benefits, significant community activity and the development of publicly funded support schemes, many barriers towards increased decentralisation remain to be solved.[47] Consequently, there is little evidence of a broader paradigmatic shift in the underlying norms and goals of energy policy towards these more decentralised forms of energy provision.[48]

5.4 Public engagement and the scale of energy systems

The scale of technologies in future energy systems will shape the roles that individuals and communities will play in managing energy in the built environment over the coming decades. Will consumers be predominantly disengaged, with only a minimal interest about energy issues beyond paying the bill, in a system where power stations remain 'out of sight and out of mind'? Or will consumers become more pro-active, for example by responding to real-time information supplied via smart metering or by participating in community initiatives to manage energy supply and demand in a local area?

One of the difficulties of discussing these potential futures is the polarisation of debate. Whilst industry and policy makers have tended to focus upon the beneficial level of convenience inherent in centralised energy systems, this is founded upon an 'information-deficit' perspective[49] which presumes a lack awareness, knowledge, interest and time to be the norm amongst energy users.[50] In contrast, advocates of decentralisation tend to demonise centralised systems as inevitably 'bad', imagining a decentralised energy future where energy is 'democratised'[51] and increased engagement is the norm.

This is an oversimplification of a highly complex problem, set against a backdrop of increasing globalisation of economic systems and individualism in social systems. To transcend this polarisation and foster debate, it is useful to disentangle the interrelations between the scale of energy systems and the level of public engagement.

Table 5.3 illustrates four divergent routes for public engagement with energy systems – with a particular focus on electricity and heat. It simplifies system scale into a single dimension from centralisation to decentralisation, and characterises levels of engagement along a continuum varying from high to low. This produces four stylised possibilities for public engagement with energy systems: centralised engagement, centralised disengagement, decentralised engagement and decentralised disengagement. Of these, perhaps the most notable are the ones typically omitted in the polarised discussions of social and technical aspects of energy scales: engaged centralisation and disengaged decentralisation. These are discussed further below.

46 Wüstenhagen et al. (2007), Keirstead (2008)
47 Walker (2008)
48 Walker et al. (2007b)
49 Owens (2000)
50 Devine-Wright and Devine-Wright (2005)
51 Greenpeace (2005)

Table 5.3 Routes for public engagement and scales of energy systems	
1. Centralised engagement Deployment of smart metering technologies enables building occupants to track their levels of consumption and shape behavioural patterns in response to different time-of-use tariffs offered by utilities. Appliances are designed to enable efficient use and bills provide details of where heat and power is generated, what fuels are used and what carbon gases are emitted as a result.	2. Centralised disengagement Building occupants are disengaged with energy beyond bill payment. Bills provide minimal levels of information about the energy system and its environmental impacts. Meters are inaccessibly located and not user-friendly. Heat and power plant are 'out of sight and out of mind'; individuals have little idea where their energy comes from or how the system functions.
3. Decentralised engagement Energy is more 'visible' in everyday lifestyles as people prefer to have energy technologies 'in their back yard'. Deployment of both smart meters and small-scale heat and power systems enables individuals and communities to play a stronger role in managing energy and the built environment.	4. Decentralised disengagement Small scale heat and power systems become common through a 'company control' business model, maximising convenience for building users who benefit from, but have little everyday involvement with, energy systems. Billing and metering systems provide minimal levels of information to users.

In route 1, large-scale power plants remain the conventional way to generate heat and power, with supply enabled by continued use of a national grid of gas and power infrastructure. But within buildings, the installation of technologies such as smart meters transforms the potential for engagement, enabling individuals and households to shape behavioural patterns of energy consumption across the day and week, for example to benefit from different time-of-use tariffs offered by energy utilities, and to track their levels of consumption over time. In this case, the meters are characterised as 'smart' not because they provide utilities with increased data about energy use but because they are designed and located in such a way as to promote and maximise user engagement.

In route 4, disengaged decentralisation highlights a scenario where building occupants benefit from small-scale energy technologies but have little or no input into their installation or operation, perhaps for reasons of convenience. The details of technology operation and management are handled by a service company that takes charge of all aspects of decentralisation, in a similar fashion to the 'company driven' model of decentralised energy identified by previous research.[52] Technical systems are decentralised but this does not occur in parallel with a shift in norms of engagement and behavioural patterns.

The four routes suggest that increased levels of public engagement are not an inevitable outcome of decentralised energy technologies, and that centralised systems are not inevitably 'disengaged' with by energy users. Whilst it has been claimed that our current system is one of centralised disengagement,[53] it is difficult to foresee whether this will change and if so, which of the remaining three routes are most likely to emerge over coming decades. In the absence of any clear preference for a single route, perhaps

52 Watson et al. (2006)
53 Greenpeace (2005)

the most likely outcome is the emergence of hybrid routes, where different levels of public engagement and degrees of centralisation co-exist across the UK, determined by cultural, spatial, institutional and economic circumstances.

Key messages

- Decentralised energy is a catch-all term that is open to significant confusion and misinterpretation. It encompasses a spectrum from large CHP plants in cities to household solar hot water heaters.
- Decentralised energy systems include regulatory, social and institutional components as well as technology.
- The challenges facing UK energy systems can be addressed through either centralised or decentralised approaches, or by a combination, but there may be tensions in an energy system that includes both – for example market rules, regulations and institutional arrangements for local investment in heat and power facilities may be unsuitable for large, centralised investments in power generation or gas storage.
- The powerful lock-in of the UK's legacy energy system to centralised institutions, infrastructures, rules and regulations has contributed to slow progress in the deployment of decentralised energy options.
- The costs of decentralised options can appear to be prohibitive, but economic appraisal techniques do not consider how these options might 'measure up' in a radically different future energy system.
- The 2020 renewable energy target will be easier to meet if investors can readily deploy electricity and heating systems at a variety of scales. Bolting on new regulations and institutions to support them whilst leaving the 'mainstream' policy and regulatory system intact may be insufficient to tackle the lock-in to centralised systems.
- Purposeful and strong action from government will be required to 'open up' the energy system so that the full range of options can be deployed at a variety of scales.
- Innovation in energy networks will be crucial to the future evolution of energy systems, particularly if they become more decentralised: e.g. more complex electricity distribution networks, new investment in district heating networks, and the extension of electricity grids to electrify road transport. Policies and regulations will need to do more to promote such innovation.

6 New and existing buildings and future decarbonisation

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6.0 Introduction

Any exploration of how the built environment in the UK could evolve to manage the transition to secure, sustainable, low carbon energy systems needs to consider the entire building stock, both new and existing. There are major challenges in fully realising the potential of initiatives designed to reduce the carbon impact of new developments. There are also questions about how best to address the challenge posed by existing building stock, including whether there is any basis for demolishing and replacing old buildings to increase energy and carbon efficiency. The issues are not merely technological. Driving through improvements in energy efficiency and reducing the carbon in old or new stock, will place particular demands on governance arrangements. Furthermore, as discussed in Chapter 4, any attempt to decarbonise energy consumption in buildings has to recognise the significance of the energy behaviours of the occupiers, as well as the socio-economic factors shaping the management of buildings and the property market.

Attention also has to be paid to the development and renewal of the built environment in a broader sense, encompassing the wider external environment that surrounds buildings. Future options for cooling, comfort and secure, low carbon systems, in a world experiencing the impact of climate change, are not confined to the structure and fabric of individual buildings. There are also implications for the governance of public spaces.

This chapter begins by considering aspirations for energy systems in new buildings and new settlements, which are arguably most amenable to influence. They have been the focus of significant regulation and planning attention. The emphasis to date has been on domestic buildings but attention is now turning to the commercial and public sectors. The opportunities and challenges for delivering new built environments which are low carbon, low energy and sustainable are discussed.

However, as the built environment in 2050 will largely comprise buildings already in existence, the opportunities and challenges that will arise in renewing this stock to meet future demands are also examined. A particular focus is on the skills and capacity that will be required in the construction, repair and maintenance sectors in the future. The chapter ends with discussion of the links between governance arrangements and approaches to decarbonisation of energy systems, revisiting issues of scale and of behaviours set out in previous chapters.

6.1 Exploiting opportunities with new build

6.1.1 New buildings

Improving the thermal efficiency of new homes has been a focus of regulations for some years, and standards have become more detailed and stringent since 1985.[1] The purpose of these regulations has been to reduce total energy consumption, to mitigate fuel poverty effects, and to enhance the energy efficiency of appliances such as gas

1 Environmental Change Institute (2005)

boilers. The Building Regulations (Part L) on the conservation of fuel and power were strengthened in 2006, raising thermal standards by 40 per cent from 2002.[2] The English Housing Condition Survey of 2006[3] suggested that average energy consumption was 300 kWh per square metre per year; under the 2006 Building Regulations this should be reduced by two-thirds. Even tougher standards already exist in other countries, for example, the European *Passiv Haus*[4] standard is technologically capable of reducing consumption to 15 kWh/m2,[5] albeit at an increased construction cost.

Current policy in England is set to go beyond these 2006 UK standards. Recent regulation aims to shape the energy efficiency and carbon impact of the new building stock that will be on offer to the public. Ambitious targets have been set by the government for all new homes to be zero carbon by 2016.[6] The exact definition of this term has been debated but is currently linked to the energy component of The Code for Sustainable Homes (CSH). This Code, which is a mandatory environmental assessment method for new dwellings in England from May 2008, is expected to play a leading role in meeting these targets. Zero carbon is currently understood to mean that over a year there are no net carbon emissions resulting from the operation of the dwelling.[7]

These ambitions have been broadly welcomed, but implementation is likely to be challenging in a number of aspects. Firstly, there is a lack of empirical evidence on the impact of energy performance standards.[8] Secondly, the relationship between the Code and the Building Regulations is unclear. Thirdly, there are concerns over whether such standards are consistently and rigorously implemented, enforced and monitored, and the suggestion that if the CSH is to be effective, greater effort will have to be deployed on enforcing and monitoring the new regulations, to ensure that they are actually delivering energy savings once buildings are in use; such monitoring has been largely absent to date.[9] In addition, even if the Building Regulations standards are met consistently in the construction of new buildings, actual, in-use, energy performance may deteriorate from the beginning 'due to a combination of shrinkage, settlement and occupier interventions'.[10] Importantly, evidence from existing dwellings shows that occupier behaviours can be a stronger determinant of energy use than building design.[11]

The same is true of building purchasers. Efforts to strengthen building regulations have been supplemented by a fiscal incentive to purchasers in the form of the current exemption from stamp duty for zero-carbon housing but take-up has been limited. Builders argue that there is limited consumer interest; consumers note that there are as yet relatively few such homes on the market.

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2 www.planningportal.gov.uk

3 Communities and Local Government (2008a)

4 A dwelling which achieves the Passiv Haus standard typically includes: very good levels of insulation with minimal thermal bridges; well thought out utilisation of solar and internal gains; excellent level of air tightness; good indoor air quality, provided by a whole house mechanical ventilation system with highly efficient heat recovery. More than 6,000 buildings have been constructed to this standard in Europe, mostly in Germany and Austria. www.passivhaus.org.uk

5 Ward (2008), although Wright (2008) points out that the SAP measures used in the English Housing Condition Survey are not accurate measures of actual energy consumption.

6 See www.communities.gov.uk/planningandbuilding/theenvironment/zerocarbonhomes/

7 Communities and Local Government (2007a)

8 Lowe and Oreszczyn (2008)

9 Lowe and Oreszczyn (2008)

10 Wingfield et al. (2006)

11 Wright (2008)

In the non-domestic sector there are signs that some larger developers and financial institutions are moving towards higher energy efficiency standards, particularly for the cooling requirements that dominate over heating in the commercial sector. This shift is part of a broader corporate social responsibility initiative, and reflects awareness that more efficient buildings may in future have higher rental and capital values.[12] This effect is most apparent in the prime office rental sector and thus in more economically buoyant urban areas. However, the bulk of new non-domestic construction and development does not match the best energy efficiency standards.[13] In particular, the steady increase of electricity use has been found to be approximately proportional to floorspace, and the energy efficiency measures of the Building Regulations have been negated.[14] Currently the majority of the non-domestic development industry is not geared up to deliver zero-carbon properties. The forthcoming Code for Non-domestic Development (a parallel to the Code for Sustainable Homes), and targets for all new non-domestic development to be zero-carbon by 2019, may help to drive innovation and perhaps a step change in the construction sector as a whole. Notwithstanding these developments, the fact remains that the non-domestic development industry is markedly conservative in its approach. For example, in the past it has attached high value and prestige to air-conditioned offices rather than promoting naturally ventilated office space. This conservatism will be difficult to change unless radical steps are taken to reframe demand and expectations.

How might this be done? In Chapter 3, in the **Green Growth** scenario social pressures create commercial incentives for large companies to deliver change. In others such as **Sunshine State** the prevailing social mood leads to community assumption of responsibility for commodities such as transport, and to a certain extent, energy. In future worlds, such as **Green Growth,** social norms make energy profligacy unacceptable. However, currently, social pressures for sustainable use of energy in the non-domestic sector appear to be having relatively little impact on the building industry as a whole. These issues reinforce the arguments made in Chapter 4 regarding the need to factor an understanding of human (and organisational) behaviours and motivations into policy design.

6.1.2 Beyond individual dwellings

The impact of new buildings on the sustainability of energy systems will reflect not only occupants' behaviours but also the wider environmental and infrastructural context in which they are sited. There are obvious issues in relation to locality and transport which are beyond the scope of this Project. But other factors such as the integration of on-site energy systems, the creation of green and blue spaces (e.g. parks and trees to provide shade, and water for cooling) also have an important role to play in designing sustainable low carbon built environments.

Some planning approaches are designed to stimulate decarbonisation in new build developments by looking beyond individual buildings. These include the so-called 'Merton Rule'. The impact of such requirements is contested. Some argue that they will encourage pump-prime funding for the UK micro-renewable market and will also encourage occupiers to think about their energy use. Others argue that the rule has resulted in local authorities simply asking for higher percentage contributions of on-site

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12 Witness the formation of the Investment Property Forum/Institutional Investors Group on the Climate Change Sustainability Interest Group Steering Group www.ipf.org.uk

13 Ravetz (2008)

14 UK Green Building Council and Communities and Local Government (2007)

renewable energy rather than devising more imaginative, effective options, and ensuring that policies that actually work in terms of overall carbon reductions are implemented and rewarded. This debate illustrates the potential dangers in target-driven rather than outcome-focussed attempts to steer behaviours towards a decarbonised future.

The Eco-towns programme is another approach intended to help develop capacity within the house building sector by promoting up to 15 new settlements built to zero-carbon standards. Eco-towns enable a perspective on decarbonisation that extends beyond the individual dwelling, including the aim that 'the development as a whole achieve zero carbon and be an exemplar in at least one area of environment technology'.[15] They could provide an opportunity for house builders to gain experience in meeting zero-carbon standards as well as creating a critical mass for the supply of key new technologies and components. However, the total number of houses involved is relatively small compared to targets for total house building, raising questions about the scale of any potential impact on construction markets as a whole.

Government commitment to the vision of zero carbon Eco-towns was also intended to result in large scale demonstration experiments where the boundaries of creative thinking and innovation are pushed far beyond other current and planned initiatives. However, there has been some disappointment with the level of innovation in proposed developments. The provision of adequate public transport infrastructure also remains problematic. The policy focus of Eco-towns has been primarily on building market capacity through the demonstration of a commercially viable model, rather than driving innovation, in terms of technology, institutional arrangements and that commercial model. Driving innovation requires a much more targeted approach as we discuss in Chapter 8. In addition, current economic circumstances are, at best, likely to delay starts to any approved schemes.

6.1.3 Challenges for industry, innovation and future business models

There are technological innovations under way that could help improve the energy performance of new buildings and the process of their construction, in both the domestic and non-domestic sectors. Off-site production and fabrication of components, rooms and buildings, such as student accommodation, hotel rooms, and prison cells is increasingly common and continues to grow. In the longer term, new building materials, including those derived from nanotechnology, promise improvements in strength, durability, weight, energy performance and sustainability unavailable to the designers and engineers of today. Advances in IT have already revolutionised the design and communication processes used in the construction of new buildings in the past ten years. Significant developments can also be seen in the area of intelligent buildings.

However, the take-up and spread of these innovative materials and processes is essential if sustained change in the energy systems of new developments is to be achieved. Take-up will depend significantly on market factors, in particular the additional up-front costs and the willingness of occupiers and owners of building to pay rents and prices to cover them. The next few decades are likely to see new technologies continue to fall in cost and become increasingly accessible and acceptable. There is potential for more innovative methods of construction to move from niche, high-value applications into more mainstream construction, much as concrete and steel revolutionised construction a century ago. Against this, the perceived need to ensure that new developments are robust against a range of possible changes – in social

15 Communities and Local Government (2007c)

values, occupiers' demands, security expectations, energy supply and climate change – could increase the up-front costs of construction.

Take-up will also depend on other institutional change in the construction and development sectors. There are considerable path dependencies within the construction and development industry as a whole that make change difficult to achieve, particularly within a tight timescale and in difficult economic circumstances. The culture in the industry is often risk-averse. In addition, the majority of new developments are relatively small projects of between one and ten houses, or a single office, developed and built by small regional SMEs, the majority of which are particularly slow to innovate and change. In recent, large-scale, public sector projects, the government has transferred even more of the project risk onto the supply side of the industry rather than the client side, which could also further inhibit innovation and risk taking.

A critical question at issue here is the extent to which the current business model of the UK house building sector is going to be able to meet the government's zero-carbon targets. Speculative house building assumes that a builder buys land, develops it, and then sells off the dwellings, leaving the builder with no longer-term interest in the site. A sector with such short-term interest in development is unlikely to be well suited to delivering zero-carbon housing, the essence of which is to yield no net carbon emissions over the long term. In the future, models will need to be established which sustain the developers' stake in the operational life of developments.

The challenges of the current economic climate for the private sector strengthen the view that the procurement of new public buildings and social housing (the latter through the Housing Corporation[16] and English Partnerships) will be key to leading industry in changing its practices. The scale of both the existing public sector estate and of new orders from the public sector means that central and local government and other public sector bodies are in a strong position to influence the construction sector. But if the UK construction industry does not rise to this challenge, it may face competition from overseas companies already experienced in delivering new housing to high technical standards. Moreover, innovation in building services has not migrated upwards in social terms.[17] Resolving the problem of energy inefficient facilities management in buildings should therefore start with the prime sector, institutional investors and the public sector.

Using the public sector in this way may require some changes to current procurement and auditing frameworks. The details of the Private Finance Initiative (PFI) and similar procurement arrangements could be refined to ensure that they do not lead to the over-engineering of buildings with large amounts of energy-consuming equipment but rather promote sustainable energy options. Government needs to work with the sector to find the best mechanisms for promoting change in development and construction practices, and for devising a new business model. This should be one which is less dependent on designing and building a specific building and then moving on, and more focussed on the long-term management and maintenance of the building and its energy use based on a continued interest in the development.[18]

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16 Soon to be part of the Homes and Communities Agency

17 Fisk (2008)

18 Communities and Local Government (2007b)

6.2 Creating opportunities in existing building stock

6.2.1 Refurbishment and renewal

All of the four project scenarios in Chapter 3 included responses to the need to upgrade existing building stock. The approaches followed differ, depending on the cultural value of heritage assets, the relative importance of energy efficiency versus carbon reduction, and the dominant scale (i.e. local, regional, national) of governance. On current trends, the vast majority of houses and other buildings that will be present in 2050 already exist.[19] Their usage is likely to be different as buildings change over time; innovative uses are likely to be found for older buildings, as illustrated by the scenario vignettes. The recent trend to adapt former warehouses and similar buildings for mixed use or housing is one example that is likely to continue. Refurbishment can significantly alter a building's energy performance and its capacity to embrace low-carbon energy supplies. It can also contribute to urban re-development that uses advantage from high density and existing infrastructure to realise economic, social and environmental benefits.

Most existing homes are technically relatively easy to upgrade, and can achieve as high environmental efficiency standards as much of the current new build[20] using well-understood technologies that are already in the market place. The German Zukunft programme[21] is currently reducing energy consumption in housing by 80 per cent through retrofitting. Even modest programmes using external wall insulation and modern central heating boilers can often reduce the energy used for space and water heating by 50 per cent.[22] However, only about 30 per cent of homes in the UK currently have loft insulation[23] and so significant scope exists for improvement in thermal efficiency at a relatively low cost per dwelling. Furthermore, unlike many micro-generation installations, most thermal efficiency measures have relatively quick payback periods. Fiscal incentives for better insulated buildings also exist, such as 'Warm Front'[24] and 'Act on CO_2'.[25]

However, a feature of measures to improve domestic energy efficiency is their traditionally very low take-up. In Chapter 4 the analysis of behavioural factors shows clearly that information and exhortation, even backed up by fiscal incentives, do not trigger responses on the scale needed to achieve energy saving and targets for reduction in carbon. In future, developments in technologies for insulation, glazing, and shading may make their application less disruptive and remove this and other factors that inhibit take up. Moreover, sustained high energy prices over the medium term may add momentum. But other strategies to seize opportunities for upgrading will be essential if the pace of change is to increase. There may be a significant role for local government to create area-based schemes for neighbourhoods which promote involvement in upgrading and even share the costs of investment.

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19 65-70 per cent of the dwelling stock in 2050 will have been built before 2000. Lowe and Oreszczyn (2008)

20 Power (2008)

21 The German Zukunft Haus Pilot Programme 2003–2005 involved upgrading and installing energy-efficiency measures in 915 homes in 34 mainly rented blocks of flats across Eastern and Western Germany mostly built before 1978. The blocks were generally in poor condition and relatively hard to let. Through these measures, energy consumption was reduced by over 80%. The German Federal Government announced in 2007 a programme to bring all pre-1984 properties up to this standard by 2020 through a system of loans, grants and tax incentives. The building upgrading programme will make a major contribution to Germany's ambition to reduce overall CO_2 emissions by 40% by 2020. Power (2008)

22 Lowe and Oreszczyn (2008)

23 www.communities.gov.uk

24 www.warmfront.co.uk

25 www.energysavingtrust.org.uk

Personal carbon allowances are a longer term measure which might act as an additional economic incentive for households to take action to reduce or alter energy use. Substantial increases in real energy prices might make this intervention more attractive to government although those in or close to fuel poverty might lack the means to act without subsidy and support

A significant problem is that there is currently no scheme equivalent to the Code for Sustainable Homes for existing houses or buildings. Another is that there is little incentive to enhance the energy performance of the 2.6 million privately rented homes (in 2006). Arguably, neither landlords nor tenants have sufficient motivation to improve their properties. Steps to encourage more retrofitting could include annual assessments for buildings similar to vehicle MOTs. Currently Energy Performance Certificates (EPC) in the domestic sector are required on sale of new or converted buildings or of existing homes; [26] these are rolled up into the recently-introduced Home Information Packs (HIPs),[27] but only influence behaviour when a house is at the point of sale.[28] Tellingly, selling a house off-plan before completion means that the EPC is based on the much-criticised SAP calculations. For rented property, an EPC has to be provided for all self-contained premises (i.e. when facilities are not shared). However, the EPC has a life of ten years reducing incentives to make improvements.

Annual certificates would highlight current low energy efficiency standards on a regular basis; in 2006, less than 10 per cent of homes were in the top energy performance categories A-C (with G being the lowest category).[29] Scope would therefore exist for introducing minimum allowable standards at some point in the future. The potential contributions of this and various other incentives to enhance energy performance of existing housing were explored in the scenarios in Chapter 3.

6.2.2 Upgrading commercial buildings and the public sector stock

In commercial buildings, there appear to be frequent market failings in respect of energy efficiency, despite the robust commercialism of the property industry. In some commercial buildings, increasing the insulation can be expensive and complicated. This is especially the case in retrofitting the more technologically advanced 'iconic' buildings. The issue of who pays is also often contentious. With the highly competitive market for most commercial floor space competing on the basis of '£ per square metre', rather than energy efficiency, little or no incentive exists for owners of commercial buildings to install insulation as they generally do not pay for the energy used. In some models of commercial tenancy, occupiers pay a fixed element for energy, removing their incentive to behave efficiently, though arguably strengthening the incentive for the owner to improve the fabric.[30] Total energy costs can be a small proportion of total costs for either party. Again this highlights the need to develop policy with behavioural and socio-economic elements in the foreground (rather than particular technologies).

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26 Clarke et al. (2008)

27 Home Information Packs (HIPs). Since December 2007, every home put on the market for sale must have a HIP. It brings together information such as a sale statement, local searches and evidence of title into a single pack, paid for by the seller. The Pack also includes an Energy Performance Certificate that contains advice on how to cut CO_2 emissions and fuel bills. (www.homeinformationpacks.gov.uk/)

28 In 2007, there were just over 1.8m transactions in England and Wales involving residential dwellings and commercial properties. Analysis shows that over 90 per cent of the transactions involved the sale and purchase of residential property. Communities and Local Government (2008b)

29 Ravetz (2008)

30 Oxera (2006)

As with the domestic sector, these commercial and economic aspects of the property market emphasise the scope for the public sector to have an impact, not just as a regulator and enabler, but also as the biggest owner and occupier of the UK's non-domestic buildings. Others with power to influence include the pension funds and other financial institutions, both at home and abroad, who own vast amounts of commercial, industrial and residential buildings, and infrastructure. These are long-term investors who could have a significant influence on the future energy efficiency of built stock. There is a major opportunity for them to become early adopters of emerging new energy efficient technologies such as thin vacuum insulation panels, novel forms of glazing and highly energy efficient surface coatings[31] provided they can be persuaded to bear the risk of such innovations or perceive that the risk is minimal compared to the benefits. Similar schemes to those mentioned above for homes, akin to the annual MOT test for vehicles, could be introduced for commercial buildings, although this would also need to be closely monitored and regulated, with the findings analysed and disseminated. These measures would come at a short-term cost, but are likely to be cost-effective in the longer term. The links to EPCs in the non-domestic sectors are discussed below.

However, as for domestic buildings, it is occupancy behaviours that drive the consumption of energy. While advanced technology for energy management can be built or retrofitted into buildings, optimum use of such systems is not assured. If advanced energy management systems are poorly maintained or run, they are unlikely to deliver good performance. Evidence suggests that building energy control systems are currently under-utilised in the commercial sector and that there is a lack of information and appropriately trained staff.[32] Managers and owners of buildings will therefore be a key group to help ensure that energy management systems are run optimally.

6.2.3 Refurbishment versus demolition

The problems in realising the potential improvements in thermal efficiency of existing buildings raise the question of whether demolition might also be a way to tackle energy efficiency. Several of the scenarios in Chapter 3 see a role for limited demolition of the most energy-inefficient properties, both domestic and commercial. They also point to the inevitable downward pressure on the value of poorly insulated property in worlds concerned with energy prices and carbon costs. However, the arguments for a widespread programme of demolition and replacement, rather than more active measures to stimulate refurbishment, are weak.

There are many social and political problems with the large-scale demolition of older stock, particularly with housing which is occupied,[33] and such demolition is widely opposed. The UK has strong traditions of heritage in the built environment, which makes demolition of many buildings problematic. The full social costs of demolition and rebuilding can be much higher than for refurbishment, particularly once the analysis includes:

- material wastage
- embodied carbon involved in demolition

31 Pitts (2008)

32 Pitts (2008)

33 Power (2008)

- carbon and energy embodied in new construction
- polluting impact of particulates,
- use of lorry transport for materials and waste, and
- use of aggregates.[34]

By comparison, refurbishment reduces landfill disposal and encourages greater re-use of materials and existing infrastructure.[35] Refurbishment is also socially more acceptable, cheaper and quicker. It has a far lower environmental and community impact, as well as helping to protect the social structure of existing communities.[36]

However, the timescales for increasing the energy efficiency of buildings and reducing the carbon impact of activities in the built environment are short and the task is both substantial and urgent. While the very best new build will deliver energy gains on a significant scale in the long term, these long term savings may not offset increased construction and refurbishment costs in the short term. Higher refurbishment standards for existing homes, including under-floor and solid wall insulation, using known methods, offer better value and greater benefits compared with demolition[37] if the incentives and leadership to deliver the retro-fitting of existing buildings can be delivered by central and local government.

6.3 A changing skills profile

All four scenarios presented in Chapter 3 emphasise a need for a radical change across the construction industry and wider building-related sectors. The need for change is also implicit in the UK's targets for zero-carbon buildings and plans for eco-towns. Currently, doubts exist over the capacity of the construction industry to deliver all housing to zero-carbon standards within the anticipated timescale to 2016. It is worth noting however that several individual house builders have new demonstration houses that currently meet the target, for example at Building Research Establishment's Innovation Park.[38] Rolling out these exemplars to the standard housing estate is the challenge. The current slump in the housing market provides an additional concern for house-builders, who are facing the prospect of severe reductions in house sales and large numbers of construction job losses, although labour, including key skills, will be released in the short term.

Large companies play a leading role in the creation of new built environments, although smaller companies deliver much of the smaller scale development together with refurbishment, repair and maintenance. While the large scale construction operations are UK based, the companies are often multinationals. The regulatory threshold for energy performance of buildings is being raised in the UK and, whilst the construction sector internationally has demonstrated that it can deliver high energy and carbon standards, in practice it has not yet demonstrated a strong track record in the UK, either in terms of ambition or achievements that match specifications in operation. A step change is likely to require substantial policy support, including action on new skill requirements as well as consideration of how the property, land and labour markets might be reshaped through fiscal and regulatory measures.

34 *ibid*
35 *ibid*
36 *ibid*
37 *ibid*
38 www.bre.co.uk

Modifications and maintenance to existing buildings are typically carried out by very small companies. This is a major factor behind the difficulties in achieving high volumes of retrofitting, and in assuring high standards of delivery. Voluntary and market-based approaches have not yet achieved high quality, high volume retrofitting. While the SME sector is capable of rapid expansion and great flexibility, the sector is not tightly regulated and has traditionally been regarded as generally low-skilled with low productivity and efficiency.

It has been estimated that the expansion in renewable energy in the UK could provide 160,000 new jobs by 2020.[39] To maximise the potential development of the renewable energy industry within a short timescale, it will be important that the right skills are available, in the right places, at the right time, and in the right quantities, to enable business to take advantage of growing markets. Many of these skills will be based in traditional craft skills drawn from the more traditional construction sectors (e.g. electricians, plumbers, and building service engineers), though perhaps brought together in novel combinations and requiring new or different understandings of how systems operate. Other skills will be new and will have to be developed. The House of Commons Select Committee, commenting on the Leitch Review of Skills in 2006, recently stated that, "*Given the current commitment to the skills agenda, we deem it is essential that Government engage with the renewable industry to ensure that the skills needs of developers are addressed*".[40] Shortages in specific skills are also likely.[41] For example, engineering skills in nuclear power are currently extremely scarce in the UK since no new nuclear power stations have been constructed in the UK since Sizewell B was completed in 1995.

A problem for the energy efficiency and renewable energy sectors in terms of skills and training, is that they are covered by not one, but 14, Sector Skills Councils that have energy efficiency/renewable energy occupations within their remit. They include Asset Skills, Construction Skills, EU Skills, Lifelong Learning UK, SEMTA and SummitSkills.[42] Developing a coherent, integrated framework for training and qualifications in energy efficiency and renewable energy is therefore difficult, though not insurmountable. An extensive range of education and training provision is available in and around London for energy *efficiency*, although provision for *renewable* energy is not as extensive.[43] They both however, are under-represented in current National Occupational Standards. The majority of training providers in London are also currently operating at full capacity, and recruiting training staff themselves is a problem and seems to be inhibiting expansion.

Shortages in construction skills are not a recent phenomenon. In the past, growth in demand led to higher wages, which in turn raised the number of entrants into the market. The shortages in some construction craft skills experienced during the 1990s have been alleviated by an influx of skilled workers from Eastern Europe although as their home economies improve, this source of supply may reduce.[44] In response to shortages in industry skills, government and industry are examining the viability of offsite construction/prefabrication, modern methods of construction and on-site advances (such as mobile communications and robotics) as a means of reducing the reliance on site labour.[45]

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39 Department of Business, Enterprise and Regulatory Reform (2008)

40 House of Commons Select Committee (2008) http://www.publications.parliament.uk/pa/cm200708/cmselect/cmdius/216/21602.htm

41 Bolger (2007)

42 SE^2 Ltd, March (2007)

43 SE^2 Ltd, March (2007)

44 Communities and Local Government (2007b)

45 Glass et al. (2008)

Any predictions for demands for future skills over a timescale of 50 years will be highly uncertain. However, it is likely in the future that demand for construction professionals will remain high.[46] These individuals are also likely to be IT-literate, multi-skilled and highly-mechanised.[47] The increasing sophistication in building design and technology may well attract young people who are IT-literate and committed to energy and environmental protection. In addition to the issue of skills training, there is also the question of how such skills are put into practice. Consideration needs to be given to how redress for poor quality of installation and maintenance can be obtained.

The skills challenges are not confined to the construction sector. The discussions in sections 6.1 and 6.2 suggest that government regulation is likely to continue to play a leading role in driving change in the construction and development sectors, provided that it is implemented, enforced and monitored. This raises the issue of the capacity of the planning and building control systems to deal with increased regulation. The planning profession, in particular, is now dealing with a range of issues concerning more sustainable practices including more carbon-efficient forms of new development and better adaptation to climate change.[48] All this calls for a rapid rate of learning through increased training for the planning profession, and for local politicians.

6.4 Governance and decarbonisation of the built environment

Much discussion of decarbonisation and the built environment fails to consider governance structures, despite their importance for encouraging and enabling increased levels of energy efficiency and the take up of new technologies. Using governance systems to promote decarbonisation requires a judicious mix of regulation, fiscal measures and proactive area-based planning by local authorities. Evidence suggests that there are powerful arguments for the greater effectiveness of strong regulatory frameworks in delivering change within a short timescale.[49] However, such frameworks need to be carefully designed to avoid perverse effects.

Examples of such perverse effects, include differential VAT rates for new build and for refurbishment and improvement, and the payment by central government of demolition costs in renewal areas.[50] There are also suggestions that the Building Regulations may promote overheating in some locations.[51] The model at the heart of the Building Regulations, the Standard Assessment Procedure (SAP) for Energy Rating of Dwellings, may not reflect energy consumption once a building is in use. This can result in unanticipated outcomes from buildings designed to reduce energy consumption.[52] Unintended effects such as these point to a need for greater monitoring and enforcement to ensure that the regulations deliver the desired outcomes. It also suggests that the current shift towards outcomes-oriented forms of regulation might be more effective in avoiding such perverse effects if the outcomes are carefully defined and monitored.

Improving the design of national regulatory frameworks should not distract from the role of local governance. In the 1970s, urban renovation was a key feature of local planning, operating on a neighbourhood and local area basis to improve the

46 Harty et al. (2006)
47 Glass et al. (2008)
48 Smith and Levermore (2008)
49 Power (2008)
50 Power (2008)
51 Ward (2008)
52 Clarke et al. (2007)

quality of the built stock. This model could be important in a more energy-efficient and low- carbon future. As well as delivering improvements in the energy efficiency of the built stock in specific local areas, local policy initiatives can help build capacity in energy efficiency, stimulate local markets and regulate the local SME sector which, as observed above, often carries out energy-related renovation.[53] Energy Service and Multi-Service Companies (ESCOs and MUSCOs), which emerge as significant institutions in the **Sunshine State** scenario, might be innovative ways of delivering new forms of energy generation and can also enhance energy efficiency. Incorporating such institutional arrangements into area renewal is another role for local planning and urban governance.

Leadership and incentives for refurbishments could take the form of financial incentives, whether direct subsidies or taxation offsets, developing area-wide schemes similar to the area improvement schemes of the 1960s and 1970s where enveloping programmes renovated whole streets, and could provide tailored and personalised information using innovative ICT. There is also potential for marrying a domestic energy efficiency programme with measures to tackle fuel poverty. Measures to reduce the energy demands of the fuel poor through insulation and other means are more effective than subsidy of their fuel consumption since the former is a one-off cost while subsidies are required on a repeated basis.

What is clear in examining the energy efficiency of existing buildings is the critical importance of occupiers' behaviour and of building management[54] and hence of regulatory frameworks that influence such behaviour and management. The energy used in buildings to heat and cool space and water is only part of the total energy consumption by occupiers, and with increased thermal efficiency measures, the proportion it accounts for will fall. Unless and until the energy supply becomes decarbonised, providing incentives to users of the built environment to use less total energy will remain vital for reducing carbon emissions. This raises the question of how such incentives should be designed. Financial incentives alone seem to have a limited effect, despite the fact that reducing energy consumption should directly reduce costs. Where energy costs are a low proportion of total costs – to a household or a firm – then even actions that would trigger a large proportionate change in energy costs may not be attractive. Greater potential may be offered by provision of innovative, targeted forms of information and the creation of institutional arrangements that encourage monitoring of energy consumption within a household's or company's decision-making and routine behaviour.

The problem of tenanted commercial properties where neither landlords nor tenants have adequate incentives to improve the energy efficiency of their buildings has been highlighted. Often the efficiency measures need to be undertaken by the party with the least to gain commercially. Premises rented by SMEs may be a particular problem because energy management or improvement is not a priority for most of them, or for their landlords. There is potential for new contractual arrangements to influence behaviour in these sectors. Green leases[55] together with real-time metering might ensure that the financial benefits of reduced energy consumption are shared between

53 Adams (2008)

54 Wright (2008)

55 A 'green lease' is a lease between the landlord and the tenant of a corporate building with an additional set of schedules compared to a 'normal' lease contract. Green leases include a legal basis for monitoring and improving energy performance which provide mutual contractual lease obligations for tenants and owners to achieve resource efficiency targets (e.g. energy, water, waste) and to minimise the environmental impacts of an organisation's estate. See www.lcca.co.uk/server/show/ConWebDoc.95

parties, while innovative facilities management contracts might drive behavioural change.

The EU Energy Performance of Buildings Directive[56] may also have a significant role in influencing occupier behaviour in the non-domestic sector.[57] The requirement to have, and in the case of public buildings display, an Energy Performance Certificate on development, sale or rental could alter future occupiers' perceptions. But their long lifetime of up to 10 years suggests that public displays of real-time metering may be more effective in changing behaviour.[58] A focus on actual energy consumption outcomes may be a more important driver for changing energy use in the built environment than an emphasis only on the designed energy performance of buildings, as is currently the case. This point applies across the domestic sector also, where smart metering is slowly beginning to be adopted. However, as was pointed out in Chapter 4, smart meters are limited unless they are connected to energy markets and other sources of real-time information. Only then can they provide a full range of services such as time of day pricing (so that consumers can choose to operate appliances when prices are low), carbon emissions and even remote control (e.g. to switch on appliances automatically when prices fall below a selected threshold).

The effective use of energy management systems will be crucial in achieving carbon savings in commercial properties. The need for energy management also applies to communal residential development. The broader issue of managing communal and community resources and infrastructure applies to energy generation at a local scale, and to a range of public realm assets such as green spaces, water features, or green roofs on commercial and public buildings. The importance of these environmental assets in adapting to changing weather conditions and mitigating the associated energy demands will grow. (The potential of energy systems at the local scale is discussed in Chapter 5). As the scenarios illustrate, different societies might develop different approaches to the management and governance of the public realm – from the highly collective in **Sunshine State** to the corporately run in **Green Growth**. Whichever route is followed, it is an issue that must be addressed. This is looked at further in Chapter 7.

6.5 The challenge of implementation

Although new buildings and new built environments can, when well designed and well executed make real contributions to decarbonisation, disproportionate attention has been given to their potential contribution, which will remain small. The major task is to tackle the decarbonisation of existing buildings as they continue to contribute, potentially in new ways, to the social and structural fabric of the future. Technologies are available to refurbish and retrofit, and there are a number of exemplars from around the world. But implementing changes takes time, investment and a willingness to act on the part of multiple stakeholders: from occupants and owners through to small companies who install and maintain energy-saving and low carbon technologies. People's motivations to invest in their homes, and companies' motivations to upgrade the buildings in which their organisations operate, are poorly understood, and multi-faceted. Energy saving and decarbonisation are amongst many, sometimes competing, demands and aspirations.

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56 www.diag.org.uk

57 Ekins and Lees (2008)

58 Burgess and Nye (2008)

Even in new build, the deployment of appropriate technologies is only a small part of the picture. The regulatory, financial, inspection and monitoring arrangements that surround the construction industry will be crucial in shaping the built environments of the future. The skills of those employed in the construction and built environment sectors are critical to effective technical implementation and the skills of planners and regulators need to keep pace with new demands. But the behaviour of building occupants will remain a key driver of the energy consumed and so the design and implementation of regulation and incentives must factor this in, in well-informed ways.

Whether new or renewed, successful, sustainable future built environments are likely to encompass energy systems at a wider range of scales than today and to place greater emphasis on public realm and community assets. Such environments will require new approaches to governance so that they are appropriately managed.

This chapter has focused on decarbonisation, but citizens in the future will also have concerns for the security and resilience of their day-to-day environment and its energy systems. In the next chapter those aspects are examined in more detail.

Key messages

- New build policies alone will not deliver carbon emissions reductions that are needed to meet the Climate Bill targets.

- There are patchy and insufficient pressures for improved carbon performance in both the development and use of buildings, although there is more progress in the new build sector than with existing stock. But there is real scope for refurbishment and retrofitting to deliver energy efficiency if the potential can be realised. Take up and spread of innovation in the development and construction sectors is needed, and could be driven faster by better exploitation of the power of the public sector as a major developer, owner and occupier of buildings. The public sector is well placed to demonstrate leadership and also to create space for experimentation

- There is scope for area based policies led by local government to lead to improvements in the energy efficiency of the built stock in specific local areas. Local policy initiatives can also help build capacity in energy efficiency, stimulate local markets and regulate the local SME sector.

- Factors such as the integration of on-site energy systems, the creation of green and blue spaces (e.g. parks and trees to provide shade, and water for cooling) have an important role to play in designing sustainable low carbon built environments. So governance of the public realm has a vital role to play in sustainable energy management.

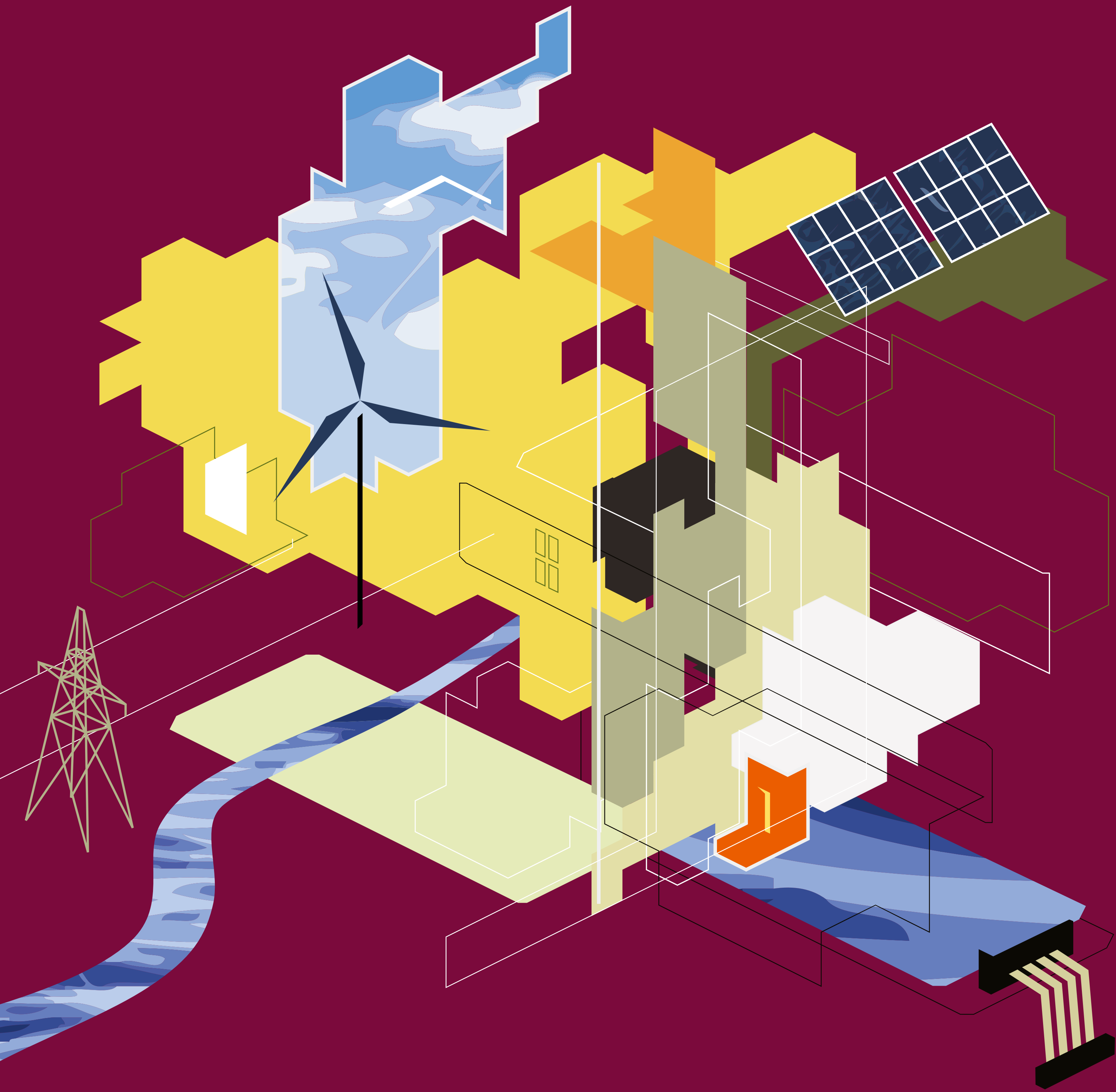
- There are inadequacies in the current construction and development sectors' business models with regard to the decarbonisation challenge. In the future, models will need to be established which sustain the developers' stake in the operational life of developments.

- There is potential for an annual assessment of building energy performance to advance change linked to minimum allowable standards at some point in the future.

- Capacity and skills in SME construction sector with regard to retrofitting is limited but market forces are likely to address this shortfall in the medium term. There are also questions of how such skills are put into practice and how redress for poor quality of installation and maintenance can be provided.

- Using governance systems to promote decarbonisation requires a judicious mix of regulation, fiscal measures and proactive area-based planning by local authorities. There are powerful arguments for strong regulatory frameworks which, if effectively implemented, can deliver change within a short timescale.

7 Security and resilience of future systems



7 Security and resilience of future systems

7 Security and resilience of future systems

7.0 Introduction

Whichever pathways UK energy systems follow in the future, policy makers and society will focus on ensuring access to secure supplies of energy. A reliable energy supply is essential for a modern economy and is needed to provide life-sustaining services such as water, heat and cooling. Citizens expect energy supplies to be available to support businesses, and to enable people to access the services that they rely on for mobility, comfort and communication.

During the past few years, concerns about energy security have risen up the political agenda. High fossil fuel prices, blackouts in power systems and changing geopolitics are just some of the reasons for this. These factors are important, but there are other dimensions to energy security. This chapter begins with an analysis of future threats to energy security, including the implications of the predicted impacts of climate change. The potential social impacts of these threats, and the extent to which they will fall on particular social groups or geographical areas, are then considered.

The chapter then turns to some of the ways in which the evolution of the built environment might help to strengthen resilience in the face of these combined threats. Security is not solely an issue of supplies of raw energy stocks. The way in which built environments are designed, modified and used will affect people's vulnerability to future energy insecurity. An integrated approach to resilience at the level of neighbourhood or region will be needed to address energy security, to respond to climate change and weather events, and to address the needs of the most vulnerable groups.

7.1 The changing landscape of security and resilience

A range of security threats are important to the UK,[1] and to the energy systems that support human activity. They range from natural hazards such as storms and heat-waves, to human-induced hazards such as protests, terror attacks, and under-investment in infrastructure. These risks are exacerbated by the fact that much of the existing UK infrastructure, for energy, water, and transport, is a Victorian legacy, built without consideration for modern terrorism or climate change. If the risks materialise, the lives and livelihoods of sections of the population will be threatened, with damage to the built environment and disruptions to the energy services that society increasingly depends upon.

The UK's recent National Security Strategy[2] provides an overview of the current security threats the UK faces, and how these might change in the future. It also considers how to address these security challenges 'to safeguard the nation, its citizens, our prosperity and our way of life'. The Strategy contends that the UK is more secure than most other countries, and that security is high when compared to many periods in history. However, the Strategy also notes that significant threats remain, many driven by global trends such as climate change, demographic trends, poverty and inequality, and competition for energy resources. Moreover, societies are becoming

1 Cabinet Office (2008a)
2 Cabinet Office (2008a)

increasingly complex, with interconnected networks to deliver water, power, gas and communications.[3] The transport of fuels and the transmission of electricity through a myriad of complex networks leave energy supply systems vulnerable to a variety of disruptions. Major urban developments are increasingly globally connected. An extreme event in one place can induce significant disruption in many others.[4]

A number of vulnerabilities in the UK have been exposed in recent years. The 10-day strike by truck drivers that blocked oil refineries in 2000 left a third of UK motorists with no fuel. Shops began to run out of food, and some hospitals were reduced to running minimal services. Vulnerability arising from capacity limitations of legacy systems, under pressure from novel demands in unexpected circumstances, was seen in the short-term power outages following surges in demand for cooling during the 2003 heatwave.[5] The floods in summer 2007 illustrated the need for a more integrated approach to energy security. Power and water supplies were lost, railway lines, eight motorways and many other roads were closed, and large parts of five counties and four cities were brought to a standstill.[6]

Built assets can never be completely resistant to natural and human-induced threats. New threats may appear while familiar ones may recede and, even where improved security is technically possible, there are often diminishing returns as expenditure on security increases. For example, electricity systems routinely build in a level of redundant capacity in case power stations or transmission lines fail, but it would be prohibitively expensive – and near impossible – for such systems to guarantee reliable supplies 100 per cent of the time. The level of security within systems is a trade-off between society's willingness to pay for improved security[7] and the willingness to accept a level of unreliability. As the scenarios in Chapter 3 illustrate, society's values, expectations and perceptions of security priorities are likely to shift over time.

The capacity of energy systems and the built environment to deal with security challenges in the future will depend on a range of factors. Not only will governments and other actors need to anticipate future sources of disruption, they will also need to ensure that systems are resilient to shocks, and are robust to more sustained changes in the external environment.[8] For example, a significant shift in the UK economy, with increased UK manufacturing, could put new demands on the energy systems. Resilience and robustness to these changes will have physical, social, economic and institutional components. The social and institutional aspects are arguably as important as the physical ones.

In the next section examples are used to illustrate an important point: that provision of energy from UK sources does not necessarily lead to higher levels of energy security. Moreover, energy security, like decarbonisation, is a multi-faceted issue which cannot be 'solved' by single technologies or policies.

3 Menoni (2001)
4 Cabinet Office (2008b)
5 Environment Agency (2007)
6 Pitt (2008)
7 NERA (2002)
8 Scoones et al. (2007)

7.1.1 Future threats to energy security within the UK

Discussions about energy security today often focus on geopolitical risks to fossil fuel supplies. The world's most developed economies are heavily dependent on fossil fuels,[9] a significant proportion of which are imported, often over great distances.[10] Security of oil and gas supplies are given particular emphasis because of their geographical concentration in locations that have historically been politically unstable. Furthermore, increasing competition for fossil fuels, amongst industrialised countries and with emerging countries such as China and India, has occurred in parallel with the re-emergence of Russia as an 'energy superpower' that is increasingly willing to use its resources as a political bargaining tool.[11] Although it has been suggested that renewables have the potential to provide 53-67 per cent of UK electricity by 2050[12] importation of fossil fuels and other sources of energy are likely to remain critically important for several decades. The scenarios in Chapter 3 illustrate how differences in the international dimension may shape the UK's future energy systems in different ways.

But geopolitical risks are not the only important factors in future energy security. Other risks include underinvestment in critical infrastructure, risks due to technical failure within these infrastructures, and risks due to civil unrest or terrorism either inside or outside the UK.[13] There are also risks linked to climate change and extreme weather events which are discussed separately in Section 7.1.2. Many of the events that have caused disruption or rapid price rises in the UK energy system during recent years can be traced to these other categories of risk.

The UK gas supply is an interesting example. Most UK homes today are heated by natural gas. Many people have worried about the security implications of importing gas, yet recent projections indicate that future imports are likely to come from a variety of sources via several different routes.[14] In a future scenario where this holds true, the supply of gas to the UK may become more secure, not less so. Yet the delivery of natural gas to final consumers within the UK has been affected by a number of recent failures in infrastructure. These include the major fire that closed the Rough gas storage facility (Britain's largest) in 2006 and the accidental damage to a major offshore pipeline in the same year. A lack of gas storage and pipeline capacity within the UK may prove to be a greater vulnerability than uncertainties over imported supplies.[15]

Whilst heating demand may in future be met to some extent by electricity or renewable heating technologies, technologies such as nuclear or off-shore wind power can only make a limited contribution to these end uses unless there is a significant change in infrastructures and end-use technologies. Even if such changes occur in the future, additional measures, such as public investment in strategic natural gas storage to tackle unreliability in the UK's gas infrastructure, may also be required to deal with other aspects of security during the transition to a decarbonised future.[16]

Even if future systems ensure sufficient spare capacity within power grids or fuel transportation networks, technical failures can have an impact on security. Typically,

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9 Department of Trade and Industry (2007a)
10 BP (2008)
11 Klare (2008)
12 Department of Trade and Industry (2004)
13 Watson and Scott (2008)
14 Oxera (2007)
15 Stern (2006)
16 Stern (2006)

failures are isolated and absorbed by the overall system but sometimes a combination of multiple failures, or a cascade of faults, can disrupt energy supplies. A good example is the blackouts in several European countries and North America in summer 2003.[17] A similar case affected the UK in the mid-1990s. Problems affected large power plant gas turbines and many new UK power plants were unavailable simultaneously. Multiple sources of energy supply which, in different ways, are a feature of the four project scenarios do confer the advantage of diversity in the face of uncertainty.

The possibility that terrorist groups may sabotage critical parts of the energy infrastructure network such as pipelines and power plants is seen as a significant threat by some experts.[18] It is also an issue of concern to members of the public, with 20 per cent of the UK population considering terrorism to be a likely cause of major electricity blackouts in the UK in the next 5 years.[19] Industrial disputes and civil disobedience have disrupted supplies in the past. In addition to the 2001 fuel protests mentioned above, examples include the 1984/85 Miners Strike and the Grangemouth oil refinery strike in 2008.

Current UK energy policies oriented towards reduction in carbon emissions have also been driven by the need to improve energy security.[20] These policies include increasing the contribution of renewable energy and nuclear power in the electricity generation mix, as well as demonstrating new technologies such as CCS. However, changes to the UK energy system to incorporate renewable technologies bring new issues for security and resilience. The output of many types of renewable electricity generation (e.g. wind and solar) varies with environmental conditions over which the operator has no control. This has implications for the ways in which electricity suppliers seek to ensure that demand and supply align at every instant.[21] However, the impact of this intermittency is often over emphasised. Research shows that a system in which 20 per cent of electricity comes from intermittent renewable technologies would not compromise the reliability of the electricity system, and would only require a modest increase in costs, estimated in the UK to be £2-3 per MWh of intermittent output.[22] In the long term, much larger proportions of intermittent generation may also be feasible, but would require more fundamental changes to transmission networks,[23] and/or breakthroughs in physical or virtual energy storage.

7.1.2 Climate change impacts

Options to address the threats to energy security discussed above will need to factor in the implications of climate change. The latest assessment of the Intergovernmental Panel on Climate Change (IPCC), demonstrates that a range of impacts are expected in the future.[24] The extent and seriousness of these impacts in the longer term will depend on the extent to which efforts to mitigate greenhouse gas emissions are successful. But even if deep, rapid cuts in emissions are made over the next five decades, impacts will still occur in the timeframe of this project from both past and future emissions over this period due to inertia in the climate system.

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17 Watson (2003)
18 Farrell et al. (2004), Yergin (2006)
19 Devine-Wright and Devine-Wright (2008)
20 Department of Trade and Industry (2007a)
21 UK Energy Research Centre (2006)
22 UK Energy Research Centre (2006)
23 UK Energy Research Centre (2006)
24 The Intergovernmental Panel on Climate Change (2007)

Many of these impacts will affect the UK, in ways that remain uncertain and with significant regional variability. Direct links between local weather events and the broad trajectory of global climate change are difficult to determine, but it is widely expected that extreme weather events are likely to become more common in the UK in future. As noted in Chapter 3, climate models predict wetter winters and drier summers.[25] Climate change and extreme weather events will have a number of impacts on the UK with consequences for the future of energy systems and for the built environment.[26] These include:

- sea-level rise, which is particularly important for coastal areas or low-lying cities such as East Anglia and London;
- increased flooding and droughts due to changes in patterns of rainfall, with knock-on effects on drainage systems and water management;
- increased incidence of heatwaves which can damage infrastructure (e.g. by softening of road blacktop (tarmac)) as well as threatening human health;
- increased incidence of storms which can damage buildings and other infrastructure;
- health impacts due to increased heat stress and the migration of diseases;
- changes in the demand for goods and services such as more year-round outside activity, and more air conditioning in the summer.

As this brief summary makes clear, the impacts will affect both the physical infrastructure of the built environment and the lifestyle and well being of the people and communities that live within it. The four scenarios in Chapter 3 illustrate different responses to the challenges, in worlds that each take the IPCC mid-range projections as the backdrop and suggest some ways that the built environment might change to adapt to these changes: sustainable urban drainage systems, use of water and vegetation in urban spaces for cooling, flood- and weather-proofing new developments.

7.2 Vulnerability to energy insecurities

Changes in the energy security landscape, whether linked to natural or human causes, will have impacts which vary according to locality and across different social groups. An assessment of where the greatest vulnerabilities lie is an important consideration for policy makers wishing to counteract the effects of energy insecurity. According to one definition, 'vulnerability is the state of susceptibility to harm from exposure to stresses associated with environmental and social change and from the absence of capacity to adapt.'[27] Whilst this particular definition stems from research on the impacts of environmental change, it is equally applicable to disruptions to energy supplies. Of particular importance are vulnerabilities that are exacerbated by social disadvantage and geographical location. In the context of an ageing society, the particular vulnerabilities of the elderly are likely to become more pronounced in the future.

25 McGregor et al. (2007), Association of British Insurers (2007), Smith et al. (2008)

26 Dawson (2007)

27 Adger (2006)

7.2.1 Poverty and vulnerability

Equity, described as justice in access to the key resources needed for an acceptable quality of life, is a central part of sustainable development.[28] Arguably, the decarbonisation challenge discussed in this Report will affect the poor the most. They are the most vulnerable to shocks (e.g. due to energy price rises) and may be subject to new forms of vulnerability (e.g. lack of access to air conditioning during heatwaves) as the climate changes. But the challenges are also likely to affect society more broadly, with implications for standards of living and people's expectations of their quality of life. The project scenarios illustrate a range of social values which might emerge – in some future worlds, new priorities other than wealth creation surface and energy systems contribute to social capital;[29] in others, inequalities are exacerbated and energy-inefficient housing, such as the former executive housing in the **Green Growth** scenario, becomes the new slums by 2050.

Health and well-being can be significantly affected by the ability to afford energy. Prolonged exposure to cold temperatures leads to a variety of health hazards including strokes, heart attacks, bronchitis and pneumonia. According to Age Concern, older people are less able to judge whether they are warm or cold[30] and will often try to cut spending on heating, leaving them vulnerable to low temperatures. However, there is little evidence that, for the wider population, deprivation carries a greater risk of death from the effects of cold weather – though this may be the case in some rural areas. Housing association and local authority properties, generally inhabited by people on low incomes, are relatively energy efficient.[31]

Recent rises in the numbers of households in fuel poverty in the face of rising energy prices globally have reversed a previously falling trend. The number of fuel poor households fell from 5.1 million in 1996 to a record low of 1.2 million in 2003, rising again to just under 3 million in 2007.[32] See Figure 7.1 as a percentage of households by English region. The framework used to deliver the reduction included £2 billion on Fuel Poverty Schemes, and £2 billion per year on Winter Fuel Payments. Local authorities across the UK have also invested £5 billion to meet the Decent Homes Standard. These policy responses illustrate a dilemma for the future. Whilst it is important for government to deal with the immediate problems caused by high prices or extreme weather events (e.g. through Winter Fuel Payments), this only provides temporary relief. In the medium to long term, improving the resilience of poor households to the effects of high energy prices and of climatic extremes will require investment to significantly upgrade the energy performance of homes. The privately rented sector has relatively poor levels of energy efficiency.[33] As the government's own advisory group on fuel poverty has argued: 'it remains the case that the only sustainable way to end fuel poverty is through energy efficiency (and now also micro-generation).'[34]

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28 This concept accords with the UK Government's Sustainable Development Strategy Guiding Principles of Achieving a Sustainable Economy, which aims to provide prosperity and opportunities for all, and ensuring a strong, healthy and just society which creates equal opportunities for all.

29 Social Capital refers to the norms and networks that enable collective action. It encompasses institutions, relationships, and customs that shape the quality and quantity of a society's social interactions. World Bank (also used by OECD)

30 http://www.ageconcern.org.uk/AgeConcern/ftf_winter_deaths.asp

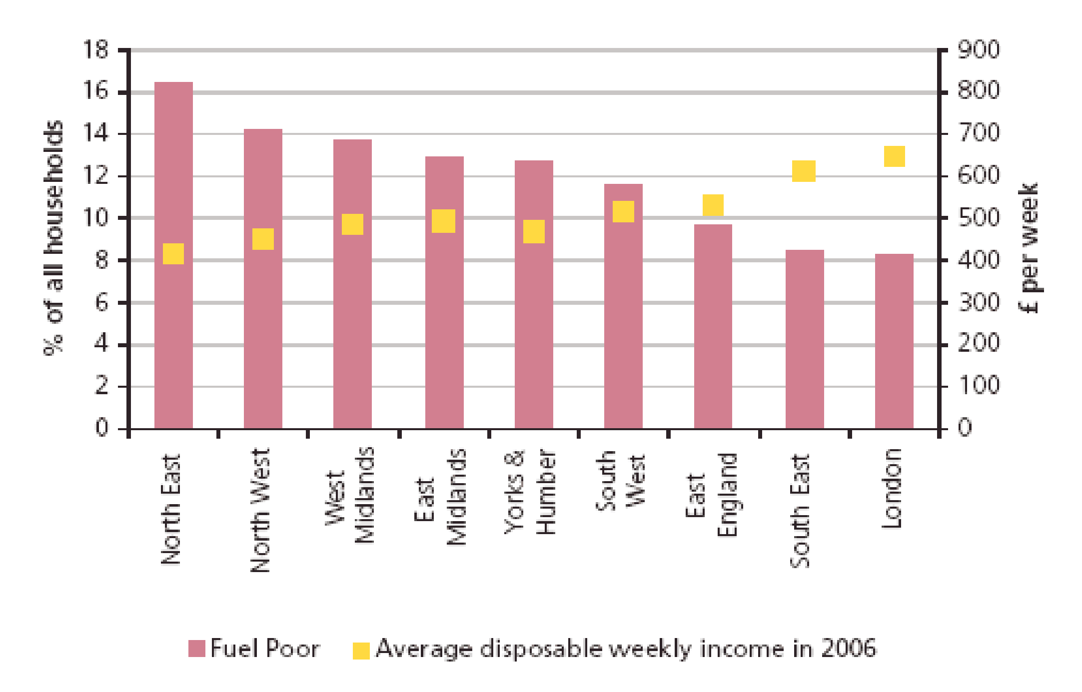
31 Communities and Local Government (2008)

32 Fuel Poverty Advisory Group (2008)

33 Communities and Local Government (2008)

34 Fuel Poverty Advisory Group (2008)

Figure 7.1: Fuel poverty as a percentage of all households by English region, 2006



Source: UK Fuel Poverty Strategy (2008)

The immediacy of concerns about winter fuel poverty may distract attention from the energy implications linked to expected increases in the incidence of summer heatwaves. The heat wave in summer 2003 killed an estimated 2,000 people in the UK[35] and an estimated 35,000 people across Europe. Heatwaves disproportionately affect older people. Studies from some US cities, where summer temperatures are higher (and the use of air conditioning much more common) than in the UK, show a link between poverty and vulnerability but there is little evidence as yet in the UK that the impact of heatwaves are more severe for those on low incomes.[36] This may be because it is not yet common for households in the UK to have air conditioning. A study of the consequences of a major heat wave in Chicago found the highest risk of death to be concentrated among socially isolated, elderly people. It was 30 per cent lower among those with links to clubs and churches.[37] Interventions to increase social capital (defined as 'the stock of active connections among people: the trust, mutual understanding and shared values and behaviours that bind the members of human networks and communities')[38] may lead to heightened resilience amongst such vulnerable individuals, augmenting any interventions to improve the thermal properties of homes and the surrounding environment. Similarly, in seeking to address excess winter deaths linked to cold weather, a built environment which is designed to take social aspects into account, such as getting exercise and eating well, could achieve better results than emphasis on thermal efficiency alone.

The interconnections between water supply, energy, and climate change may exacerbate vulnerabilities in future. Water will become more expensive with increased costs of energy for treatment and distribution. The need for water treatment may

35 Smith and Levermore (2008)
36 Kovats and Kristie (2006)
37 Semenza et al. (1996)
38 Cohen and Prusak (2001)

also increase as temperatures rise and as water-borne disease vectors now endemic in tropical areas spread their range, adding to costs. Water poverty may become widespread and interconnect with fuel poverty. It could affect people's ability to cope with heat waves, as water is vital for hydration and body cooling. These interconnections, and a growing focus on summer overheating as well as on winter warmth, suggest that the future will require a more sophisticated understanding of vulnerability than that captured by the current concept of fuel poverty. Better integrated strategies will be needed to develop the built environment in ways that help to address future vulnerabilities.

7.2.2 Spatial variations in vulnerability

There is considerable spatial variation across the UK in the distribution of vulnerability to insecure energy supplies and the impacts of extreme weather events and climate change. Incomes vary across regions and between urban and rural areas, and this influences the distribution of fuel poverty. For example, the fuel poor are most prevalent in certain neighbourhoods within cities, such as Liverpool, Birmingham and Manchester.[39] Urban regeneration schemes may help alleviate fuel poverty through the deployment of community district heating and cooling systems where energy efficiencies can be passed on in reduced costs.[40]

But many rural locations also have significant poverty. Changes in rural demography in the UK are characterised by younger people moving to cities[41] and the better off from urban environments moving to rural areas,[42] including for second homes. The rural population is projected to grow at a higher rate than the urban population in England up to 2025.[43] If these projections are realised, the needs of the less fortunate in rural locations may be overlooked. Fuel poverty is one form in which those needs are expressed. Many people in rural locations have limited access to piped gas, and have to use bottled gas, heating oil, or electricity for heating and hot water instead. The costs of these alternatives are often higher than natural piped gas. The electricity grid may also be less reliable because power cables tend not to be buried underground in rural areas, and there are fewer interconnections within rural grids. Again, local energy systems, probably based on renewable sources, may provide communities with greater resilience in the future.

Access to the means of coping with heat waves is also unequally distributed. The interplay between the interior of buildings and the external environment is key to avoiding mechanical, energy-consuming, cooling technologies. Research by the Commission for Architecture and the Built Environment (CABE) shows that green space increases the value of nearby homes,[44] suggesting that the homes of the less well-off are less likely to benefit from these external resources. Similarly, flooding risk is unevenly distributed. Areas prone to flooding tend to command a lower price in the housing market and are likely to attract the poorer sections of society. This means that consideration needs to be given on an area-by-area basis to the total package of vulnerabilities faced by residents.

39 Centre for Sustainable Energy (2003)
40 Walker (2008)
41 Commission for Rural Communities (2007a)
42 Campaign to Protect Rural England (1998)
43 Commission for Rural Communities (2007b)
44 Commission for Architecture and the Built Environment (2005)

7.3 Enhancing resilience

Whilst many of the security threats outlined in this chapter are external to the UK's built environment, this does not mean that they cannot be mitigated through action to reshape that environment. There are many ways in which the built environment might contribute to resilience to changes in the energy security landscape as the UK undergoes decarbonisation. Some of these are illustrated in the project scenarios that accompany Chapter 3. In the **Green Growth** scenario, for example, urban heat island effects are tackled by outlawing heat dumping. Actions include banning air conditioning in commercial buildings, an approach that presents design challenges. The conventional design of large internal spaces, accommodating large numbers of people and heat-intensive IT equipment, are not amenable to natural ventilation. Solutions may require a mix of architectural and other innovations. For example quiet, pollution free, electric vehicles might transform noise and air quality in city centres making natural openings in buildings more attractive, while IT technologies might evolve to reduce the energy demands and wasted heat of office equipment. Also in this scenario novel building approaches are adopted from Europe, with floating settlements emerging in areas prone to flooding.

In the **Carbon Creativity** scenario there are also large scale engineering solutions for resilience, such as higher flood defences and larger diameter drainage pipes, exploiting new, lower-carbon, concrete technologies. There is a focus on exploiting the efficiencies of high-density living/working with mixed-use redevelopments of existing environments which not only exploit energy efficient technologies but also go some way to tackle the carbon pressures of transport. Micro PV is incorporated at the building level but not linked to the grid. Groundwater is used for cooling, and heat pumps and advanced glazing contribute to the energy efficiency of buildings, helping to reduce demand-side pressures. In the **Sunshine State** scenario there is, eventually, the use of virtual storage to deal with supply-demand imbalances arising from an increase in micro and local electricity generation. New, easy to implement, PV technologies are widely taken up. Local pumps and fuel cells have been deployed. Households not only use smart meters but have responded well to appliances which offer aesthetic visual feedback linked to energy consumption. Green roofs are widespread, absorbing heat, and a resurgence of water-meadows help manage the impact of flooding. In the **Resourceful Regions** scenario, the rise of geopolitical concerns and a dwindling of trust are allied with a strong role for regions to respond to local vulnerabilities and exploit local resources. Smart metering is imposed in many regions to reduce the risk of outages. There is extensive greening of urban public spaces and the cooling effects of local waterways are also exploited in cities such as Birmingham. Architects are increasingly designing for future flexibility and modification. Existing infrastructure is adapted to exploit new technologies.

These examples illustrate that a range of strategies could be used to develop the built environment and improve resilience. Three broad approaches merit further discussion, some of which coincide with the pathways to decarbonisation outlined earlier in this Report (see Chapter 1):

- strategies to reduce the amount of energy required to deliver energy services within the built environment;
- integrated energy planning at different scales;
- measures to strengthen resilience of energy systems.

Strategies to reduce the amount of energy required within the built environment have focussed on thermal efficiency – both in new build and in retrofitting and refurbishment of existing stock. As this Report sets out in Chapter 6, tackling the energy efficiency of existing stock will be critical. However, concerns have been raised regarding the tendency to promote greater air-tightness of dwellings in efforts to increase their energy efficiency. Air tightness enables the indoor environment to be controlled and energy demand to be reduced during winter, but may lead to overheating during the summer, as may triple glazing and south-facing windows in the absence of mechanical ventilation or designs incorporating solar shading.[45] Unforeseen consequence of higher air-tightness might include householders investing in air-conditioning for cooling during the summer, or adverse health effects.[46] Use of air conditioning may, in turn, have negative impacts on carbon emissions and aggravate heat-island effects.[47] Smart monitoring may offer a means to safeguard against the overheating of domestic buildings, with temperature sensors triggering alarms above certain critical levels.[48] It is an important challenge for building designers and urban planners to create buildings within urban spaces that manage the complex interconnections between energy use, building use and heating/cooling requirements under conditions of higher costs and climate change.

Integrated, local planning incorporates on site generation of energy. The potential for on-site generation (known as micro-generation) is large,[49] but in most cases it will not be enough to supply all of the energy that occupants need when they need it.[50] Such on-site installations will need to be integrated into local energy networks and/or storage systems as part of any strategy to reduce vulnerability to price rises and disruptions. Furthermore, as shown in Chapter 5, there is an economic case for deploying energy systems at a scale larger than individual buildings to take advantage of economies of scale, although the opportunity for integration with neighbouring buildings may be lower in rural areas than in urban areas. More generally, the technologies appropriate in rural areas might be different from those appropriate in towns and cities, because greater space is available.

As the case of decentralised energy generation illustrates, resilience strategies can operate at different scales. For example, measures for coping with excess levels of heat could include green spaces (community level), solar shading (building level) and fan-evaporation cooling (individual level).[51] Cities and regions are increasingly attempting to embed energy security and risk management features into their built environments and systems of governance.[52] The UK utilities sector is currently obliged to prepare plans and develop response strategies to cope with supply disruption.[53] The introduction of policies, guidance, codes and regulations to improve the resilience

45 Roberts (2008)
46 Roberts (2008)
47 Smith and Levermore (2008)
48 Hinnells (2008)
49 Energy Saving Trust (2005)
50 Watson et al. (2006)
51 Goodier et al. (2008)
52 Coaffee (2008b), Coaffee (2008a)
53 Coaffee (2008b)

of the built environment to extreme events tends to be complex and difficult to apply consistently.[54] They work in some circumstances but not in others. 'Resilient engineering'[55] also demands more resilience in the professions and the structures and processes which govern construction activity.

Strengthening the resilience of energy systems is also important. Given climate change projections, resilience of energy infrastructures to changed temperatures, flooding and increased storm risk clearly becomes an issue. This requires an understanding of the likely changes, and planning for avoidance, mitigation and recovery in the face of such hazards, as well as enhanced awareness among residents and businesses in at-risk locations. The work of the UK Climate Impacts Programme and its local partnerships is already putting in place the frameworks for enhanced resilience.[56]

Many of the strategies to improve energy security, and the resilience of the built environment to some impacts of climate change, emphasise the concepts of redundancy (in terms of spare capacity and interconnectedness) and of diversity (in terms of sources and distribution options).[57] An energy system with low levels of diversity in the type of electricity generation it uses, the routes it uses to pipe natural gas, or the geographical location of its distribution centres for oil is particularly vulnerable to single security threats. Diversity is therefore an important feature of a secure, resilient energy system and hence, a secure, resilient built environment. The built environment can help to strengthen the diversity of the energy system by providing sites for many different sources of electricity and heat generation, by improving the number of interconnections in electricity and heat networks, and by incorporating a range of different actors, institutions and business models.

Taking all these issues into account, tackling energy security and improving resilience can align with the goals of decarbonisation. What is needed is a form of integrated resilience assessment and planning, at the level of the neighbourhood, urban area and region, which incorporates concerns with:

- reducing energy use and carbon emissions;
- ensuring energy security;
- protecting the most vulnerable groups in society, and;
- anticipating and adapting to climate change.

This form of comprehensive planning at the local or regional scale will be challenging, putting substantial demands on the knowledge of local and regional governance actors and on their ability to build partnerships across different sectors. Rather than a means of delivering a definitive resilience plan, it is likely to be a continuing process in which learning to become more resilient is emphasised.

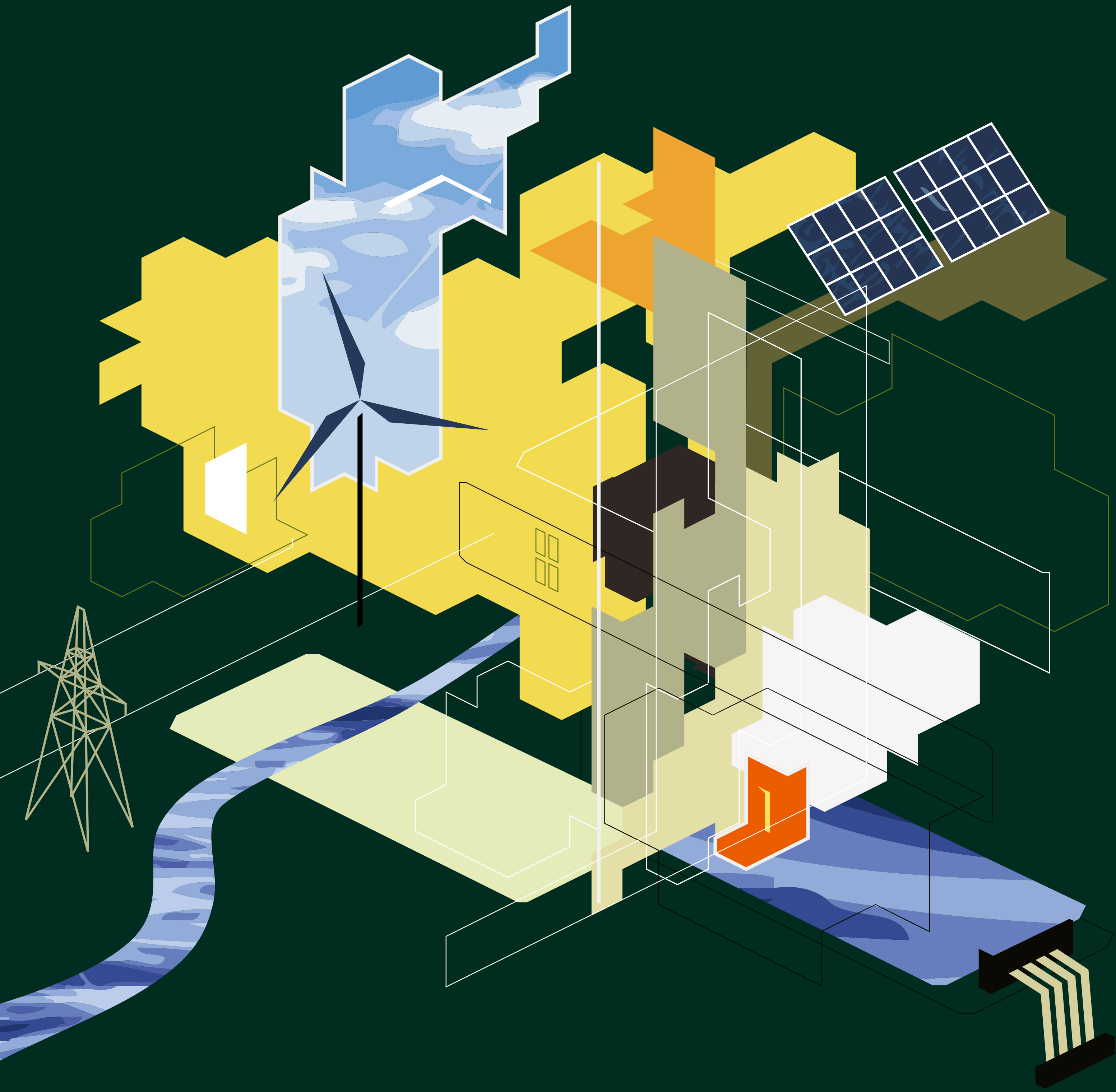
Building the partnerships that would underpin resilience planning is one way of building the human and social capital, and capabilities to deal with problems when they arise that is often emphasised in resilience literature.[58] The UK will need to ensure that skills, knowledge and capacity are available within local communities, professional and occupational groupings to meet the multi-faceted challenge of energy security.

54 Spence (2004)
55 Hollnagel et al. (2006)
56 http://ukcip.org.uk/index.php
57 Stirling (2007)
58 Adger (2006)

Key messages

- Energy security, like decarbonisation, is a multi-faceted issue which cannot be 'solved' by single technologies or policies.
- Levels of security of systems are influenced by a range of external and internal threats. Geopolitical risks are not the only important factors in future energy security.
- Multiple sources of energy supply confer the advantage of diversity in the face of uncertainty.
- A focus on electricity supplies will not tackle all the dimensions of insecurity in the medium term. Most UK homes today are heated by natural gas. Measures such as public investment in strategic natural gas storage to tackle unreliability in the UK's gas infrastructure, may also be required during the transition to a decarbonised future.
- A more sophisticated understanding of vulnerability to energy security threats than that captured by the current concept of fuel poverty will be required in the future. More integrated strategies will be needed to develop the built environment in ways that help to address future vulnerabilities.
- There is considerable spatial and social variation across the UK in the distribution of vulnerability to insecure energy supplies and to the impacts of extreme weather events and climate change. Urban regeneration schemes may help, alleviating fuel poverty through the deployment of community district heating and cooling systems. Local energy systems, probably based on renewable sources, may provide rural communities with greater resilience.
- A range of strategies could be used to develop the built environment and improve resilience. The overall requirement is a form of integrated resilience assessment and planning, at the level of the neighbourhood, urban area and region.

8 Conclusions



8 Conclusions

This chapter draws out the key issues for policy-makers and other decision makers to address as they shape and deliver strategies for sustainable energy management and the built environment, offering pointers to action in support of:

- Overcoming 'lock-in' - in systems, regulatory frameworks, business models and behaviours - to enable decarbonisation to occur;
- Addressing opportunities to exploit energy systems across the full spectrum of scales;
- Enabling behaviour changes and encouraging engagement with decarbonisation;
- Exploiting opportunities to strengthen security and resilience and tackle vulnerability;
- Upgrading not only buildings but places and spaces;
- Achieving innovation in the development and construction industries;
- Strengthening the evidence base.

8 Conclusions

8.0 Introduction

During the lifetime of this project the arguments for acting on decarbonisation have grown ever stronger. Further evidence on global warming indicates that a high emissions scenario could result in global temperatures rising by 6.4°C by 2100.[1] Other energy challenges have also been drawn centre stage, with unprecedented rises in global oil prices and the associated impacts on fuel poverty, and significant events in the geo-political and global economic environment. Government policies and targets have been evolving rapidly and a new Department of Energy and Climate Change has been created.

There is recognition of the need for acceleration in the pace of change if new and challenging targets for decarbonisation are to be met whilst also addressing energy security and fuel poverty. Change in the built environment has a significant contribution to make as half of UK emissions arise from energy use within it. The setting of zero carbon targets for non-commercial buildings, the introduction of zero carbon house building targets, and the Community Energy Savings Programmes are examples of policies which are starting to address changes needed in the built environment.

This Report is distinctive in looking at the interconnectedness of energy systems and the built environment, and at the human, social and economic factors that shape their co-evolution. It has examined a range of possible future trajectories through a decarbonisation transition, drawing on previous transitions, current scientific evidence, and structured scenario development. It points strongly to the need to understand and address lock-ins (see Chapter 2) if the UK is to make a transition to sustainable, low-carbon energy systems.

The period of transition is likely to be both lengthy and uncertain, and there is no consensus on how policy should develop to deal with the evolving circumstances. Some people argue that direct promotion by governments of particular solutions to perceived problems will not succeed and could well result in adverse side effects, and so market-led approaches should prevail.[2] Others argue that there is already a new energy paradigm and so there is a need for completely new frameworks and institutions.[3] It will be some time before this debate is concluded, but decisions made now will have profound consequences for the future of the economy, energy security and the global environment.

Identifying issues that influence the transition will assist in steering its course.

This Report emphasises how economic conditions, societal choices and policy work together, and, in some cases, against each other, to produce particular patterns of technology use in energy systems and the built environment. The analysis demonstrates that an understanding of the co-evolution of energy systems, the built environment and broader societal processes needs to be at the heart of re-shaping a wide range of policies. The implication for policy is that an integrated approach is essential.

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1 Meehl et al. (2007)
2 Robinson (2008)
3 Helm (2007)

This concluding chapter provides an analysis of the factors that may impede change and offers pointers to the scope for intervention to increase the pace of policy implementation. Some of our conclusions we believe to be innovative; others reinforce points that have been made by others but which thus far have not been influential. They are framed around two critical areas for policy:

- the strategic issues that need to be addressed in future policies for energy systems and the built environment;
- the factors leading to the effective implementation of policies.

8.1 Strategic issues

8.1.1 Overcoming lock-in to enable decarbonisation

This Report has emphasised that there are multiple pathways to achieving decarbonisation: reducing energy use; increasing energy efficiency; switching to low carbon energy sources; and capturing carbon emissions for long term storage. ***Success will depend on pursuing a number of pathways to decarbonisation simultaneously.***

However, the pursuit of many of the options may well be limited by the phenomenon of lock-in, with institutional inertias, habitual ways of thinking or behaving, established path-dependencies, current business models and frameworks of incentives, all making it difficult for new approaches to take root.

Energy networks will play a critical role, either reinforcing or disrupting lock-in. The decentralisation of energy systems would significantly increase the complexity of distribution networks. New heat networks might be constructed in towns and cities, some of which may also be designed to deliver 'coolth' in hot weather. Networks of carbon dioxide pipelines may be needed to transport carbon dioxide to storage sites. Electricity grids could be extended and reinforced to facilitate the operation of electric vehicles and their contribution to storage of electricity, or to enable an expansion of electric heating. Even continued centralisation of electricity supply with more variable sources such as wind power will pose challenges for transmission network operation. Ofgem's recent long term scenarios have illustrated how networks for electricity, for example, may be required to change significantly.[4] Therefore:

If the full range of options for decarbonisation is to remain available, existing lock-ins will have to be disrupted.

Investment patterns will need to be shifted towards low carbon, in both energy systems and the built environment.

An emphasis on flexibility and reversibility is needed, since it is impossible to predict the precise changes that will be required in the long term.

Investment and policy evaluation frameworks need to use multi-criteria methods and processes which take into account social, cultural and environmental perspectives, not only short-term economic optimisation. Such approaches can help to reconcile decisions made today with long-term policy goals.

Policy therefore needs to foster experimentation and innovation (see Box 8.1 for some examples).

4 Ofgem LENS report: http://www. ofgem.gov.uk/Networks/Trans/ElecTransPolicy/lens/Pages/lens.aspx

The success or failure of such experiments cannot be predicted. The extent to which successes can be fully integrated into energy systems and built environments will depend on how open these systems and environments are to change, and how capable of learning they are, both from successes and from failures.

8.1.2 Beyond centralised energy systems?

The UK's energy system today is highly centralised and this has served the UK well since World War II. Power systems have reaped economies of scale, the gas and electricity grids have enabled the vast majority of people to access modern energy services. Centralised natural gas supplies have brought affordable heating to most UK homes.

However, targets for large reductions in carbon emissions, coupled with more specific goals such as targets for the expansion of renewable energy, are likely to require the deployment of energy systems at a range of more decentralised scales. Within decentralisation, there is a wide range from city-wide CHP systems, such as those typical of other northern European countries, to renewable heating systems in individual buildings. In the UK, popular discussion of decentralised energy often equates it with household microgeneration.

Awareness of, and understanding of how to implement and exploit systems across the full spectrum of scales will be critical. Decentralised systems can help deliver energy security and tackle fuel poverty as well as contributing to emissions reduction and energy efficiency.

Decentralised energy sources are deployed close to centres of demand, helping to reduce energy losses. Under some circumstances they can enable households and communities to play a more active role in energy provision, and can reinforce other drivers to encourage change in energy behaviours.

But decentralised systems do carry certain risks, and are particularly likely to require innovation and far reaching change to energy networks.

Reaping the benefits of decentralisation and maintaining energy security will need investment in the development and use of much more sophisticated information and communication technologies and control systems, and stronger incentive mechanisms, particularly within the UK electricity system.

If government and other stakeholders want more decentralised energy to help meet policy targets, particularly within the built environment, it will be essential to overcome the current lock-in to centralisation. The experience of the past two decades during which governments have sought to encourage the contribution from decentralised energy sources shows that a piecemeal approach is unlikely to be effective.

Stronger actions are required to overcome lock-in and open up the energy system to experimentation and new ideas (see Box 8.1).

Box 8.1: Examples of policy options for opening up the centralised energy system

- Energy system experiments. These would be encouraged through funding and incentives from government to complement incentives for individual technologies. For example, they could involve trialling the integration of electric vehicles in specific local areas, or the construction of small local grids/networks with multiple small scale electricity generators.
- Policy decentralisation, for example through increased powers to local authorities which enable them to invest in and govern local energy infrastructure. This might include electricity generation, electricity and heat networks. It could also include setting up new businesses (e.g. local energy service companies).
- Reform of the energy regulatory system. This could include changes to the remit of regulators so that their decisions are more closely aligned with government policies on emissions reduction. It could also include stronger incentives provided by regulators to energy network companies (for gas, electricity and heat) to innovate and experiment.

8.1.3 Changing behaviours

A key strategic issue for policy makers is the extent to which intervention to increase the pace of change in people's energy behaviours is desirable, necessary, or practicable. Evidence in this Report shows that human behaviours and social values play a key role in shaping the co-evolution of energy systems and the built environment. Millions of individuals influence energy demand and energy systems through their day to day activities and decisions.

Conceiving human behaviour as a problem that must be addressed at the level of individuals or households, for example by correcting supposed deficits in information, is unlikely to be successful.

Sustained behaviour change requires systematic intervention, acknowledging the variety of influences – economic, social, psychological and technological – that shape behaviour.

This fact is increasingly well recognised, and is manifest in the social marketing approaches developed by the Department of the Environment, Food and Rural Affairs, with their associated models of behaviour and frameworks for intervention.

Changes to infrastructure and to the regulation of suppliers (of energy and buildings) can shape the environment in which people exercise choice. Interventions such as intelligent building energy management systems, may indirectly urge changes on energy users. But unless the interventions are well-designed and take account of economic, social and technical aspects users may, through their behaviours, resist or potentially undermine their effects.

Achieving change in energy behaviours requires a multi-faceted approach, including enabling more varied and potentially more active forms for people to engage with energy systems (see Box 8.2). New modes of engagement will become important in seeking to innovate energy systems at different scales.

Box 8.2 Examples of more active engagement

- Feed-in tariffs to encourage more individual users to become energy suppliers by installing small-scale generation.
- Energy suppliers are regulated differently, enabling them to develop a different relationship with consumers based on making money by providing services (comfort, warmth and entertainment) rather than units of energy.
- Green leases, linked to real-time energy consumption data, involve landlord and tenants in more active energy management.
- Community-level structures create new forms of engagement, e.g. local authorities are enabled and encouraged to see energy at the heart of their responsibilities and to collaborate with other local actors, such as small businesses or individual citizens, to play a more active role in local energy service provision.

However energy systems evolve, this Report has shown that there is still a long way to go before energy systems and the built environment will have embraced the 'IT revolution'. Smart meters are often mentioned in this context.

So called 'smart meters' cannot deliver a full range of truly smart services – such as time of day pricing to automatic load control – without extensive investment in the development and deployment of IT and data management infrastructure. Government intervention to promote and bring forward innovation to deliver the IT infrastructure to exploit the functionality of smart meters could greatly accelerate this process,

Coupled with breakthroughs in energy storage technology, investment in truly smart metering could revolutionise current perceptions of the kinds of energy systems which are considered to be desirable and feasible.

There is technical scope for such ICT-enabled energy management systems to allow the active management of energy demand alongside a more passive role for the consumer, but even this is likely to require a change in consumer attitudes if it is to be successful. ***Innovative energy management practices, where consumers need to demonstrate willingness to delegate responsibility for the operation of their appliances to utility companies or others, will require trust in the utilities if they are to become socially accepted.***

Changes in the relative costs of services, linked to their carbon emissions, are another potential approach. This link to emissions which is typically made indirectly, through energy price signals, could be made more directly through carbon allowances, carbon trading, or even carbon taxation schemes. People have not yet responded to energy prices and energy efficiency measures at the scale and pace required to meet future emissions targets, and their motivations to do so are likely to be strongly linked to economic circumstance and prevailing social norms.

The serious pursuit of decarbonisation may well require interventions that create a willingness to change behaviours aligned explicitly to carbon, rather as well as a range of complementary policies for energy efficiency.

As a starting point in making changes it would be useful to consider how to move away from the current tendency to use energy consumption and energy price as a proxy when seeking to influence behaviours that result in carbon emissions. However, making carbon visible through high prices would take strong political leadership.

8.1.4 Strengthening security and resilience

Geopolitical threats to energy supplies often dominate the debate on energy security but they are not the only important factors. Domestic factors such as ageing infrastructure and inflexible distribution networks, civil disruption, or extreme weather events, as well the potential impact of technological failures, also need consideration. When domestic factors are considered, attention often turns to the capacity of electricity generation facilities to meet demand. This issue may become more important in the future if electricity increases its contribution within the UK energy system, in the way foreseen by some of this Report's scenarios.

The electricity system is not the only domestic energy infrastructure that is vulnerable to security threats. The security of the UK gas infrastructure is also essential. In future, the security of heat networks, carbon storage sites, and networks to refuel hydrogen vehicles may also be important.

Vulnerability to energy security threats is not uniformly distributed across society. In addition, new sources of vulnerability, linked to the capacity to cope with the impacts of a changing climate, are likely to emerge. ***The future will require a more sophisticated understanding of vulnerability than that captured by the current concept of fuel poverty*** (see Box 8.3).

Box 8.3 Examples of approaches to address vulnerability

- Urban regeneration schemes could help alleviate fuel poverty through the deployment of community heating and cooling systems, or the strengthening of natural cooling through redesigned spaces in the public realm.
- Local energy systems, probably based on renewable sources, could offer a solution to rural energy vulnerabilities.

Both these options require community engagement to operate successfully and could be usefully supplemented by building the capacity within communities to provide other means of support for vulnerable groups.

Energy security is therefore a multi-faceted issue, which cannot be 'solved' by single technologies. Better-integrated strategies will be needed to develop the built environment in ways that help to address future vulnerabilities.

No energy technology option is inherently more secure than another. Security is a property of energy systems and needs to be analysed and strengthened using systematic approaches.

A range of strategies can be used to develop the built environment in ways that improve the resilience of energy systems. Designing new buildings for reduced energy consumption could make a major contribution. Area-based approaches to retrofitting existing properties may provide a step-change in energy efficiency and there are successful examples elsewhere in Europe from which the UK can learn.

Models of development that allow new-build developments to contribute to the energy efficiency of existing building stock should be encouraged (see box 8.4).

Box 8.4 Using new development to encourage energy efficiency in existing stock – possible approaches

- Amassing a pot of funds for local refurbishment;
- Encouraging the implementation of district heating and cooling in and beyond the development site;
- Using landscaping to manage solar gain within buildings.

Creating greater complexity and capacity in energy networks has the potential to strengthen resilience, enhancing the flexibility to respond to local problems and to make the most of multiple sources of supply.

The use of multiple energy sources can enhance the security of energy systems to shocks, such as disruptions to oil supplies from particular countries. Increasing diversity in these ways can improve robustness to stresses (e.g. the impacts of climatic effects and weather events). Increasing diversity could involve developing energy systems at more decentralised scales, integrated into the built environment, introducing additional supply technologies (e.g. solar hot water), additional distribution routes (e.g. more interconnections in electricity distribution networks), and additional infrastructures (e.g. heat networks).

An integrated approach is required in order to understand the threats to energy security and the possible impact of mitigation options within the built environment. ***A form of integrated resilience assessment and planning, at the level of the neighbourhood, urban area and region, which not only incorporates energy efficiency and carbon reductions but also anticipates the need to adapt to future climate change and to address future vulnerabilities, is needed.***

This would build on the work already being undertaken within regions and at the city level on resilience planning, with the support of UKCIP, but would extend this work to consider the positive contribution that diverse and flexible energy systems could make and the ways that change in the built environment could be managed to accommodate such systems.

8.2 Implementation challenges

8.2.1 Upgrading buildings, spaces and places

It is clear that urgent attention needs to be paid to improving the energy performance of the existing built stock. This will continue to form by far the largest proportion of the built environment in the future, and yet its current energy and carbon efficiency is extremely poor. There is strong evidence of inefficiency in the domestic sector, and no reason to suppose that the same does not apply to older property in the retail, industrial and commercial sectors, particularly in non-prime locations, i.e. outside the highest value areas in local property markets where much older non-domestic property is located.

Existing stock is slowly being improved but a step change in the rate of improvement is needed to meet carbon emission targets. Many technologies already exist and there are further technological innovations in development, such as paint-on insulation and new glazing technologies.

Continued research and development is essential if innovation is to make retrofitting to increase energy performance easier, more cost effective, and feasible in the more challenging building stock.

The effective implementation and use of such technologies will require engagement with very large numbers of building owners, managers and occupiers, and the involvement of the many small companies that dominate in this construction and building-based energy system activity. As with seeking to influence individuals' energy consumption behaviour, so tackling the scale and rate of retrofitting will require an integrated approach, combining: targeted information provision; attention to how people and firms currently assess and consider their building energy efficiency; appropriate financial incentives; consideration of the need for tighter regulation; and enhanced capacity within the construction industries.

In addition to tackling heating efficiency, retrofitted buildings should be designed to stay cool in hot weather.

Given the current low levels of take-up of energy efficiency technologies in existing domestic and non-domestic buildings, it is our view that there needs to be a significant increase in the incentives for taking action. Better incentives are needed to overcome the current imbalance between the perceived benefits of taking action and the monetary and other costs of that action**.** In the case of tenanted property in the domestic and non-domestic stock, there needs to be consideration of how the costs of energy efficiency measures are borne between tenant and landlord and how the financial savings from reduced energy consumption would also accrue to the two parties.

To push households and firms into taking action on this issue, it may be necessary to signal a strong intent to impose, and enforce, mandatory regulation at a given time in the future, say in 3 to 5 years, if sufficient progress has not been made meanwhile. In the interim, a package of measures could support and encourage voluntary take-up through provisions such as subsidies, property tax rebates and information services.

It needs to be recognised, though, that these measures will need a substantial uplift to be effective; i.e. information will need to be targeted, subsidies will need to be increased and any tax rebate transparent and salient. Such regulation could be linked to a system of annual or biennial performance tests for the built stock, akin to the annual MOT test for vehicles, to encourage continuous attention to the level of energy efficiency of the building.

There is also broad scope for moving beyond the individual building to consider areas within villages, towns and cities, i.e. the spaces and places in the built environment, to explore mitigation and adaptation to climate change. ***Planning of the built environment needs to consider not only the options for exploiting the natural cooling contributions of well-designed spaces, but also the options for decentralisation of energy systems, if diversity is to be fostered.***

Some decentralisation options are already being routinely considered within new development schemes, but wider consideration of potential for decarbonisation beyond the development site itself needs to be encouraged. This has considerable potential to change local areas. Focussing on the area rather than the individual buildings addresses some of the challenges of engaging with literally millions of individuals and organisations.

An area approach has the potential for dealing with a larger proportion of the stock and overcoming some of the barriers to individual action, by making retrofitting visible, reaping economies of scale and building capacity in local retrofitting firms (See box 8.5). These approaches could also draw upon the resources of local communities in tackling the standard of the existing stock, thus connecting with the current community empowerment agenda.

Box 8.5 Possible area-based initiatives.

- Build on the lessons of area-improvement policies from the 1960s and 1970s to develop area-based retrofitting schemes with energy efficiency in mind.
- Develop schemes for linking new in-fill and adjacent developments to improvements to existing stock in the surrounding area. The integration of decentralised energy generation and distributed energy and heating schemes (see Box 8.1) would form part of this process.
- Develop variants on town centre management to bring an integrated approach to managing an urban area, delivering improved energy management alongside other improvements to the public realm, including greater resilience to climate change.
- Exploit the flexibility of the Local Development Framework to develop innovative development plan documents which promote and integrate energy efficiency, innovations in energy generation and distribution, greater resilience in energy systems and attention to impacts on vulnerable social groups.
- Use existing zoning schemes, such as Enterprise Zones and Simplified Planning Zones, as a framework for schemes to achieve high energy and carbon efficiency standards, such as zero carbon emissions in use or even zero carbon emissions over the lifecycle of the development – including the embodied energy of the building material and of the construction and demolition processes. This would be monitored to support effective learning from experience. Relief from selected taxes – stamp duty, property tax, capital gain tax – might be available, possibly together with targeted central government funds, all consequent on demonstrating achievement of the zero carbon target. Support from local planning in terms of carbon assessment, urban design advice and consultation with local communities would be forthcoming but the emphasis would be on facilitating innovation in building design and energy systems to meet the zero carbon standards rather than regulating the details of the development proposal.

8.2.2 Innovative development and construction industries

The sections above have discussed the considerable lock-in effects in contemporary energy systems and possible approaches to speeding innovation. The Report has shown that the construction and development sectors (including those responsible for refurbishment and upgrading, as well as new development) are also typified by strong path-dependencies and established routines. To drive change throughout the development and construction sectors will be a major challenge. Regulation has already made an important contribution through targets for zero-carbon housebuilding and non-domestic development and there has been some innovation in moving the sectors towards a zero-carbon standard for new buildings. But even this contribution is limited in scale and is confined to specific market sectors and locations. Furthermore, the achievement of these targets may be slower than desired because it is so dependent on new development being viable.

This Report points to particular barriers to change posed by current business models in the development sector which limit the stake of the developer in the site to the period of construction and subsequent sale. ***In the future, models will be needed***

that sustain the developer's stake into the operational life of the development, for several reasons.

These reasons include the fact that the demands of managing complex, localised, energy systems require institutional arrangements for the longer term management of the development. Management arrangements also need to acknowledge that the systems will need to adapt over time to the impacts of climate change. If longer term returns from more efficient (even carbon negative) energy systems accrue in part to the developer, this would create a new set of incentives for developers to innovate in terms of building form and estate energy systems. It may even be possible to envisage local communities sharing in both the management and financial returns of such innovative developments provided new institutional arrangements can be created.

Urgent consideration needs to be given to how such models may be developed in consultation with the property, construction and development sectors.

With the longer term performance of the built environment in mind, greater attention needs to be given to the quality of new developments and of refurbishment and improvement work. It is our view that this is in part a matter of skills training, but also depends upon how such skills are put into practice. ***To ensure that actual construction, retrofit, and maintenance practice is of a high standard, consideration needs to be given to the means by which poor quality can be identified and redress obtained.***

Professional and trade accreditation schemes establishing liability for poor quality work would be one such means. Reviewing the current insurance schemes underpinning both new build and refurbishment in the domestic and non-domestic sectors would be another, especially where innovative building forms and localised energy systems are incorporated into schemes. Managing the range of issues concerning sustainable practices, including more carbon-efficient forms of new development and better adaptation, calls for a rapid rate of learning for the planning profession and for local politicians, as well for the relevant industries, and suggests the need for increased training, information and support.

8.2.3 Fostering effective policies and building the evidence base

The design and implementation of effective policies is currently hampered by a lack of firm knowledge and information. First, there is a dearth of data on energy consumption and building energy performance. This is particularly the case for the non-domestic stock. ***We would encourage consideration of the creation of an Observatory on energy and the built environment to capture, produce, and hold consistent and comprehensive data on all the different dimensions of energy use within buildings.***

Second, there needs to be greater understanding of what determines energy behaviours, in their broadest sense. We need more knowledge about the dynamics of behaviour in both the domestic and non-domestic sectors. We need to understand how energy consumption as modelled for the Building Regulations differs from building performance after construction and then again once the building is occupied and in use. Such an understanding requires a multi-disciplinary effort. The research councils are well-placed to join together and fund multi-disciplinary research to these ends and are already beginning to tackle some of these issues, for example, under the Engineering and Physical Sciences Research Council's Sustainable Urban Environments programme. It will be necessary though to continue to support and even extend such research efforts. It will also be important to ensure that research results are linked to policy development, deployment and evaluation.

There needs to be much greater attention to learning within the policy process to ensure that knowledge of problems of implementation on the ground is fed back into revised policy design.

Evidence papers commissioned for this project have drawn attention to a number of cases where policies are confused, contradictory or ineffective. Examples include the differential between VAT rates on refurbishment and on new build, which makes refurbishment activity more expensive. Refurbishment could be a central element of improving the overall energy performance of the existing stock. In new build, the Building Regulations are an example of a policy that is poorly monitored to ensure that the modelled energy savings are actually delivered. In addition there is a lack of resources for enforcement. A further example is subsidy schemes for household energy efficiency measures, such as loft insulation, which are widely accepted to have a very low take-up. The blame for this low take-up is often put at the door of the household but it reflects a failure of policy design to incorporate an understanding of how such household investment decisions are taken.

A comprehensive review of policies concerning energy and the built environment, which assessed the extent to which they are individually contributing to the overall goal of reduced energy consumption and carbon emissions, would bring considerable benefits, especially if it considered how the different policies are interacting with each other, identifying contradictions and tensions within the overall policy package. The work being undertaken by the Climate Change Committee in advising Government on its carbon budgets, and subsequent work within Government in setting the budgets and defining how they will be met, should provide the foundation for such a review.

8.2.4 Leading by example

Government has to play a leadership role. It directly occupies buildings across the UK, is a major owner of the domestic and non domestic built stock and is a major client of the development and construction sectors. Changes to public procurement and management practices could make a substantial contribution by providing examples of good practice and by building capacity within critical sectors such as construction and facilities management. Because of its size and volume, public procurement can drive change along the supply chain so that firms supplying services and equipment develop the capacity to deliver different forms of buildings and building management practices to other clients.

We recognise that this is an area where some advances are being made, for example, in the Building Schools for the Future initiative. The extension of this approach across the public sector estates will require an innovative strategy on behalf of the many different government departments and agencies that develop and manage public buildings and spaces. A comprehensive assessment of specifications will be needed to avoid perverse effects, such as framing operating temperature specifications in ways that prevent designers from deploying low-energy cooling systems.

There are currently barriers to such innovation. Managers of the government estate have traditionally been risk averse.

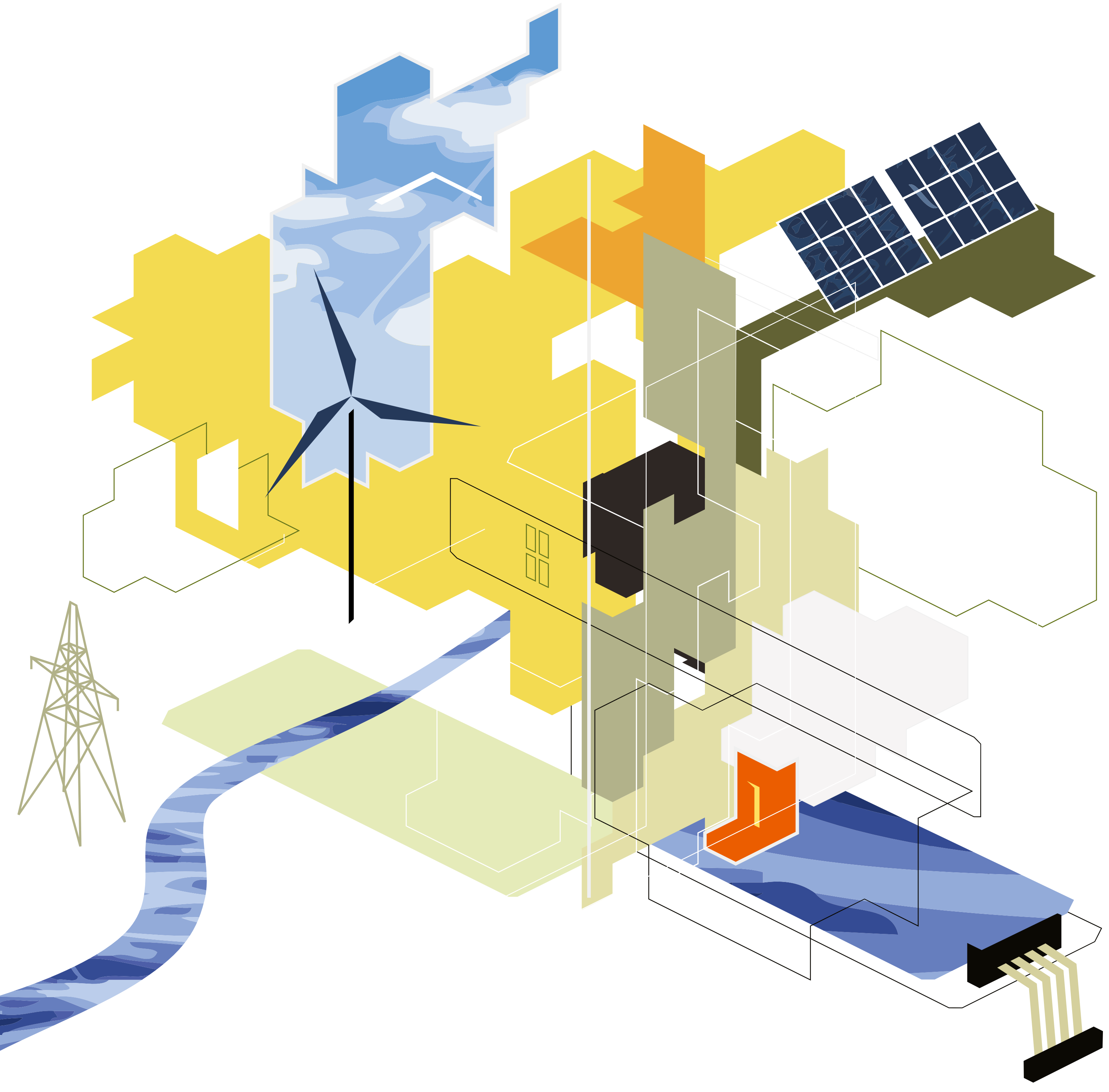
Fostering innovation has to allow for the possibility of failure and this will require new frameworks to be put in place to allow for this possibility. Fear of failure may otherwise inhibit pushing the boundaries of good practice. The practices of bodies that audit government at all levels may need to adjust so that innovative practice – where there has been positive learning from failure – is not penalised.

Methods of evaluation will need to adjust to take account of this. Providing that mechanisms for monitoring past experience and learning from it are in place, organisations should be allowed to innovate and, occasionally fail. Failure can be a path to learning how to innovate successfully and to applying lessons from such experiences to the broader public estate, provided that a supportive culture is fostered within the relevant bodies.

We recognise that there have been a variety of initiatives concerning the government estate, across different departments, public bodies and levels of government.

There is a need though for integrated leadership across all these different parts of the government estate enabling learning across organisational boundaries and making implementation effective. Consideration needs to be given to where such leadership responsibility should reside.

In view of the scale of challenges ahead it will be crucial to go beyond the incremental change that has resulted from policies to date. An urgent step change is called for, with strong leadership from government, not only to deliver real change across the built environment but also to set the agenda for sustained popular engagement with decarbonisation.



Appendix I: Scenario narratives

Appendix I: Scenario narratives

Resourceful Regions

How this world comes about: An international climate of political instability drives energy security up the domestic agenda of most countries. Fossil fuel-rich countries can afford to 'game' at the expense of energy importers by forging and breaking alliances opportunistically. This increases the price of fossil fuel while also reducing consumer, corporate and political levels of trust in the role of multi-lateral agreements and institutions to meet the UK's ongoing energy needs. Low levels of trust have spurred greater national (and sometimes regional) desire for control over decision-making – if countries can't talk directly trust is impossible; bilateral agreements are now more common because a country can walk away if dissatisfied.

During the period 2010-20 competing political and economic models – aggravated by resource competition and climate security – lead to growing instability and conflict. Governmental scepticism about the effectiveness of multinational agreements, and the (un)willingness of other countries and/or institutions to commit to them means that *ad hoc* coalitions, particularly bilateral arrangements become more predominant. Trade at this level remains significant.

An increase in bilateral arrangements can be seen within the UK as well as internationally. The subsidiarity that began with Scottish Devolution and the Welsh Assembly in the late 1990s has continued, with powerful regional assemblies across England, increased powers for the Scottish Executive, and a Welsh Parliament on a par with Scotland's. The UK now has a federalist feel – in common with some of its European Union counterparts. Most of the regional assemblies have used their tax varying powers (to put taxes up, in the main), along with flexing their muscles to regulate service provision and take ownership of significant regional assets.

The regional blocs within the UK have each leveraged their own natural resources such as water, wind, food, coal etc. for competitive advantage. Independence doesn't mean autarchy, but does mean that trading groups prefer bilateral agreements to multilateral ones. To improve their economic performance regions have sometimes been able to draw on technological expertise in other parts of the UK or more globally through agreements that cover particular technologies or knowledge areas. Some have looked to parts of Asia and South America for partnerships. The North East Assembly has recently agreed a deal with Norway for additional oil supplies. This approach has led to some inequalities between regions in the UK but more specifically to differentiation, in terms of the energy mix, the knowledge base and the skills of each region.

With resource scarcity affecting parts of the UK in different ways, regions have generally had to develop their own solutions to meet their specific local or regional situation. Inevitably, tensions over water, in particular, have started to occur between the different regions of the UK. Exclusivity agreements for water between Scotland and the South East of England led to isolated riots in the hot summers of 2030 and 2031.

The links and interdependencies between water supply and electricity begin to surface in the general public's awareness. Highly tailored electricity flows have emerged at the regional level. Intelligent consumption and demand management are both introduced to ensure that the UK's natural resources meet the needs of the domestic population before international deals can be made. Recycling becomes 'a way of life' and an integrated part of the supply chain both commercially and residentially.

The energy mix differs somewhat by region in the UK as the federalist model strengthens, and stems from the various sustaining innovations that predominate in each area. For example, coal mines have been re-opened in Yorkshire (with coal sold both to other UK regions and abroad) and Nottinghamshire is set to follow suit. The regional assemblies insist on a stake in the new coal companies in order to maintain some control over the decision making. It's not without its problems, however, with opportunist open-cast mining uncovered in parts of both regions. This coal, and coal gasification, makes an important contribution to electricity generation. While there is awareness of technology standards across Europe and more widely, these are frequently adapted to fit the specific needs of a local environment.

Gas is used as a bargaining tool by many nations, forcing others to pay inflated prices to secure consistent supply. Dependency on nuclear power to provide a third of the UK's electricity caused considerable public debate – the UK government rejected the European nuclear model and decided to 'go it alone' with nuclear technology it felt was more reliable in order to benefit all regions of the UK. Fifteen years later and – eventually – the criticism has almost disappeared now that the technology has been seen to work and the new plants have reached their targets. The national government provided significant funding for infrastructure investment to the North West region in return for the region providing the main sites for the plants and the region is now reaping the rewards – it is at the forefront in terms of provision of green spaces for its citizens, retrofitted rental housing and efficient, sustainable tramways.

On the dock of the bay – 2050

Overall, most energy is produced from fossil sources and is expensive to clean up, but fossil fuels have significant efficiencies compared to the past. The delicate nature of governance across the globe means that even with some bilateral agreements in place, there are power shortages several times a year when agreements are ignored or supplanted by newer arrangements, or when systems simply breakdown. Some regions invest in fuel cells, batteries, spare generators and other technologies to help bridge outages as best they can.

With significant power, regional planning authorities rather than national or European Union directives have driven changes in the built environment. Inward investment has been made by many areas to try to create a more energy efficient built environment. Most regions have imposed smart metering in order to reduce consumption and the likelihood of blackouts. Scotland, Wales and the North East have all introduced taxes on wasteful energy consumption to fund energy improvements for poorer households and those living alone aged over 80, which has reduced social inequalities somewhat. But one of the most successful public campaigns has been the 'Wool is Warm' campaign run in Wales, which encouraged people to turn down their thermostats to save energy and wear an extra layer of clothes indoors.

One of the most notable changes in urban public space has been the profusion of trees. Although there is differentiation in regional regulation, green shade is everywhere, especially in public spaces, an extension of the trend towards tree planting which was seen at the beginning of the century. Water spaces are also valued because of their cooling effects, and cities such as Birmingham have made the most of its network of canals and basins. There are strict rules protecting green spaces against development in some regions, and even restrictions on people's ability to pave or patio their gardens (to mitigate against both flash flooding and heat effects). In some places green roofs are encouraged, although these tend to be the prerogative of particular developers, and their cost calculations on particular sites about water run-off and so on. There are some unintended consequences however – reducing the affect of the urban heat islands means that there is more demand for energy in winter. In addition, there is considerable conflict over the countryside, with pressure for development in the form of coal mines, quarries and intensive agriculture to produce regional resources.

The emphasis has generally been on retrofitting of existing commercial and residential buildings, using regional materials. Regional differentiation has increased, with particular regional or national styles much more identifiable than ever before. Indeed, when travelling between regions, one can often notice clear differences in aspects such as road surface, extent of suburban housing development, and type of streetlighting and so on. These contrasts are most in evidence in the towns closest to the English-Welsh border.

Some parts of the South West have implemented more radical planning schemes in order to accelerate the pace of retrofitting, in order that the region is more robust in the face of climate-induced weather changes. While it doesn't get involved in detailed planning debates, the national government has started to provide incentives to businesses to increase the pace of commercial retrofitting – with a recent advertising campaign which encourages every UK business to 'play their part' in ensuring the UK is self-reliant and robust for the future. Light emitting diode lighting and day lighting are integrated fully in most commercial buildings in support of this culture. There is an emerging practice among younger architects to make their buildings as adaptive as possible to change in use, so that they can be modified as needs change, rather than have to be demolished at far greater cost.

This is a world in which people value their own power and achievements – a television series celebrating 'Britain's inventors' has been a surprise success – and value continuity of trusted systems. In this world politics has a curiously old-fashioned feel to it, valuing self-reliance, heritage, and security. Paradoxically, perhaps, leaders in the UK's regions and nations are playing exactly the same game, so the UK is closer to break-up than at any time since the Act of Union in 1707.

What it means to 'belong' to a region, though, has shifted over time. Most people are very comfortable with multiple identities – such as being Pakistani and Lancastrian. However, there have been some tensions in poorer performing regions, particularly where lower income groups have suffered disproportionately from climate-induced impacts and have required regional support as a result.

In the 3rd decade of the 21st century the UK remains predominantly a service sector based economy. However, for the first time in decades UK manufacturing as a proportion of the UK economy begins to grow. In 2050 the UK's Gross Domestic Product growth rate has decreased to 1.5 per cent having been around 2.5 per cent in previous decades. This hides a rather patchy overall picture of economic development across the regions.

Some regions have used their tax raising powers and chosen to invest heavily in sustaining innovations and infrastructure and skills to support them, while others have not. Climate migrants are welcomed when they have useful skills. Those parts of the country that prioritised saving energy have fewer power outages. Regional norms have started to emerge; for example in the North West central heating must be turned off by April 20 every year. Where there has been metropolitan investment, public transportation is effective and efficient. While government has sought to pressurise regions to prioritise investment, it has no powers to force their hand. Consumer pressure has generally been more effective.

It is a similar picture across different transport systems too – the regional assemblies insisted on regional dimensions to the franchises, thereby undermining cross-region public transport provision and causing pricing confusion for many customers. Those regions that made the decision to invest in their own energy supply have proven more robust than those that prioritised more experimental and disruptive innovations. The rail system built its own power plant during the 2020s and this has allowed rail usage to be reliable and to evolve broadly in line with demand.

Efficient public transport systems are a big draw for those people otherwise forced to pay high petrol prices and suffer on poor infrastructure in badly performing regions that chose to invest elsewhere. There are growing imbalances in demographic distribution across the UK as a result. Particularly, the past high population density of the South East of England is changing. Many people try to work locally and more flexibly in order to reduce their travel costs and wasted time.

London has seen some outflow of both businesses and residents due in part to the heatwaves that proved so unpleasant for people and costly for businesses. Effective trade deals for energy kept the city competitive and affordable for some until the 2030s, but it was forced to increase commercial rates and council tax substantially to meet energy agreements it made with the United Arab Emirates in the 2040s.

Brief timeline:

2013	Growing global instability over resource scarcity and rising commodity prices
2015	Welsh Parliament gains additional powers
2018	Coal mines re-open in Yorkshire
2024	Rail network builds its own power plant
2030	Isolated riots over regional water exclusivity agreements
	UK manufacturing as a proportion of the UK economy begins to grow
2042	Energy agreement between London and the United Arab Emirates

Resourceful regions

Sunshine State

How this world comes about: As fossil fuel supplies become scarcer and harder to secure, prices rise and energy is more widely used as a diplomatic bargaining tool. Many of the agreements which underpin the international economy start to fall apart. It's clear that fossil fuel – even coal – will be a declining resource, globally. The UK follows a path of improving its energy security, both by reducing demand and by increasing alternative supplies which it can control. Although securing energy supplies is the dominant concern in this world, decarbonisation remains an issue and the legal requirements of the Climate Change Act and of the 2016 Building Obligations, together with the Sustainable Communities Act, are powerful tools to help shape this world.

"Don't let what you can't do stop you from doing what you can do" has been the watchword since the UK economy, like that of other energy importers, juddered through the 2010s, a decade dominated by the realisation that oil production had peaked earlier than many had expected, by relatively high and fluctuating energy costs, by geo-political manoeuvring, and economic downturn. The experience for consumers in that difficult decade was of tighter incomes and less to spend, of power cuts, sometimes fuel shortages. At the same time, it proved to stimulate a surprisingly powerful shift in political and social philosophy, energising changes in local communities.

It was a world away from the 'live for the present' consumerism of the last part of the 20th century, and the shock has led to the emergence of new social values, which reinforce the importance of self-direction and self-determination, but also the need to try new ideas to resolve problems. Although there is technological innovation in this world, the principal driver of change is the development of new social institutions, many of which are about better ways of sharing limited resources at a local or community level. One of the motivations for this has been deteriorating mental health outcomes, worsened by climate change anxieties, which could have had huge public health costs if not addressed. Many of the new social institutions consider tackling mental health to be their priority, particularly in terms of the impact it has on the isolated and more vulnerable members of society who perhaps do not have strong family support structures in place.

This is a world where almost anything which can be decentralised has been. Transport has become more of a shared local community resource in many areas, with community-funded electric buses serving many areas. A significant number of private cars are also electric, whilst others run on locally produced hydrogen. These shifts have effectively resulted in large amounts of energy storage which can be used to balance the variable output from some renewable electricity technologies.

Constraints on energy production meant, certainly in the early years, that far greater emphasis was placed on reducing energy consumption. The reluctance of the existing utilities to move away from their market-based models meant that they were, effectively, brought back into social control through legislation, and the grid became a public resource. (There were diplomatic complaints from France and Germany, where some of the large companies were headquartered, and the government had a surge of popularity when it faced these down). At the same time, regulation put the reduction of consumption at the heart of the utilities' public purpose, and clever framing of their governance promoted the development of multi-utility service companies (MUSCOs) at whatever scale could be made to work. Many towns took advantage of this to take their utilities back into local management, sharing the savings from reduced consumption between the users and local community investment funds. In places where such incentives were not sufficient, the Minister's office had the power to implement rationing of energy, and water.

The economy continued to draw on the fossil fuels it had access to, including the rapidly declining North Sea oil and gas, and, where international agreements existed, imported oil (at a cost). Coal, likewise, is still used where long-term agreements have been honoured. Use of gas has diminished as price and availability have made it unviable, although in several communities there has been modest substitution of biogas as it was a good way to get fuel from waste. The life of the existing nuclear power stations was extended wherever possible, although the economic downturn meant that plans for new build were cancelled, amid scepticism which suggested that the industry was also over-claiming on its likely long-term energy production.

At first, local renewables and microgeneration did little to replace the declining fossil fuel base; from wind to solar to small tidal schemes, all were expensive and erratic. Investment was also difficult because many of the companies involved in the technologies were small, and there were skills shortages.

But as the technologies evolved, during the 2010s and the 2020s, costs came down rapidly, and performance improved. A huge gain came from the development of solar technologies which could be applied as films (eventually even through a paint-based application) which meant that the long-term promise of cheap (and local) solar power started to emerge during the 2040s. It took some time to find effective ways to connect it to the local grid rather than it servicing only the building it was attached to. Local CHP plants also emerged in some places, especially where biomass could be grown as part of the fuel base. Other waste to energy options have also been pursued with some success – gasification, pyrolysis and anaerobic digestion. Some areas have developed biotech-based energy, although this was often unstable.

Edge of town – 2050

Related technologies also evolved at the same time, such as local pumps (to enable reuse of electricity which was generated and not used) and hydrogen fuel cells. New ways of thinking about power also helped. Virtual storage, helped by materials innovation, allowed the electricity supply industry to move away from its traditional model in which supply and demand always had to match.

Skills in the energy sector, however, were slow to develop. Some organisations resolved this by bilateral partnerships with European companies which had expertise already. The government also encouraged engineering and environmental sciences students by subsidising their education. The Transition Initiative movement, which had helped prime some communities with the skills needed to prosper in this world, also helped through its community-led Knowledge Exchange, the TIX. Organisations such as ICLEI – Local Governments for Sustainability, which linked local governments, also found a new prominence.

As with energy supply, a similar local emphasis is seen in the approach to reducing energy consumption in buildings. This, however, is supported by central government. Initially, this was a 'stimulus-to-aggregate-demand' scheme to mitigate the effect of recession on the UK economy. Home insulation, mostly, turned out to be relatively straightforward work, and people could be trained to do the basics quite quickly. In a world of energy shortage, paying unemployed people to work on insulation programmes made sense, and part of the cost was borne by the utilities, as one of the quickest ways for them to meet their energy reduction targets. Some of those working on home insulation have further developed their skills and become small businesses in their own right; they help people and places do 'resilience' adaptation. Increasingly over time, buildings were adapted so that they were better at coping with a hotter and wetter climate, as the technologies became better understood.

Smart metering helped, and behaviour change for reduced energy consumption was reinforced by meters with highly visible consumption displays – in kitchens and living rooms, rather than at the end of the hall. Some local authorities issued the so-called 'Swedish lamps' which adapted to more pleasing shapes as the user reduced their consumption, which seemed to be a more effective visual guide for many than a graph or a numeric display.

Some houses and commercial buildings, from the 1950s and '60s, were so poorly constructed that they were too expensive to upgrade, even through quite complex insulation schemes, and much of this stock proved to be in the public or social ownership. Following the introduction of the 2016 Building Obligations Act in some areas these buildings were simply knocked down. In others, where UK cities had partnerships with European cities which had better developed building expertise, it was rebuilt using techniques such as offsite construction. Some of this aged better than others, and even by 2050 it was becoming clear which authorities had rushed into their investments, and which building systems had proved to be more robust.

Successive Energy Regulation Acts (ERAs) had required local authorities to assess local planning decisions in terms of their energy impact on the local area, and this has influenced the shape of the built environment over time. Local shopping streets have returned, as fewer people want to waste fuel for short journeys. Those edge of town supermarket sites which are still in the hands of the grocery companies have long been converted to local storage and distribution centres or other uses. Another dramatic effect has been the end of the school run, as schools gained the legal right to decline pupils who could not make their own way to school either by walking, cycling or public transport.

One of the decisive developments occurred when Bradford Council took the Competition Commission to court over a decision which threatened to undermine its local Energy Reduction Strategy (ERS), and the High Court ruled that the Commission's ruling had lower legal standing than the ERS. Following the resignation of the Chief Executive of the Commission, her replacement announced quickly that future Competition assessments would require full external and lifetime costs to be taken into account.

One of the biggest differences has been in greening the local environment, particularly to create more sustainable urban drainage systems. Green roofs are widely installed, and not just on new buildings, which helps both to absorb heat and also mitigates flash flooding. Generally there is more tree cover. 'Soft flood systems' are preferred to 'hard defences'; large areas have been re-designated as 'water meadows' to catch and hold river flooding. The government supported this with a compensation fund for those who found their houses on the designated areas, and were therefore all but valueless overnight.

The emphasis on devolved responsibility meant that communities often felt that they had the power to act effectively, but it also meant that some were more effective than others. If there is polarisation in this world, it is a spatial polarisation, in which areas with effective leadership and substantial local social capital tend to do better than others. Initially the role of government was to intervene when disparities became too acute. Eventually these were resolved by changing the rules. Regional conflicts were reduced by creating new 'bio-regions', aligning administrative and political power with resources. This introduced a new form of bio-governance effectively into Britain and supported the afforestation programmes established as offsetting initiatives. The Sustainable Regions Act, in 2034, laid out the groundrules for collaboration and conflict resolution.

This is not a world of significant economic growth. Growth stalled during the 2010s, and the cost of energy means that the economy is not dynamic. But this is true everywhere and, increasingly, economic theorists are arguing that the sustained growth of the 19th and 20th century was down largely to falling energy costs rather than knowledge. It is possible to 'decouple' energy from the economy, but not completely. The numbers are hard to find, but statisticians constructing Gross Domestic Product time series data reckon that after a period of declining incomes in the 2010s, 'Gross Domestic Product growth' was around 0.25-0.5 per cent per year, if that. But as advocates point out, a 'steady state economy' is not the same as a low-to-zero growth economy. It's a different mind set.

The shift in values in this world means that economic growth rates are no longer the main yardstick by which a society's success is measured. People are more likely to know their neighbours, car pool for journeys and they are more likely to eat more healthily; there is less energy intensive food production. Local currency schemes and time banks emerged during the recession and are now flourishing across many regions – making Gross Domestic Product quite an unreliable guide to social and economic activity nowadays. In the UK, the government has instituted a new 'Measure of Domestic Progress', sometimes known as the 'sunshine index' based on the earlier work of William Nordhaus, James Tobin, and Herman Daly in calculating sustainable economic welfare. However, it proved difficult to provide measures for supporting the lowest income groups in the absence of economic growth and this led to some social tensions.

Expectations have shifted from the turn of the century, this world is slower and it is different, but it is still an affluent world by any historical standards.

Brief timeline:

2012-16	Emphasis on reducing energy consumption
2016	Building Obligations Act
2019	Bilateral skills agreements between some UK energy sector organisations and European countries
2021	Last edge of town supermarket built
2032	3rd Energy Regulations Act
2034	Sustainable Regions Act
2041-44	Cheap and local solar power emerges
2044-45	Local pumps and hydrogen fuel cells in wider use

Sunshine state – 2050

Green Growth

How this world comes about: Increasing energy costs, driven by rising demand and shrinking supplies of fossil-based fuel, and the translation of concern over climate change into effective action to reduce emissions, has led to radical action to move to a 'new energy economy', and also to use technology effectively to reduce both energy losses and emissions from buildings and travel. This radical transition requires significant investment in technology, and international collaboration. This is a world of a 'green boom' but it is not without its risks.

The long recession of the 2010s, in Europe and elsewhere, led to the realisation that the age of cheap and easy energy was now over. The outcome was a radical restructuring of the economy to de-couple economic performance from energy consumption, informed by a shift in underlying social values which emphasised universalism and benevolence as against the more individualist values which had underpinned the globalisation boom of the last quarter of the 20th century. These values also supported the increased urgency around dealing with climate change, with strong commitments on carbon reduction reinforced by international agreements; the energy agenda and the carbon agenda became mutually reinforcing.

Although high prices for essential resources meant that the market started to respond to the energy transition, the speed of change desired – by politicians and by voters – was greater than the market would have delivered on its own. The UK, in common with much of the European Union, has adopted a mixed approach.

In energy, a strong tax-led approach – based on carbon impact – has pushed up the price of fossil fuels, despite hostile campaigns from the road freight industry, intense private lobbying from the oil industry and open grumbling from the energy utilities. This approach has succeeded because – based on the earlier model of London's congestion charge – the tax revenues raised have gone directly to funding investment and development of large scale renewables. Tax reductions could be achieved through the purchase of carbon offsets.

For this is a world in which big is still regarded as essential. The calculations done by economists and engineers at the UK's Department of Carbon, Climate Change and Energy reckon that small scale decentralised renewable energy systems simply can't deliver the amount of energy required by a modern economy. But at the same time, policy makers have also pushed nuclear out of the mix, except as a transitional technology, because the amount of investment a nuclear programme requires would squeeze out investment in large scale renewables. One thing that was saved, though, is the research funding into nuclear fusion. This is regarded as a technology with potentially huge energy rewards, because, in general, engineers are optimistic that the technological difficulties will be overcome.

In some areas of the economy, regulation drove reduction in demand for energy; in others, public procurement has been the chosen policy vehicle, as we'll see shortly.

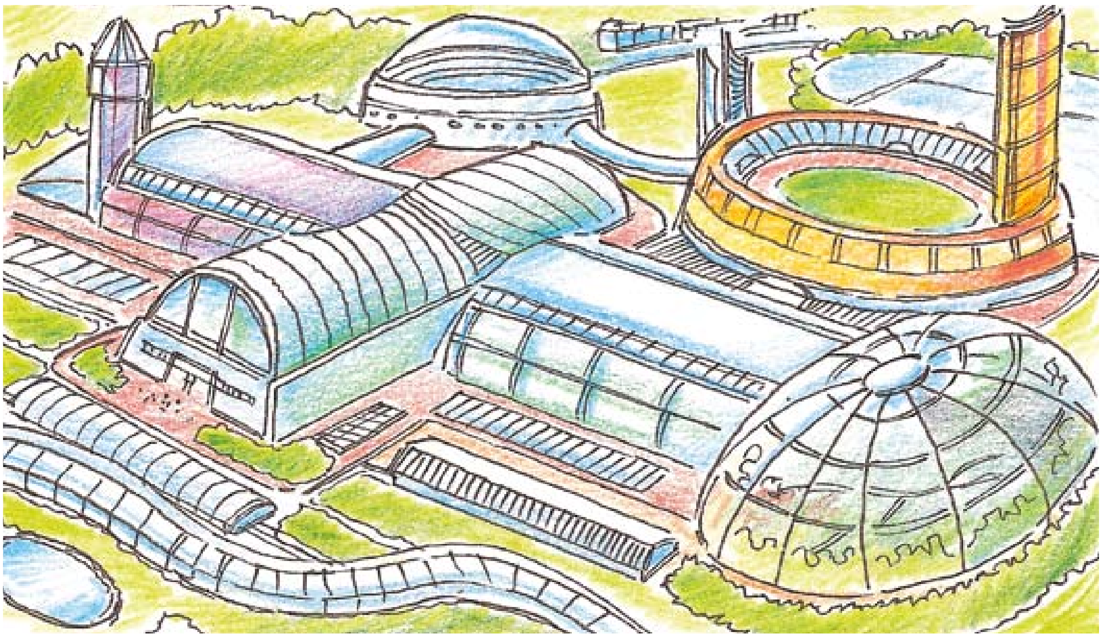
By 2050, the majority of the UK's energy is coming from renewable sources, though not necessarily from within the UK. Certainly, the tidal barrage across the Severn was built, and successfully, at least in terms of energy production. (Some of the biodiversity impacts have been as bad as environmentalists feared). Hydroelectric power comes from the Pyrenees and there are significant banks of windfarms sitting offshore, more extensive, and with larger turbines, than their onshore predecessors. And a reasonable proportion of the UK's energy has recently started to come from the solar arrays in southern Iberia and the northern Sahara, even if the technical transmission difficulties have not been fully resolved.

Against this background, there has been some development of local power systems, although these fail to compete on price with large-scale renewables. However, because the grid is still slightly unstable – an inevitable feature of the intermittent power supply, and because large-scale storage technologies are still developing as materials evolve – businesses and communities often invest in local energy production, sometimes linked to their waste management systems, to help manage power outages.

Supply fluctuations are also managed through smart power systems. It's rare, at least in winter, for washing machines to operate at peak times, even if people are still frustrated to find lights or music systems being switched off by the grid.

Individuals have 'energy avatars'[1] which are fully automated and provide information on energy usage. These have helped change people's attitudes and consequent behaviour. While many people were originally motivated by the financial savings, they have now started to change their fundamental values and find being part of such a social movement rewarding and motivating.

With both energy and carbon management central to public policy, addressing the energy consumption of the transport and domestic sectors became more important. Transport proved responsive to variable road-pricing, which accelerated the development of lower emission and electric vehicles while also reducing personal car use. Car clubs, with a 'pay as you go' proposition, developed quite quickly. Effective communications technologies reduced the need to travel for business, and their manufacturers responded to carbon taxes by developing far more efficient products.



Green growth – 2050

1 An energy avatar is an electronic, usually graphics-based, version of the user. In the context of energy, avatars could be used within households to provide immediate and interactive information about energy service and suggestions on how to reduce consumption.

In general, regulation on closed loop production systems has nudged the corporate laggards into line; market leaders had long seen the benefits of this whole-system approach. There has also been strong growth in virtual meetings; the use of virtual environments for business discussions may have seemed self-conscious in 2008, but it was straightforward by 2050. Such developments, however, were not completely straightforward; power consumption of computer server farms had spiralled in the 2010s until aggressive energy management and innovation approaches brought it down again. One of the biggest changes in domestic energy was the introduction of parallel 12-volt electrical systems within houses, although this large infrastructure project turned out to be every bit as complex as sceptics had foretold.

The impact on the construction industry was intense, and the pace of reform in a sector which had often been regarded as old-fashioned and inward-looking was intensified by regulations which required a full-service approach both to construction and management of new buildings, in which the developer was required to take responsibility for maintenance and service once the building was completed.

In housing, the average age of the UK's housing stock, coupled with its vast inefficiency, proved to be an opportunity to 'skip a generation' and move to a new approach to construction. The Welsh Assembly was a pioneer, issuing a contract in 2017 for the demolition of a large 'low-demand' estate in the Rhondda Valley and its replacement by a new generation of zero-emission housing. These homes were built cost-effectively using modular designs developed in Sweden and off-site construction techniques. Their underfloor electric heating systems were popular with the residents. This was one of the first projects to require that the new development was managed by the developer. The UK construction industry proved unequal to this challenge at first, because of its traditional attitudes and a shortage of skills, and German and Scandinavian companies repeatedly won such early contracts.

In East Anglia and the Wash, innovations included the development of floating districts, which sat on the saltmarshes which had encroached on the coast.

In other parts of the country, 'Eco-Zones' (based on the old Enterprise Zones) gave tax breaks to developments which were carbon-positive, and since these were built during the 'transition' years when fossil fuels provided a significant part of the energy mix, these often included local wind turbines and community Combined Heat and Power (CHP) schemes. By 2050, the turbines seemed to date these developments. However, useful lessons had been learnt from these developments even though they were now branded as failures.

Some of these schemes might never have got through the old planning system. But the development of the 'Strategic Planning Framework' has given governments powers to impose large-scale developments on local areas, if they consider it necessary in the national interest. It is repeatedly a source of local complaint.

The emphasis on new build and smart management of energy systems means that there is less emphasis on 'retrofitting' of existing houses, and houses with high energy and carbon consumption become less valuable. (High carbon consumption is seen a sign of personal and social failure, and ostentatious plane travel is regarded with the same disdain as the conspicuous consumption of red meat). Older stock on the outskirts of towns and cities is particularly down-valued, because of the cost of transport; convenient and well-connected locations are much more desirable. Housing stock from the 1980s – once sold as 'executive homes' – but now requiring an energy-intensive lifestyle, have become the new slums. Rehousing schemes are mooted.

By contrast, the higher density flats that were being built in such large numbers in the 2000s have undergone mixed fortunes. These proved unpopular during the 2010s and 2020s, when demographic change meant that the main demand was from family units. Prices fell, but by the 2050s, households including families were learning to live in different ways and their location close to urban facilities were making them desirable again.

In commercial buildings, one of the most radical changes was the banning of air conditioning systems from 2031 (the legislation had been passed in 2021, to give building managers time to adapt). The rationale was two-fold – as temperatures grew warmer, the energy consumption of air conditioning systems started to be a significant issue in a world where renewables were still coming on stream. But secondly, as 'heat island' effects became increasingly pronounced, there were important social equity and public health arguments – buildings shouldn't just dump their excess heat into their surroundings. (After all, the argument went, they weren't allowed to do that with noise or waste). The most radical effects were on shopping centre and supermarket management and design. Public health became a concern after the deaths of several thousand elderly individuals in London and Birmingham due to the night time heat one summer.

As always, shifts in public policy took time to translate into the education and training systems. It was only when UK companies repeatedly failed to win housing development contracts that the government and the industry took it seriously, but it wasn't until the late 2030s that this had an effect, at least in the existing construction sector. Fortunately, the UK's engineering sector proved to be surprisingly robust, and many of the new building systems fitted better with their expertise and business models. Most of the newly skilled in the housing sector had an accreditation via the Engineering Employers' Federation (EEF). Most of the companies which adopted new techniques, and were most innovative in using the so-called docile and aggressive materials, turned out to be led by graduates from these EEF schemes, and in 2040, the Federation renamed itself the Engineering and Building Employers Federation.

A similar shift is seen in the energy sector, where traditional companies failed to adapt to new technologies and new systems. Big winners here included the IT service businesses, whose expertise lay in connecting complex systems and managing them on a service basis for their clients.

Although the economy has grown steadily, at least after the recession of the early decades of the 21st Century, at around 2 per cent per year, the balance is different from the late 20th century. The reconstruction of the energy and housing sectors has required a huge level of investment, with a concomitant increase in both taxes and savings levels. Growth, therefore, is investment-led. There is less spending on consumption. But this is tolerated because people don't believe that there is an alternative, and because the sense of technical progress, and optimism, is palpable.

Although there are people who are disenfranchised – as there always are in technology-driven societies – politicians have been shrewd enough to realise that if these people are not helped it could challenge the credibility of the whole 'transition' project, so social safety nets are in place, often involving retraining for the skills needed by the new economy.

And there are always new challenges. By 2058, it looks as if biotech has finally succeeded in creating a fuel which can power vehicles effectively. And a pilot scheme for a local hydrogen energy scheme has just been unveiled in Sheffield, paid for by central government. If it works, it could be the start of something big.

Brief timeline:

2017 Proposed demolition of some 'Low-demand' estates with replacement by a new generation of zero-emission housing built to Swedish model

2019 Tax system based on carbon impact, with scope for tax reduction through purchase of carbon offsets.

2022 First electricity generated by the River Severn tidal barrage

2033 Legislation to prevent 'Heat dumping' from buildings is introduced

2040 Successful transmission of electricity from Iberian solar array farm

Green growth

Carbon Creativity

How this world comes about: By 2020, China and India are dominant global economic players. Because of their impressive economic performance, however, rising energy costs and pressure on raw materials starts to have a significant effect on the BRIC (Brazil, Russia, India and China) countries' growth rates by the late 2010s – and, in an inter-related economy, on material living conditions elsewhere. Global energy management becomes closely linked with climate change and carbon reduction and, in the absence of significant breakthroughs in new energy sources, the focus is on working together to manage existing resources better.

This is an outward-looking world in which free movement of capital and goods are still regarded by political and economic elites as the ideal model for economic development. However, competition for natural resources and declining economic growth rates prompted the rise of populist calls for protectionism in many countries.

In the UK, the stable economy that was so well supported by the service sector begins to slow down reflecting an average change in Gross Domestic Product growth rate from 2.75 per cent to 1.75 per cent in 2050. UK and other European countries continue to enjoy per capita income levels that are among the highest in the world, although the more rapid growth of the BRIC countries means that Europe's output as a *proportion* of total global economic output has fallen.

Perhaps the most popular policy response to greater resource stress is a stronger focus on free trade blocs. Alongside the European Union and NAFTA, there has been growth in the influence of organisations such as MERCOSUR in South America, ASEAN in South Asia and the African Union. This renewed focus has had two broad effects on energy and sustainability policy. Firstly, there has been greater focus on multi-national agreements, which are primarily negotiated and agreed between blocs, committing participants to reducing emissions (primarily through a robust carbon market). Secondly, blocs are increasingly making use of their combined strengths to negotiate multinational agreements – not least of which are long term energy supply contracts in an attempt to guarantee supplies in future. Moreover, these supply contracts do not deal simply in oil and gas, but also in the supply of electricity – facilitated through further development of an international electricity grid.

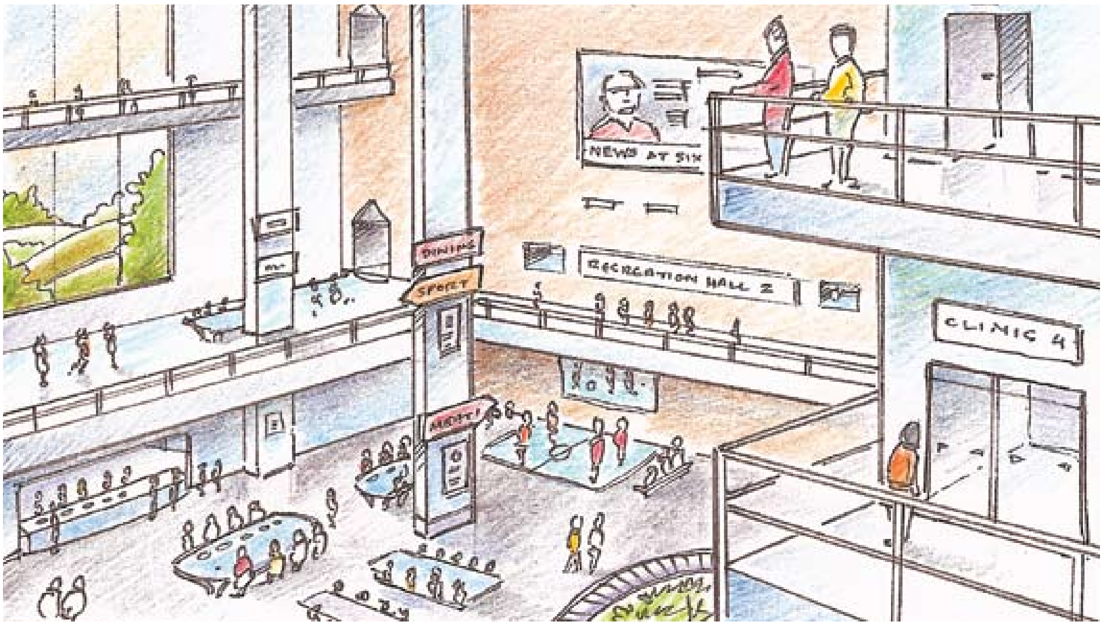
Despite this renewed focus on transnational co-operation, however, there have not been any substantive new international institutions for dealing with global problems. Institutional inertia plus a resistance on the part of incumbents to share their veto position have proven significant barriers to a new international architecture.

London, capitalising on its historical strength and skills in international trade, has emerged as the global centre for carbon trading – which by 2025 has developed into the world's biggest commodity market. This well-established market also has a direct and visible impact on consumer behaviour. The carbon market ensures that the carbon price of each product is embedded in its cost. The UK's manufacturing industry has not been able to respond to the demand for low carbon goods and therefore products are imported. Alongside the carbon market itself, a thriving service sector industry in carbon reduction consultancy has emerged, with consultants advising businesses and householders on the best way to reduce their carbon bills.

The introduction of this market has made a significant impact on behaviour, making the level of carbon emissions a much more pertinent issue when deciding which products and services to purchase. It is still a society driven by consumerism, but energy demand management becomes a big feature of everyday life. In part this is driven by the cost of carbon-based fuel, but it is also because energy supply, generally, remains tight. It's expensive to drive so pressure on public transport systems has increased although innovation investment in it has not kept pace. In areas with high density developments near public transport nodes, the need to travel has declined. New sources of decarbonised power are slow to come through, so prices of this power also remain high. In this world, cost saving is still considered a very attractive reason for reducing energy consumption, both for individuals and for commerce – energy as a proportion of income expenditure has grown. This concern, combined with the economic slowdown in the early decades of the 21st Century, produced a reduction in CO_2 emissions from wealthier economies, as they move towards a period of reduced household consumption and prudence.

Social values have shifted over this period – continuity of systems is cherished and while there is a desire for security, there is also a need for universalism. Consumers are having to adapt to a world with choice constrained by carbon considerations. Some consumers are finding it difficult to adapt.

Extreme weather contingency planning has become critical in order to deal with infrastructure damage in a more cost effective way. Ongoing maintenance has also become more important in order that areas are not so vulnerable to the impact of summer and winter extremes – such as buckled roads during three successive hot summers. In addition, 'hard engineering' approaches to the more frequent flooding – such as higher walls, bigger pipes – are being used, with concrete and other materials being produced with a lower carbon impact than in the past.



Carbon creativity – 2050

Much energy in this world is still generated from the incremental development of conventional sources – coal, gas and oil. Centralised generation remains important. However, price volatility and rising cost of carbon emissions (driven by the carbon market) provide an increasing incentive to invest in proven technologies such as large scale CHP plants and coal with Carbon Capture and Storage (CCS). One side effect of the spread of CCS technology has been the re-emergence of 'King Coal'. Countries (including the UK) with accessible coal reserves have seen the rejuvenation of their mining industries, as fuel which was previously too expensive and dirty in terms of carbon emissions becomes economically and ecologically viable again. Centralised CCS facilities are attached to all large power stations with storage on site or remotely transported via the 'carbon' grid, which is a network of pressurised pipes.

Within Europe, the European Union started to promote the nuclear option much more vigorously as a way of encouraging supply security. While the economics, safety, and carbon costs of nuclear generation are still fiercely contested (and the cost of securely storing nuclear waste is still high), the relatively stable price of fuel and security of supply make this an increasingly popular option. Although the UK had a shortage of nuclear engineers to work on replacing its 20th century capacity, it was able to utilise the skills of other European Union nations in this area to ensure it could benefit from such developments.

UK energy generation and distribution is supported through the UK's membership of the European Union Gas and Electricity Regulation Organisation (EUGERO). This regulatory body was set up in 2025 to distribute electricity and gas. Its establishment reflected, in part, the concern of a number of European countries for the need to share resources and restrict the growth of small scale production. The focus of the EUGERO is very much on decarbonising energy, but it has also sought to protect the carbon poor by regulating energy utilities to prevent the exclusion of the poor from the market or the creation of energy 'deserts' with poor supply.

Large scale building infrastructure work is still commissioned through public-private partnership arrangements to support the ageing infrastructure. Retrofitting of novel insulation and other energy efficiency measures to the existing housing stock has been incentivised strongly by regulation and the economic reality of a good payback. Ease of installation, with low impact on property design, has been the key to success and the small business sector has developed to deliver these effectively; this was after early rogue traders were cracked down on for their faulty workmanship. There are some services which seem impervious to scale; some of these businesses would have been installing satellite dishes seventy years ago.

There are also some new developments for planning and housing under the permissive planning system that evolved during the 2040s. The targets and initiatives of 2006-16, e.g. zero carbon homes, along with impetus from the carbon market, have led to high density mixed-use (residential and commercial) developments. These have received some bad press, particularly from the older population who enjoyed the space that lower density developments of 30 years ago afforded. In contrast, the younger generation and the local planners are enthusiastic about these areas as they offer flexibility and a community environment – in their minds they are the mid 21st century equivalent of the loft conversions so trendy and coveted in the late 20th century.

The design and build of these units reflects the growing knowledge of how to mitigate and adapt to climate change. These mixed use areas incorporate green spaces, photovoltaics on some roofs (but not connected to the grid), solar panels and natural ventilation systems and are, therefore, cooler and better adapted to the changing environmental conditions. Groundwater is also used widely to cool buildings. Combined with the now widespread European Union knowledge of improved efficiency heat pumps, advanced glazing etc., these developments look to tick all the low carbon boxes. Indeed there has been significant payback from retrofitting – costs have gone down because the market has expanded and economies of scale have been taken advantage of. To meet the requirement for installing and maintaining these technologies, apprenticeship opportunities and higher education courses in these areas have sprung up and student registration has been high due to the high demand and decent margins. Most large organisations sign up to the European Union Investment in Carbon Champions Programme to further improve skills and knowledge sharing across the continent; there is now a well established set of environmental and design tools for building performance. Curriculum Vitae include lifetime personal and professional carbon use.

Brief timeline:

2013-18 3 Multi-lateral agreements on reducing emissions (through carbon markets)

2021 European Union promotes nuclear power to encourage security of supply

2025 Carbon trading is the world's biggest commodity market; London is the centre for trading

European Union Gas and Electricity Regulation Organisation set up

2033 Regulatory incentives to encourage retrofitting of residential and commercial buildings

2042 High density mixed use developments common

Carbon creativity

Appendix II: Using the Scenarios

This section offers some suggestions for how to work with the scenarios. The approaches described here are based on those used in other Foresight projects and in other public sector scenario projects.

The list is not comprehensive, but does offer some insights into how to use the scenarios to inform strategy. The approaches described here work best in facilitated workshop sessions with upwards of 12 participants. Typically, they require one full day, although it is possible to hold productive conversations with fewer people and, if required, in less time. Two approaches are described here. Neither of them suggests that those involved identify the scenario they want to happen and then identify what to do to ensure that it does. Mainly that is because the scenarios describe possibilities rather than predict outcomes. The reality is that the future may contain elements of all four scenarios. The uncertainty is which elements – and, consequently, which challenges – will dominate.

Gaming

The basic approach to gaming involves exploring the scenarios from the perspective of a number of different stakeholders and then using the futures perspective to devise recommendations for the present.

A typical gaming workshop can be structured in six steps:

Step 1: Carry out a SWOT (strengths, weaknesses, opportunities, threats) analysis of the first scenario from the perspective of one of (say) three stakeholders e.g. Government, citizens, industry and law enforcers.

Step 2: Use the SWOT discussion to determine the extent to which each stakeholder likes living and working in the scenario and identify what they want Government to do to maintain or improve their level of satisfaction.

Step 3: Step out of role and – imagining that the scenario is an accurate representation of the future – make a number of recommendations for current policy. These recommendations should reinforce the elements of the scenario which participants believe to be beneficial to the UK and should address those elements which are likely to be less beneficial.

Step 4: Consider the risks to Government (or other key actors) in pursuing the policy recommendations made in Step 3. Develop a strategy for managing risk.

Step 5: Repeat steps 1–4 for the other three scenarios. An alternative approach is to work in parallel across the scenarios.

Step 6: Compare the results of the different scenario discussions to identify robust policy challenges, those which appear in all or most of the scenarios, and scenario-specific challenges.

Gaming workshops offer a rich perspective on the policy challenges facing Government and other actors. The outputs from gaming workshops generally highlight a number of significant policy challenges and risk issues that need to be addressed in the near future.

Reverse Engineering

Reverse engineering is a process of deconstructing the scenarios, using similar techniques to the ones used to develop them, to identify future events which require a policy or strategic response.

A typical reverse engineering workshop can be structured in five steps:

Step 1: Discuss the benefits and detriments of a given scenario.

Step 2: Identify trends and events which need to happen for the scenario to occur (some of these events are embedded in the narrative, but the group should identify more).

Step 3: Map trends and events on a 2 x 2 matrix, according to whether they are certain or uncertain and whether they will have a high or low impact on a given policy area or actor.

Step 4: For high-impact events that are certain to occur, ask the group to identify whether:

- the events will occur in the short, medium or long term;
- whether the impact is positive or negative;
- what the response should be.

Step 5: Repeat across all scenarios.

Reverse engineering exercises use the scenarios to identify opportunities and threats facing the organisation in the short, medium or long term. They are a powerful and productive way of setting a forward agenda for action.

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Glossary

Adaptation

Change in human or natural systems in response to climate change or other pressures. It is the complementary approach to mitigation (qv).

Bioenergy

Usable energy derived from biological, typically plant, material which is contemporary rather than coming from fossil sources.

Blue space

Water features such as canals, streams, lakes and rivers used to make the built environment more pleasant; they can also add to its resilience to heat waves, floods and other shocks.

Built environment

All the developed settings in which people live and work, from villages to large cities, and including housing, health and educational and other government buildings, shops, work and leisure places, transport and energy infrastructure and the spaces between them.

Carbon

The chemical element in coal, oil and gas whose conversion to carbon dioxide releases energy. Carbon dioxide is the most significant greenhouse gas. The amount of it released can be expressed in tonnes of carbon or of carbon dioxide. To convert from CO_2 to Carbon, multiply by 12 and divide by 44.

Carbon Capture and Storage (CCS)

Technology now under development to allow carbon dioxide to be captured, mainly from large producers such as power stations, and stored indefinitely in geological structures or elsewhere.

Centralisation

The supply of energy in bulk from a small number of sources, as seen in the UK's current energy system.

Climate Change

The Earth's climate changes constantly. This term is usually used to mean artificial or anthropogenic climate change caused by greenhouse gas emissions, which have to be distinguished from natural variation in climate.

Co-evolution

Concept that technology, social systems and practices change alongside each other rather than, for example, technological innovation or social need driving one another independently.

Combined heat and power (CHP)

The generation of electricity and heat in a single plant, for industrial or domestic use. By utilising the heat produced when the fuel is used to generate electricity, it increases the efficiency of the process.

Community ownership

Ownership of energy infrastructure or other assets by the community which uses them.

Coolth

Pleasantly cool living conditions. The cooling equivalent of warmth.

Decentralisation

The provision of energy in smaller amounts, perhaps from local sources and with local ownership.

DEFRA

The Department for Environment, Food and Rural Affairs.

Demand-side management

Measures such as smart metering which manage energy demand, in contrast to approaches which rely on supplying all demands for energy.

Distributed energy

Energy obtained from a large number of small sources, including renewable energy converters, rather than a small number of centralised sources.

Distribution system

The system which takes electricity from the transmission system and distributes it at low voltage to final consumers.

DTI

The Department of Trade and Industry.

Embodied carbon

The amount of carbon used in the whole process of manufacturing a final product, including the production of the inputs needed to make it.

Energy

Energy can be converted from one form to another – for example, chemical energy in coal can become electrical energy in a wire – but cannot be created. The SI unit of energy is the Joule.

Energy Avatar

An electronic, usually graphics-based, version of the user. In the context of energy, avatars could provide immediate interactive information about energy service and suggestions on how to reduce consumption.

Energy consumption

The amount of energy used by an individual, business or process.

Energy demand

The amount of energy used to provide all the goods and services in society. People usually want the effect of energy use (heat, light or movement, for example) not energy itself, so a given amount of activity can be accomplished with higher or lower energy demand.

Energy efficiency

A measure of the amount of work obtained from a given amount of energy input. Something which is energy efficient uses energy in a way which maximises the work obtained from it.

Energy storage

The capacity to retain energy in any form, ranging from a battery or a domestic hot water tank to a hydroelectric reservoir.

Feed-in tariff

The rate paid to small-scale electricity producers for power they sell to the distribution network.

Fuel cell

Device using fuel such as hydrogen to generate electricity in small amounts, for lighting, transport or other uses.

Fuel poverty

Inability to afford a basic level of domestic heating and lighting. Defined as spending more than 10 per cent of household income on these.

Gigawatt-hour (GWh)

The amount of energy delivered in an hour with power at a rate of 1GW.

Global warming

An increase in the average temperature of the earth's atmosphere due to the Greenhouse Effect, especially a sustained increase that causes climatic changes.

Greenhouse effect

Warming of the Earth by the capture of infrared radiation emitted from its surface by specific molecules in the atmosphere, most importantly carbon dioxide. The amount of carbon dioxide in the atmosphere rose from 315 to 380 parts per million between 1960 and 2003.

Green space

Parks and other urban spaces characterised by extensive vegetation which make the built environment more enjoyable for people and more resilient to external stress.

Heat island effect

Also the Urban Heat Island effect. Raising of temperatures in cities by comparison with surrounding rural areas due to buildings and hard urban surfaces absorbing and retaining more heat than open land.

Hereditament

Property: strictly speaking, property that can be inherited; used for rating valuation purposes.

Hybrid

Energy system, for a vehicle, building or area that can run on a range of fuels.

Infrastructure

The systems that underlie and enable society, including those that supply electricity, oil, gas, water, transportation and telecommunications, and remove waste.

LED

Light-emitting diode. A diode which emits light when a current is passed through it in the correct direction.

Lifecycle cost

The complete cost of making and using something, including a building, and disposing of it after use.

Lock in

The phenomenon by which past investment decisions and current social practices make it difficult to adopt new technology. An example is the QWERTY keyboard. The cost and inconvenience of abandoning it outweigh the advantages of more efficient alternatives.

Low-carbon technologies

Energy technologies which use little or no fossil fuel. Examples might include renewables, nuclear power or bioenergy.

Mitigation

Action taken to reduce an undesired effect such as climate change. It is the complementary approach to adaptation (qv).

Ofgem

The government regulator of electricity and gas networks.

Oil Equivalent

The amount of energy released by burning the specified amount of oil. One tonne of oil equivalent is 41.868GJ.

Peak Oil

Period at which world oil production will reach its maximum and begin to decline. Individual countries such as the US and the UK have passed their oil production peaks and the world as a whole may do so in around 2020.

Power

The rate at which energy is used. The SI unit of power is the Watt, which equals one Joule per second.

Refurbishment

Adapting rather than replacing an asset: in the context of this report, improving energy efficiency and comfort in buildings rather than demolishing them and building anew.

Renewable energy

Energy derived from self-sustaining sources, mainly the sun, the wind and rivers, as well as wave, tidal and geothermal energy.

Resilience

The capacity of human and natural systems to deal with surprises or changes including climate change, severe weather events, or terrorism. An increasing policy priority for the UK and other countries.

Retrofitting

The addition of new features to an existing building, vehicle or other asset.

Scale

The typical organisational size of a system. A village renewable energy scheme would have a far smaller scale than the current natural gas supply, which involves the movement of materials across many thousands of kilometres.

Smart materials

Materials which can adapt to their environment, for example building materials which become lighter and more reflective on a sunny day.

Smart metering

Metering systems which make the energy use of specific devices apparent to the user, and which may contain technology to allow energy use to be reduced at times of peak demand.

Sustainable

Of technologies, practices or societies: capable of continuing indefinitely with zero or acceptably low and replaceable resource demands.

Thermal energy efficiency

The efficiency with which a thermal (nuclear or fossil fuel) power station converts heat into electricity: or for a combined heat and power station, the efficiency with which it converts the heat it uses into electricity and usable heat. In this case the production of each must be specified separately.

Transmission system

The national system through which high-voltage electricity is transported from power stations to be fed into the distribution system.

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