Energy Choices for the UK

Seeking affordable, secure and sustainable energy supplies
“Centrica’s innovative and important project suggests that there are significant savings to be made from a variety of possible modifications to the UK’s present energy strategy and policy. The work deserves careful study by the government, regulators and all those concerned about the effectiveness and cost of energy policy.”

Prof Stephen Littlechild
Acknowledgements

Foreword

Summary

Chapter 1. UK energy policy at a decision point

Chapter 2. Where we are today

Chapter 3. Where we may be heading

Chapter 4. Rationalising our targets

Chapter 5. Lowering costs and bills

Chapter 6. An alternative energy strategy for the UK

Chapter 7. Policy to make it happen

Analytical appendix
We would like to thank Sir David King and Prof Stephen Littlechild for their independent expert review of our analysis and findings throughout the course of the project. Over a number of meetings they debated our insights, and advised us as we developed our conclusions and recommendations. Their work ended on 30 September 2013, in advance of Sir David’s appointment to HM Government as the Foreign Secretary’s Special Representative for Climate Change.

We would also like to thank officials at the Committee on Climate Change and DECC for their advice on methodology and assumptions.

Finally, we would like to thank Baringa Partners LLP for their expert advice, challenge and support as we used their modelling capability to draw out practical insights and policy implications for this report. Their modelling capability enabled us to examine more than 50 different scenarios, covering the entire UK energy system (heating, electricity, transport), including more than 100 technologies, and stretching all the way to 2050.

This work is a product of several months’ intensive analysis by a team in Centrica, supported throughout our company by teams who have expertise across the energy value chain, from sourcing energy through to supplying it.

While a range of experts have commented upon our analysis and insights, all the views expressed in this report are ultimately our own.
At Centrica we are deeply conscious of the cost-of-living challenge for most customers and the impact of rising bills. We are also committed to tackling climate change, and fully support the UK’s decarbonisation targets.

A sustainable energy policy is not just one that is green, but one that is enduring. As the UK economy starts to mend, we believe it is more important than ever that the UK pursue the most cost-effective pathway to meeting these targets. If we do not, businesses and householders will not accept the targets and decarbonisation will be put at risk. This report is intended to bring affordability for customers back to the forefront of the debate, but not at the expense of our decarbonisation objectives.

In recent months there has been an unprecedented focus on the energy sector in the UK, against a backdrop of declining real disposable income for many consumers. Aware of this affordability challenge, we commissioned a detailed evidence-based study with a view to finding a more affordable pathway to a lower-carbon future.

Our intention is to build on the growing understanding of options to tackle climate change and to inform the policy choices of the future, rather than to re-examine the decisions of the past. We have looked at the entire energy system through to 2050, with a focus on the period to 2030. Our aim has been to explore sustainable pathways, not short-term ‘fixes’.

There are no simple answers. Scenarios modelled on a computer are not the same as real world implementation with all its challenges. However, our intention is to offer ideas and solutions that help deliver carbon savings more cost-effectively and to spark a debate with all interested parties on these very important issues. With that in mind, I am grateful for the challenge and review provided by Sir David King, Prof Stephen Littlechild and others to ensure credible, robust and independent analysis.

As the international community begins to focus on the Paris climate change negotiations in 2015, the UK has a responsibility to continue demonstrating leadership in tackling climate change. Pursuing a pathway that maintains public acceptance without undermining the competitiveness of our businesses is essential if we are to expect the rest of the world to follow.

We offer this as contribution to the debate about what makes an enduring energy strategy for the UK, from the perspectives of society, the consumer and the investor.

Sam Laidlaw
Summary

Britain’s homes and businesses rightly expect secure energy supplies that are both affordable and meet our environmental commitments.

All of us rely on the gas flowing, to heat our homes and businesses, and the lights staying on, for our schools, hospitals and factories. And as the scientific evidence constantly reminds us, our environmental commitments must be met. Yet this must be done in such a way that does not undermine the competitiveness of our businesses or put living standards at risk, particularly if we are to expect the rest of the world to follow our example. As household budgets recover from the greatest recession since the Second World War, now more than ever costs must be kept under control. Achieving this is at the heart of the challenge facing UK energy policy today.

The UK’s energy policy is designed to meet these objectives, but setting good policy is complicated by tensions, uncertainties and the need to ensure public acceptance.

Often, there can be inherent tensions between policy objectives. For example, forcing the closure of older coal plants or the building of renewable, often intermittent, generation delivers environmental outcomes, but impacts on security of supply. Policies to enhance security of supply, such as a capacity mechanism to encourage new power station construction, increase system reliability but potentially add greater cost.

Targets and policies are essential to guide the UK’s direction. The nature of the energy system means that decisions taken on these today will determine the course of the UK energy system for more than a decade. However, these decisions are being taken in the context of a hugely uncertain future.

• New technology breakthroughs are unpredictable in their timing and nature, but can radically change the costs and options available.

• Consumer demand and behaviour is subject to considerable uncertainty and can have

• material consequences on the required energy supply. In addition, smart meters are likely to help change demand patterns, but their impact is uncertain.

• Commodity prices – the prices of fuels – have varied dramatically over time, and their future levels are subject to significant uncertainty.

• International developments will also have an impact. Major negotiations on climate policies are due in Paris in 2015 which could influence the UK’s pace or direction.

Finally, and perhaps most importantly, whatever direction the UK takes, it must have public acceptance. Customers, or taxpayers, must be willing and able to pay the additional costs of decarbonisation. The public also influences which types of measures can be adopted, for example, how much more onshore wind or solar we can install on our landscapes, and how many more homes we can insulate.

We propose three guiding principles to help navigate policymaking through these difficulties, and deliver security, affordability and environmental sustainability.

We assessed the lowest-cost pathways to achieve the UK’s 2050 decarbonisation targets under a wide range of possible future scenarios. We took the whole UK energy system into account and used publically available assumptions on costs and technology performance, which were primarily from DECC, National Grid or the Committee on Climate Change. The scenarios we tested were designed to explore the full range of uncertainties described above.

We found that decarbonisation comes at a cost, but that those costs can be limited provided policy is specifically designed to deliver the most cost-effective outcome.
We propose that a cost-effective strategy for energy policy adopts three key principles:

1. **The principle of “lowest-cost, least regret”**

Given the uncertainties, we believe affordability and adaptability must be at the heart of delivering our 2050 decarbonisation target. It is important not to lock into certain technology pathways too soon only to find more cost-effective options emerge later. This is especially true when enough lower-cost options are available to meet near term targets.

Therefore, **lowest-cost** measures should be prioritised to ensure decarbonisation targets are met as affordably as possible, and to minimise the risk of today’s measures being overtaken by cheaper or better options in the future. Furthermore, **least regret** options should receive the most focus. These are the options that make economic sense in the widest set of future scenarios, given the uncertainties ahead. Their robustness to future uncertainty means we can be confident that investment won’t be wasted.

Embedding a ‘lowest-cost, least regret’ approach in the UK’s energy strategy would maintain a focus on affordability regardless of what lies in the future, while ensuring secure supplies and meeting our climate change commitments.

2. **Set simple and cost-effective decarbonisation targets**

The existing carbon budgets framework, as set out by the Climate Change Act, is an effective way to guide the UK to achieving its climate ambitions. It provides enough certainty that the UK is on a realistic pathway to 2050, but allows flexibility about the mix of options chosen.

Other targets, such as 2030 power sector carbon intensity, renewable targets for 2030 or technology-specific targets tend to add cost and complexity by being overly prescriptive or creating conflicting priorities, and are inconsistent with a ‘lowest-cost, least regret’ approach.

3. **Support those most impacted by the cost**

Decarbonisation comes at a cost, even in a cost-effective approach. Vulnerable customers and energy-intensive industries are most likely to feel the impacts of these additional costs. Therefore, it is important that an affordable energy policy has clear measures to help mitigate this impact.
Applying these principles has implications for energy use across many sectors of the economy.

This report explores the practical implications of pursuing a ‘lowest-cost, least regret’ approach for a number of sectors of the economy.

We found that:

- **In power generation**, the key low regret options were switching from coal to gas generation and new nuclear power. In contrast, solar PV appeared to be a high cost option, since it generates no output at times of peak demand, namely winter evenings, and therefore does not support security of supply without investment in back-up. Offshore wind has the potential to be high regret because it is an expensive option that may not be needed until the mid-2020s, or at all if Carbon Capture and Storage (CCS) technologies become economically viable.

- **In homes and businesses**, energy efficiency measures form an important part of the solution. Efficient gas boilers, loft and cavity wall insulation and high electrical product efficiency standards should be fully adopted. Smart meters are also an important enabler of energy savings and more effective grid management in the future. However, solid wall insulation appears costly prior to 2030. It may only be cost-effective for a minority of solid wall properties – namely fewer than 500,000 old, large, off-gas grid properties.

- **Renewable and district heating** are also important technologies. Renewable heating, in particular larger non-domestic biomass and air source heat pumps consistently appeared to be a more cost-effective source of renewable energy than most renewable electricity systems. In addition to renewable heat sources, district heating can also make use of waste heat captured from power stations and industry.

- **In transport**, there is considerable low-cost opportunity from efficiency improvements in conventional petrol and diesel vehicles, implying that tight efficiency standards could be an important part of energy policy. Gas-fuelled HGVs could play a role in the 2020s and 2030s. Electric vehicles were important in a number of scenarios, but by no means all.
A “lowest-cost, least regret” approach could save up to £100bn between now and 2030.

We compared a lowest-cost approach with the trajectory the UK may be on, should the main thrust of current policy be continued into the future.

We believe that between now and 2030, up to £69bn of costs could be avoided by focusing on the lowest-cost, least regret technology options.

In addition, we considered what the most appropriate framework of targets would be, to guide the UK’s energy pathway to 2050.

We support the current proposals for the fourth carbon budget. The next critical decision is for the fifth carbon budget. We believe a further £10bn of cost could potentially be avoided by choosing a fifth carbon budget level consistent with a straight-line trajectory in emissions reductions to 2050. This is as opposed to ‘front-loading’ effort, which would force more costly solutions.

The UK also has a target in place to deliver 15% of its energy from renewables by 2020. If the carbon budgets alone set the renewables deployment rate, the 15% target would be achieved in c.2025 and £17bn of costs would be saved, compared with rigidly sticking to a 2020 target.

Further targets, for example those that focus on specific technologies or sectors, should be avoided.

This report outlines our methodology, analysis and policy proposals. However, it is not intended to provide the answer, but to stimulate an informed and rational conversation about the future of the UK’s energy policy. It offers guiding principles to underpin policymaking, that of a ‘lowest-cost, least regret’ approach, and suggestions for how to implement that in practice.

Over the next few years we have a collective responsibility to ensure the UK’s sustainability and security obligations are met affordably. We hope the findings in this report help contribute to that.
Chapter 1

UK energy policy at a decision point
UK energy policy is at a decision point. Choices made in the next two years will impact our energy system for a generation.

The UK’s energy market is recognised as a world leader in delivering security, and social and environmental goals. Our energy system has been one of the most secure and reliable in the world. Greenhouse gas emissions were 27% lower in 2013 than they were in 1990. Average UK domestic gas prices were the second lowest in the EU-15, and domestic electricity prices were the fifth lowest.

However, the UK’s energy objectives (to maintain security of supply, meet environmental goals and remain affordable) are facing challenges:

- **Security of supply** is potentially impacted by the closure of almost one-fifth of coal-fired power stations by 2015, owing to age or environmental regulation. Traditional sources of natural gas, such as the UK Continental Shelf, are declining. Instead, supplies will increasingly need to come from Norway, Qatar, or Russia, and potentially also new international sources such as West Africa and the USA. The UK will have to pay international prices. Over time, indigenous onshore shale gas could make a contribution.

- To ensure **decarbonisation**, the UK has a range of targets in place. These are having a major impact on policy and investment decisions today, and will only put more pressure on our carbon-intensive energy system.

- As the UK recovers from the worst recession since the Second World War, **affordability** is front of mind for consumers, businesses and politicians alike.

There are tensions between these objectives, and trade-offs need to be made. Factors include: the pace of decarbonisation and its affordability; the amount we are willing to pay to ensure we have the fuel sources we need and the lights stay on; and the impact of intermittent low-carbon generation on the security of the electricity system.

Over the next two years, a series of decisions will be made that could fundamentally change the shape of our energy system for at least the next two decades.

- The UK will review and finalise its greenhouse gas emissions targets covering 2023 to 2027 (the fourth carbon budget).

- The UK will also decide on targets for emissions from 2028 to 2032 (the fifth carbon budget).

- Decisions will be made on the need for a target for the carbon intensity of the UK power sector in 2030, and if needed, the appropriate level for this target.

- The EU will decide on potential renewables and carbon reductions targets for 2030.

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1. World Energy Council energy index (2013). Britain was ranked fifth of 128 countries.


3. The Energy Act of 2013 granted power to the Secretary of State to set this carbon intensity target.
The UK will also decide on the policies, technologies and measures required to deliver these targets.

- The UK government has begun to contract low-carbon power generation, such as nuclear and offshore wind, through Contracts for Difference.
- The final design of a capacity mechanism will be set, to ensure security of supply in electricity.
- In the residential market, the UK government is consulting on a proposal to reform its flagship energy efficiency policy, the Energy Company Obligation (ECO). As part of this proposal the scheme will be extended until 2017. The long term shape of ECO beyond this date will be an increasing topic of debate to ensure it is fit for purpose in delivering the measures required to transform the UK’s old housing stock cost-effectively.
- In addition, the domestic Renewable Heat Incentive scheme was launched in April 2014. It will be important to track how well this ground-breaking new scheme performs and be open to adjustments to ensure that cost-effective renewable heating roll-out is maximised.

The choices we make will impact not just the shape of our energy system but also its costs.

Taken together, the UK energy policy schemes mentioned previously could cost around £10bn p.a. by 2020, most of which will be recovered from consumers through changes in energy bills. In addition, around £2.5bn p.a. is currently spent on social energy policies, paid for from general taxation.

In 2013, households were already paying nearly £130 each for environmental and social policy (see figure 1.1). This was an increase of 14% compared to 2012, making policy costs the fastest growing component of the energy bill year on year.

Recent government proposals to reform energy efficiency and social discount schemes (namely the Energy Company Obligation, and the Warm Homes Discount), will offset policy costs increases in 2014 by around £424. These changes are to be welcomed. However, the longer term trend in policy costs remains upwards as increasing levels of low carbon power generation will require support under various incentive schemes.

More low carbon sources of energy and improved efficiency will be required to meet the UK’s carbon reduction objectives. But the energy policy decisions that are made today will be felt by consumers for the next 20 years and longer, given that many of these policies will be supporting investments for much of their lives. It is therefore crucial that policy is designed to deliver carbon savings in the most cost-effective way to limit the impact on customer bills.
Figure 1.1: Breakdown of average British Gas domestic gas and electricity bill in 2013

*Based on actual 2013 results, this is an average of all payment types/tariffs/regions and based on consumption levels of 492 therms for gas and 3,688 kWh for electricity.
The UK’s target and policy choices will need to be made in the context of three major factors: public acceptance; international developments; and external uncertainties.

Public acceptance: customers must be willing to pay the additional costs of decarbonisation, through their taxes or energy bills. If it is through their bills, there will be a potentially regressive impact from some of these levies. The costs must also be acceptable to business. If the UK is at a severe competitive disadvantage, our businesses will close or relocate overseas. This would be bad for our economy and bad for global emissions. The public can also influence which types of measures can be adopted, such as how much more onshore wind or solar we can install on our landscapes, and how many more homes we can insulate.

International developments: the decisions the UK takes will matter on the international stage. In 2015, country leaders will gather in Paris for major climate change negotiations, attempting to agree action on what is a global problem. The UK is seen as a leader, but to retain our credibility we must hold firm on our commitments and long-term targets. However, if we are to hope the rest of the world will follow suit, we must also demonstrate that our targets can be achieved in a way that does not undermine the competitiveness of our businesses or put living standards at risk.

External uncertainties: finally, there are significant external uncertainties that could impact the UK’s energy pathway and cost.

- Technology: new technology breakthroughs, or innovation to drive down the costs of existing technology, have an important role to play in affordable decarbonisation. Similarly, the failure of promising technologies to materialise can have a profound effect on system costs. The unpredictable nature of technology development makes this very hard to quantify. However, history demonstrates the game-changing impacts that new technology can have. For example, shale gas drove USA natural gas prices down from $12/mmBtu to $2/mmBtu, and in the UK the cost of solar PV modules fell by two-thirds between 2010 and 2012, from roughly £1.5/W to £0.5/W.

- Consumer demand and behaviour: economic output is a strong driver of business energy demand and is subject to considerable uncertainty. Likewise, consumer behaviour change can have a large impact. The average temperature to which people heat their homes in winter has gone up by 6°C over the past four decades, despite little change in the external temperature. A 1°C decrease in average internal temperature today can reduce household gas demand by 10%. This can be achieved by heating the right rooms at the right time with smart-enabled technologies, minimising the impact on comfort levels.

- Commodity prices: forecast prices of oil, gas, coal and power typically span a very wide range, albeit one that looks conservative given the significant changes seen in the past decade (see figure 1.2). Indeed the long-term ranges indicated in these forecasts may still be too narrow. In 2006, the DTI high case for oil prices in 2015 was around $60, which is half that of today’s central case forecast. This is a challenge for policymaking since subtle differences in commodity prices can lead to substantially different economic conditions for certain technologies as well as different levels of overall energy demand.
For example, low gas prices and high oil prices could make natural gas vehicles an economically viable option without the need for subsidy.

DECC commodity costs forecasts have been used in this report. These tend to be at the higher end of the range of external analyst estimates, particularly after 2020 (see figure 1.2).

- **Biomass availability:** biomass could have a very significant role in the UK’s decarbonisation strategy, particularly in the long term. It is a very versatile resource as it can be burned at high temperatures, making it suitable for industrial processes as well as commercial heating; it can be produced in liquid form as biofuels, making it suitable for transport applications; and if used in power generation, it is not subject to intermittency issues.

However, there is much uncertainty over how much sustainable biomass could be available to the UK and some increasing debate about the environmental benefits of large scale deployment. If its availability is limited, then industry, transport and power have to find alternative ways to decarbonise – which typically require more expensive technologies. Conversely, there is the long-term potential for technology breakthroughs to increase supply (e.g. algal biomass).

Figure 1.2: Comparison of DECC oil & gas commodity cost projections with other forecasts
Chapter 2

Where we are today
The UK has a number of targets and policies in place to help achieve its objectives.

The UK energy system in 2013

- Oil provides around one-third of primary energy in the UK, the majority of which is used in transport.
- Natural gas also provides around one-third of the UK’s primary energy, but import dependency has increased rapidly over the past decade. Roughly 50% comes from the UK’s own resources compared with almost 100% in 2000. The remaining 50% was imported by pipeline from the continent or by ship in liquefied form, primarily from Qatar. Two-thirds of this gas is used to heat our homes and in industry, and the remainder is used to generate electricity.
- Coal makes up almost one-fifth of the UK’s primary energy, and is virtually all used in electricity generation.
- Bioenergy makes up 4% of the UK’s primary energy supply; almost 70% is used in electricity generation.
- Nuclear, other renewables (hydro, wind, solar) and electricity imports provide c.10% of the UK’s primary energy, used directly for electricity.

Estimates for greenhouse gas emissions from the UK in 2013 were 570 MtCO$_2$e compared to final greenhouse gas emissions from the UK in 2012 of 581MtCO$_2$e which was around 2% of global greenhouse gas emissions.


To meet its energy objectives, the UK has a number of targets and policies in place.

The Climate Change Act (2008) set a legally binding target to reduce the UK’s greenhouse gas emissions by 80% in 2050, compared with 1990 levels.

The Climate Change Act represented both a commitment by the UK to reduce its own greenhouse gas emissions and a gauntlet thrown down to the rest of the world to follow suit. A number of other countries have also made commitments, either in parallel or subsequently, the most ambitious being Denmark, which intends to remove fossil fuels entirely from its energy system by 2050. The world’s largest emitter, China, has committed to reduce emissions per unit of GDP by 17%\(^{10}\), and the second largest emitter, the USA, has committed to cut emissions by 17% by 2020 from 2005 levels\(^{11}\). However, at an international level, progress to tackle climate change has been limited, with the focus now on the next milestone: the climate negotiations in Paris in 2015.

Fuel poverty also rightly receives policy focus. There are around 2.4m households in fuel poverty in England\(^{12}\). The government has long aspired that “as far as reasonably practicable” no household should be in fuel poverty, and is in the process of defining new targets to address the issue.

The 2050 target is underpinned by carbon budgets, to ensure the UK is on course to meet its goal.

In addition to setting a long-term decarbonisation target, the Climate Change Act requires the government to set, and then adhere to, carbon budgets consistent with meeting the target. The budgets provide the UK with emissions limits for consecutive five-year periods. They are technology and sector neutral, enabling the market and the government of the day to judge the most appropriate way to meet those budgets depending on the options available at the time.

Carbon budgets enable the UK to take a measured pathway towards its long-term targets; a ‘front-loading’ of effort risks increasing costs given the uncertainties ahead and ‘back-loading’ effort increases the risks that the targets are not met.

The first **three carbon budgets** to 2022 have already been set, and they require a c.35% reduction on 1990 levels by 2020. The UK is on track to achieve them and by 2012 had delivered a 27% reduction\(^ {13}\). This is attributed to a number of factors: the increasing use of gas (displacing coal) to generate electricity, the economic downturn reducing industrial and domestic energy demand, and government policy.

The **fourth carbon budget** covers the period 2023-2027 and has also been set, at 1,950MtCO\(_2\). This equates to a c.50% reduction on 1990 levels of greenhouse gases by 2025. The government has committed to review that target in 2014, should the UK’s “domestic commitments place us on a different emissions trajectory than the Emissions Trading System trajectory agreed by the EU”. In the first part of its review of the fourth carbon budget, the Committee on Climate Change examined the implications of various EU 2030 policy options. They found that an EU greenhouse gas emissions reduction pathway of 20% in 2020 and 40% in 2030 (compared to 1990 levels) could, depending on how the targets are shared between Member States, result in a UK share of EU greenhouse gas emissions (in traded and non-traded sectors) consistent with the legislated fourth carbon budget. Since this review the European Commission has put forward proposals for a 40% greenhouse gas emissions reduction in 2030.
The role of the power sector in meeting carbon targets

The power sector is one of the largest emitters, so will need to undergo significant decarbonisation to meet the 2050 goal. However, it may need to do this ahead of other sectors because other sectors do not have as many alternatives to reduce their carbon footprint. A low-carbon power sector also enables other sectors to source some of their energy from electricity (such as electric cars in transport and electric heat pumps in heating).

The fifth carbon budget covers the period 2028-2032 and will be set in 2015. Its level is particularly important because it will determine when significant investment in low-carbon power generation is required (see box above).

The carbon budgets are supplemented by a number of sub-targets.

In 2009, the UK signed up to an EU directive committing to supply 15% of its primary energy from renewable sources by 2020. This covers the electricity, transport and heat sectors. In 2012, renewables accounted for just over 4% of energy consumption in the UK.  

The European Union is considering an additional renewables target for 2030. Current proposals are for an EU-wide 2030 renewables target of 27%, but with no national level targets.

An EU Energy Efficiency Directive was also put in place in November 2012, setting a non-binding UK target for final energy consumption of 129.2 million tonnes of oil equivalent (Mtoe) by 2020. Final consumption of energy in 2012 was 140.6 Mtoe, meaning an 8% reduction in demand will be needed by 2020. Preliminary estimates for 2013 show final consumption of energy increased by 0.5% from 2012 to 141.3 Mtoe.

Figure 2.2: UK power sector emission intensities and fuel sources

<table>
<thead>
<tr>
<th>Carbon emissions intensities in power generation (gCO₂/KWh)</th>
<th>UK electricity generation by fuel source (2012)</th>
</tr>
</thead>
<tbody>
<tr>
<td>New Gas CCGT <strong>390</strong></td>
<td>1% / Imports</td>
</tr>
<tr>
<td>UK Grid Average (2012) <strong>486</strong></td>
<td>2% / Wind, wave, solar</td>
</tr>
<tr>
<td>New Coal <strong>850</strong></td>
<td>2% / Hydro</td>
</tr>
</tbody>
</table>

The Energy Act of 2013 gave the Secretary of State power to set a target for the **carbon intensity (CI) of electricity generation**. The carbon intensity relates to the amount of emissions per unit of electricity (grammes of CO\(_2\) per kWh). Electricity from coal has the highest carbon intensity, new gas-fired power stations have less than half the carbon intensity of new coal, and renewables and nuclear have no, or almost no, emissions. In 2012 the CI of electricity was 486gCO\(_2\)/kWh, with coal still dominating the UK generation mix (see figure 2.2).

DECC models three scenarios for 2030 CI, namely 50gCO\(_2\)/kWh, 100gCO\(_2\)/kWh and 200gCO\(_2\)/kWh. The Committee on Climate Change has advocated the 50g level.

In summary, the UK has a range of targets, some fixed and some still to be finalised, covering different time periods and different sectors (see table 2.1). The government has also introduced a range of policies across all sectors to achieve these targets (see figure 2.3).

### Table 2.1: Adopted and debated environmental targets affecting UK energy policy

<table>
<thead>
<tr>
<th>Target</th>
<th>2020</th>
<th>2025</th>
<th>2030</th>
<th>2050</th>
</tr>
</thead>
<tbody>
<tr>
<td>Greenhouse gas reductions (vs 1990 levels)</td>
<td>34%</td>
<td>≥50% subject to review in 2014</td>
<td>Decision due in 2015</td>
<td>80%</td>
</tr>
<tr>
<td>Contribution of renewables</td>
<td>15%</td>
<td></td>
<td>Target currently being debated</td>
<td></td>
</tr>
<tr>
<td>Power sector carbon intensity</td>
<td></td>
<td></td>
<td>To be decided in 2015</td>
<td></td>
</tr>
<tr>
<td>Energy efficiency</td>
<td>129 Mtoe</td>
<td></td>
<td>final energy consumption target</td>
<td></td>
</tr>
</tbody>
</table>
**Figure 2.3: Key environmental and social policies currently in action in the UK**

<table>
<thead>
<tr>
<th>Policy</th>
<th>Objective</th>
<th>Mechanism</th>
<th>Government estimated cost (2013-14)</th>
</tr>
</thead>
</table>
| ECO    | • Deliver carbon reduction measures that are not cost-effective under the Green Deal  
       • Subsidise cost-effective measures to low-income households, including a focus on rural low-income areas  
       • Improve the ability of low-income and vulnerable households to heat their homes | • Obligation on energy suppliers to deliver measures directly, or indirectly (e.g. via a brokerage)  
• Funded via energy suppliers from customer bills | £1bn |
| Green Deal | • Encourage uptake of cost-effective efficiency | • Finance available with c.7% interest rate  
• Repayments made through energy bill | N/A |
| CfDs (Contracts for Difference) | • Support for new low-carbon power investments (e.g. renewables, nuclear, CCS)  
• Replacing the Renewables Obligation (RO) | • Compensates generators for the difference between the wholesale power price and an agreed ‘strike price’  
• Funded via energy suppliers from customer bills | N/A (c.£7.6bn by 2020, including RO and FIT costs) |
| Renewables Obligation | • Support renewable electricity generation  
• Being phased out and replaced with CfDs | • Levy on customer bills to top up renewable generators | £2.4bn |
| Renewable Heat Incentive | • Support renewable heat technologies of all types, with incentive levels set to encourage more cost-effective off-gas grid properties | • Taxpayer-funded incentive available to customers and businesses | £251m |
| Feed-in Tariffs | • Encourage uptake of small-scale renewable and low-carbon technologies (e.g. solar panels by households) | • Payments for generation and export of electricity  
• Funded via energy suppliers from customer bills | £633m |
| Carbon Price Floor | • Carbon price signal into the power sector to compensate for the failure of the EU Emissions Trading Scheme to provide an adequate carbon price  
• Benefits generation with lower carbon intensity (i.e. renewables and gas over coal) | • Tax on electricity generation proportionate to its carbon intensity | £740m |
| Winter Fuel Payment | • Provide cash benefits to pensioners to help with energy costs | • Cash payment to eligible households of up to £300 p.a., paid for through taxation | c.£2.2bn |
| Warm Homes Discount | • Provide energy bill discounts to vulnerable in society to help with energy costs | • £135 discount on energy bills of eligible households paid for through taxation | c.£300m |
| Cold Weather Payment | • Provide additional support to vulnerable in the event of very cold weather | • Cash payment to eligible households of £25 for each 7 day period where temperatures average below 0°C | Weather dependent (£146m in winter 12/13) |
In addition, the Energy Act of 2013 included a capacity mechanism to ensure security of electricity supply. The first capacity auctions are likely to take place in 2014, for generation in 2018. By 2020, the cost of capacity payments could be c.£2bn\textsuperscript{15}.

The government has also set a target to ensure every household has a smart meter by 2020. Smart meters will enable customers to keep continual track of energy use in their home and to take advantage of time-of-use tariffs, reducing their costs and lowering peak emissions.

A range of other environmental policies cover the transport, industrial and commercial sectors. Schemes are also in place to support groups most impacted by energy costs, such as energy-intensive industries and the fuel-poor.

Although the UK has considerable discretion over policy design and funding levels, as a member of the European Union its legislation needs to be consistent with the market liberalisation and harmonisation objectives of the EU, and compliant with State Aid rules.

\textsuperscript{15} High level estimate based on DECC’s estimated “Cost of New Entry” of £49/kW and c.50GW of capacity

Taxpayers and bill-payers currently fund these policies.

Some policies are funded by general taxation, such as the Renewable Heat Incentive and the social policies designed to alleviate fuel poverty. The majority, however, are funded via the household energy bill, such as ECO, the Renewables Obligation (RO), CfDs and Feed-in Tariffs (FITs).

In order to keep these costs under control the Treasury has set a Levy Control Framework, which caps the allowable costs of these measures through to 2020. The 2020/21 limit is set at £7.6bn (real 2012), covering the RO, CfDs and FITs. This figure is expected to increase post-2020 as additional investments are made under these schemes. The 2013/14 level is set at £3.1bn. ECO is not included in the Levy Control Framework, despite being funded by bill-payers; nor are the costs of the capacity mechanism.
The Climate Change Act represented both a commitment by the UK and a gauntlet thrown down to the rest of the world to follow suit.
Where we may be heading
The UK’s current policy trajectory appears to be delivering our carbon and renewable targets for up to £69bn more than may be necessary.

The energy system in 2030 will be shaped by policy decisions made today. We developed a forecast for the UK’s likely trajectory based on how the government foresees these policy decisions unfolding. We then assessed whether or not this trajectory is the most cost-effective or appropriate, given the uncertainties ahead, by comparing it with a range of alternative scenarios. These scenarios included a ‘lowest-cost’ decarbonisation pathway (see Methodology on page 26).

All of the scenarios in this chapter meet all existing UK targets (carbon budgets, renewables targets and the Energy Efficiency Directive).

To assess the relative costs of our scenarios, we compared them to one in which there are no decarbonisation targets. Figure 3.1 demonstrates the difference in additional total system costs between the ‘policy forecast’ scenario and a lowest-cost scenario (‘cost optimal’), over and above the costs of a system with no decarbonisation targets. By 2030, the cumulative costs of ‘policy forecast’ could be as much as £69bn more than those of ‘cost optimal’. The ‘cost optimal’ scenario itself is some £75bn more expensive than one in which there are no carbon targets.
System costs are uncertain and are very sensitive to commodity costs and demand.

System costs are most sensitive to commodity cost. However, these are outside the UK’s control, shaped by global forces. Energy demand is also a key sensitivity, and here there is considerable scope to influence system costs by encouraging higher efficiency through both technology and behavioural changes (see figure 3.2). We have focused our assessment on domestic energy efficiency technologies. However, a number of studies have also identified the scale of energy-saving opportunities through either behavioural changes or non-domestic measures. These studies have identified the scope for policy-makers to do more in these areas.

The impact of technology is also uncertain. System costs could be some £6bn p.a. higher if emerging technologies fail to materialise by 2030. However, there could be considerable cost reductions with new technology breakthroughs. By their very nature, the impacts of these are unpredictable.

While the impact on 2030 system costs of biomass availability is small, biomass is important in the longer term due to its flexibility to be used in a number of forms across a number of sectors (particularly those with relatively few abatement options such as industry and aviation).

A sector-by-sector summary of the results follows over the following pages.

**Methodology**

- We used the Redpoint\textsuperscript{16} Energy System Optimisation Model (RESOM) to compare the estimated costs and impacts on the system of the UK’s current energy policy trajectory with a range of alternative decarbonisation scenarios.

  - This model has been used by DECC, the CCC and National Grid. It is a lowest-cost optimisation model that covers the whole UK energy system (including electricity, transport and heating) through to 2050.

  - Where possible DECC assumptions for technology and commodity costs were used\textsuperscript{17}. Any data gaps were filled using publically available information (see section 1.2 of the analytical appendix for more details on the assumptions used).

- We developed an illustration of the UK’s current policy trajectory by combining information from a number of recent DECC publications (e.g. draft EMR delivery plan and ECO Impact Assessment). We called this our ‘policy forecast’ scenario (see sections 1.3 and 1.5 of the analytical appendix for more detail on how the ‘policy forecast’ scenario was constructed).

- We then constructed a ‘cost-optimal’ scenario by using RESOM to generate the lowest-cost decarbonisation pathway possible, given the underlying cost and technology assumptions.

- Finally, we constructed seven alternative scenarios to test the impact of a range of different uncertainties on the lowest-cost decarbonisation pathway (see table 3.1).

- All the scenarios we examine in chapter 3 meet the UK’s existing legal obligations, including the Renewable Energy Directive, the Energy Efficiency Directive and the first four carbon budgets (assuming the budgets are met through domestic emmissions reductions). The fifth carbon budget, as proposed by the Committee on Climate Change, is also met.

- In chapter 4 we examine the impacts of various different types and levels of target on energy system costs.
Table 3.1: The scenarios used to assess cost-effectiveness under a range of uncertainties

<table>
<thead>
<tr>
<th>Key Uncertainty</th>
<th>Low Cost Cases</th>
<th>High Cost Cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technology</td>
<td><em>Not assessed – while technology breakthroughs could have a material impact on the energy system, they are by their very nature unpredictable</em></td>
<td><strong>Technology pessimist</strong> • No CCS before 2030 • No new nuclear before 2025. 25GW maximum • 15GW onshore wind maximum • No more than 10% biomass in primary energy demand</td>
</tr>
<tr>
<td>Demand/Behaviour</td>
<td><strong>Low demand</strong> • Lower business energy demand • People decrease their thermostats 1°C • Less car use and more public transport</td>
<td><strong>High demand</strong> • Higher business energy demand • People increase their thermostats by 1°C • Car usage grows in line with historic trends</td>
</tr>
<tr>
<td>Commodity Costs</td>
<td><strong>Low gas and oil prices</strong> • DECC low gas and oil cost scenarios (Jul-13)</td>
<td><strong>High gas and oil prices</strong> • DECC high gas and oil cost scenarios (Jul-13)</td>
</tr>
<tr>
<td>Biomass Availability</td>
<td><strong>Plentiful biomass</strong> • 22% of primary energy demand by 2030 • 30% of primary energy demand by 2040</td>
<td><strong>Limited biomass</strong> • No more than 10% of primary energy demand</td>
</tr>
</tbody>
</table>

Figure 3.2: The range of energy system costs in 2030 of our eight uncertainty scenarios compared to ‘cost optimal’ £bn p.a. (real 2012)
Power generation

- New nuclear appears relatively cost-effective and features prominently in all scenarios.
- CCS is a promising technology, so its viability should be established quickly.
- Gas-fired power generation appears to be a low regret option.
- Offshore wind and solar PV are expensive and deployment should be limited.

DECC has provided an indicative view of the potential mix to 2030 in its Electricity Market Reform (EMR) delivery plan consultation (July 2013). This outlines a range of possible scenarios to 2030 but the main analysis reflects the central assumption used consistently in DECC’s analysis, namely a trajectory to around 100g CO$_2$/kWh power sector carbon intensity in 2030. This is the scenario used in the current policy trajectory cost estimate.$^2^0$

DECC’s estimated 2030 costs of the various power generation technologies available, with and without back-up are shown in figure 3.3.
Under DECC’s current cost expectations, **new nuclear** is the most cost-effective low-carbon generation option *(figure 3.3)*. This explains why at least 7GW of new nuclear is deployed by 2030 across our scenarios. The current policy trajectory has slightly higher levels of ambition, expecting some 14GW of nuclear in total.

An important step was taken in October 2013 when the UK government announced it had agreed terms with EdF on an investment contract to build a new nuclear plant – Hinkley Point C. The proposed support would be at a strike price of £92.5/MWh\(^{21}\) for a duration of 35 years, subject to an EU State Aid review. The first new nuclear reactors to be built are likely to be costlier than DECC’s 2030 estimates, and the high financing costs and construction risks mean that deployment should be monitored closely. Nevertheless, the UK should continue to pursue the development of a new generation of nuclear power stations, provided they can be delivered at the lower costs indicated by DECC. This is likely to require full competitive tendering of the supply chain.

**Carbon Capture and Storage (CCS)** consistently appears to be a key technology for the cost-effective decarbonisation of the UK energy system. However, the technology is at early stages of development and there is considerable uncertainty about its potential and its costs. It is therefore important to establish the viability of CCS quickly, neither relying on it being available at scale by 2030 nor ruling it out yet.

**Gas-fired power generation** features at scale across all of our scenarios (c.25-34GW). However, the usage levels vary from c.15% to c.55%. This demonstrates that its role can adapt to the needs of the system, providing baseload or flexible back-up for more intermittent forms of generation. Gas-fired power generation is therefore useful to the system as a ‘no-regrets’ deployment option. Indeed, in the short term, coal-to-gas switching appears to be a highly cost-effective, low-regret means of reducing emissions. It is only by 2030, when carbon costs are high, that any form of zero-carbon source of electricity can compete with gas-fired power *(figure 3.3)*.

**Offshore wind** appears expensive compared to new nuclear and CCS *(figure 3.3)*. This leads to low levels of deployment by 2030 across most of our scenarios, compared to ‘policy forecast’ *(figure 3.4)*. Only in ‘technology pessimist’ and ‘high gas/oil prices’ do levels of offshore wind approach that of ‘policy forecast’. In the case of ‘technology pessimist’, significant limits on alternative options – particularly CCS – require a greater contribution from offshore wind, and in the case of ‘high gas/oil prices’ the cost of using gas to generate electricity is less economic. However, even in these scenarios, the major build-out of offshore wind does not commence until 2025. The role of offshore wind in 2030 will in part be determined by whether or not CCS becomes viable by the early 2020s. Until this is clear, ambitions for offshore wind should be scaled back, but not to the extent that it undermines the development of the supply chain or jeopardises R&D efforts, given the potential long-term role.

\(^{21}\) £/MWh in 2012 prices. The strike price will be reduced to 89.5 £/MWh if EdF build a second new nuclear plant Sizewell C

\(^{22}\) DECC: Electricity Generation Costs December 2013; Centrica analysis
Solar PV has limited value to the UK energy system as a whole because it is not available during peak electricity demand periods (such as winter evenings). Once the cost of backing up intermittency is included, solar PV becomes a much more expensive option (see figure 3.3). As a result, even with the significant reduction in costs that has been observed, solar PV is not a cost-effective alternative under any of the various uncertainties tested. However, DECC’s recent review of FIT payment levels for solar PV suggested a central case deployment level of 11.9GW by 2020 and potentially as much as 20GW “early in the next decade” if costs fall further (current levels are c.2.7GW)\(^\text{23}\).

‘Policy forecast’ has some 25GW more total installed power generation capacity than any other scenario, and some 40GW more than the ‘cost optimal’ scenario (see figure 3.5), although the electricity demand levels in 2030 are similar in both scenarios. A generation mix that is less reliant on wind and solar PV has higher utilisation rates (less intermittency) and therefore requires less overall nameplate capacity. This results in substantial savings for the customer as well as higher confidence in the deliverability, with fewer planning issues, pylons and grid connections.

**Figure 3.4: Comparison of the 2030 power generation mix under different scenarios** (Nameplate capacity, GW)

\(\text{DECC: UK Solar PV strategy part 2, April 2014}\)
Figure 3.5: Comparison of power capacity mix from 2012 to 2030 between ‘Policy forecast’ and ‘Cost optimal’
Domestic energy efficiency

- The potential for loft insulation, cavity wall insulation and boiler replacements must be maximised.
- Most of the solid wall insulation potential is not cost-effective, so ambition should be limited before 2030.
- The smart meter roll-out should continue.

DECC has indicated its ambitions for insulation in its proposed ECO reforms and impact assessment. ECO will aim to deliver a total of 900,000 cavity wall insulation measures and 600,000 loft insulation measures for the period March 2013 to March 2017\(^{24}\), although more could be required to hit carbon targets if savings per install are lower than DECC expects. In addition, a 2017 minimum target has been set for solid wall insulation (SWI) at 100,000 installations.

This represents a scaling back of short-term ambition for SWI compared to the original ECO design. However, DECC appears to maintain its long-term aims for SWI, stating of the near 8 million solid walled houses that “it is clear that they must be tackled at some point”\(^{25}\).

**Loft and cavity wall insulation** represent very low-cost carbon abatement options (table 3.2) and are deployed at the same rate and scale in all scenarios. As many homes as possible should be upgraded by 2030, and this is aligned with the ‘policy forecast’ scenario. DECC’s own estimates indicate there are still almost 5.7m lofts with potential for more insulation, and almost 4m homes for cavity wall insulation (table 3.2). It is encouraging that the proposed updated ECO scheme now includes these measures.

<table>
<thead>
<tr>
<th>Technology</th>
<th>£/tCO2</th>
<th>Deployment potential (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>External Solid Wall Insulation</td>
<td>197</td>
<td>7.6</td>
</tr>
<tr>
<td>Internal Solid Wall Insulation</td>
<td>105</td>
<td></td>
</tr>
<tr>
<td>Loft Insulation (top-up)</td>
<td>39</td>
<td>5.7</td>
</tr>
<tr>
<td>Hard-to-treat Cavity Wall Insulation</td>
<td>49</td>
<td>3.1</td>
</tr>
<tr>
<td>Easy-to-treat Cavity Wall Insulation</td>
<td>13</td>
<td>0.8</td>
</tr>
</tbody>
</table>

Source: Estimated impacts of energy and climate change policies on energy prices and bills, DECC, March 2013
Modern boilers have an efficiency of around 90%, but there are still over 3 million old ‘G-rated’ boilers installed in the UK, which are less than 70% efficient. Upgrading these inefficient boilers for modern boilers, even before they are no longer operational, is a cost-effective source of emissions reductions. It is encouraging that boiler replacements are one of the most successful measures taken up through the Green Deal, but more could be done to increase awareness of the scheme to increase the rate of replacement.

Solid wall insulation (SWI) is far less cost-effective than other domestic energy efficiency measures and should be deprioritised. Indeed, this finding is aligned with the latest thinking from the Committee on Climate Change, after new evidence on cost-effectiveness led them to conclude that “much solid wall insulation is no longer cost-effective, potentially costing several hundred pounds per tonne of CO$_2$ abated, raising questions over desirability”\textsuperscript{26}. There are some exceptions where SWI may be cost-effective (for example, internal insulation in large off-gas-grid properties). However, the volume of cost-effective potential in the medium to long-term is considerably lower than the current policy ambition (see Analytical Appendix 1.5 for more details on policy ambition post ECO changes).

This discrepancy could be because in current policy the focus on SWI is about tackling fuel poverty rather than achieving cost-effective decarbonisation. If this is the case it is worth considering whether such measures should be funded from general taxation rather than from levies on the energy bill as this would be more progressive, and therefore more in keeping with the social objectives of such a scheme.

Smart meters become increasingly important in order to match supply and demand as more intermittent power generation comes onto the system, and peak power demand increases with the electrification of heating (e.g. through air source heat pumps). When combined with time-of-use tariffs and/or demand-response technologies, smart meters become an important tool to help shift electricity demand away from the peak period. This is supported by early indications from smart metering trials, which suggest consumers with smart meters and time-of-use tariffs reduced their peak electricity demand by an average of 9\%.\textsuperscript{27} Smart meters also offer additional low-cost carbon reduction as they can encourage individuals to adopt more energy-efficient behaviour and could reduce overall consumption by around 3\%.\textsuperscript{28}

\textsuperscript{26} CCC Fourth Carbon Budget Review – part 2 December 2013
\textsuperscript{27} Based on early findings from the Low Carbon Network Revolution project in which British Gas is a delivery partner.
\textsuperscript{28} DECC (2012) Smart meter roll-out for the domestic sector IA.
Renewable heating

- Renewable heating is cost-effective and current policy is under-ambitious.
- Air source heat pumps (ASHPs) and biomass boilers in the industrial and commercial sector offer the largest potential, followed by district heating.
- Domestic ASHPs and biomass boilers in off-gas-grid properties offer a smaller, but meaningful, opportunity.

Renewable heating covers a range of technologies that are capable of generating energy from renewable sources for space heating, hot water or industrial processes. This primarily includes biomass boilers, heat pumps and solar thermal technologies, which can be deployed either at an individual building level or across multiple buildings through the use of district heating pipe networks.

Non-domestic renewable heating provides the largest opportunity for cost-effective carbon abatement in renewable heating, and could meet around 16% of UK heat demand in 2030 (125TWh). The key technologies in this segment are ASHPs for commercial space heating and biomass boilers for industrial process heating.

ASHPs are now included in an expanded non-domestic RHI scheme with an incentive of 2.5p/kWh. Large biomass boilers currently receive 2p/kWh of RHI for each unit of renewable heat. Both these measures are very low-cost sources of renewable energy when compared to offshore wind, which will receive c.9.5p/kWh from 2014/15.

Figure 3.7: Comparison of renewable heat generation scenarios in 2020 (TWh)
District heating could account for 7% (or 56TWh) of UK heat demand by 2030, and appears a desirable measure across all our scenarios. However, it is only cost-effective to deploy in densely packed domestic and commercial premises, such as flats or city-centre developments. The cheapest low carbon heat sources are biomass boilers or connection to a source of waste heat (such as from an industrial process or a power plant).

Domestic renewable heat offers a smaller but meaningful opportunity for low-cost abatement, at around 3% of total UK heat by 2030. In this case, ASHPs are the most important technology, and are most cost-effectively deployed in either new-build homes or properties not connected to the gas grid. Across our scenarios, a minimum of 700,000 properties had ASHPs by 2030 but in some scenarios, such as ‘technology pessimist’, almost 1.5m were deployed. The UK government launched the domestic renewable heat incentive (RHI) scheme in April 2014 which pays domestic owners of ASHPs 7.5 p/kWh for 7 years.

In terms of total potential, DECC’s Renewable Energy Roadmap identifies around 52-72TWh of renewable heat in 2020\(^3\). This is around 8-12% of UK heat. Current levels are some 16TWh. However, renewable heating could play a much larger role in meeting the 2020 renewable target cost-effectively if barriers to deployment and use could be overcome. Over 100TWh of renewable heat could be delivered by 2020, (see figure 3.7). This result is remarkably consistent across the full range of scenarios examined.

In practice, delivering c.100TWh of renewable heat by 2020 could require: c.10% of industrial process heat to come from biomass; between 100,000 and 200,000 homes and businesses per year to connect to a district heating network; and between 50,000 and 250,000 non-domestic heat pump installations may be needed (depending on the average installation size).

Delivery of the 2020 renewable target will require high levels of renewables ambition in at least one sector of the economy. Since renewable heating is considerably more cost-effective than renewable power, it would be a sensible area in which to focus efforts.

**Transport**

- Strongly promote efficiency improvements in conventional cars.
- Consider promoting diesel-to-gas switching in the heavy goods vehicle fleet.

Transport makes up around 41% of the UK’s energy use\(^3\), at just over 600TWh. This generates around 30% of UK carbon emissions and so the sector cannot be ignored as a source of abatement potential.

Efficiency improvements in petrol and diesel cars can deliver substantial low-cost and early carbon abatement. Fleet fuel economy improvements from 41mpg to 73mpg by 2030 would save up to 22MtCO\(_2\) – this alone is equivalent to 4% of the UK’s CO\(_2\) emissions in 2012\(^3\). With appropriate incentives, taxes and tighter standards in place, this transition could be made easily. New efficient diesel cars purchased today can deliver 60-90mpg, and there are a number of smaller petrol cars available at around 70mpg, making a 73mpg 2030 fuel economy achievable with little need for technological advances.

Natural gas fuelling of heavy goods vehicles appeared consistently across our scenarios, in addition to improving efficiency standards, with some 500,000 vehicles switching from oil-based products to gas. Switching from diesel to gas generates a 25% carbon saving\(^3\), and under current oil and gas prices and tax regimes it would be economic to make the switch simply for financial reasons. However, there are currently constraints around refuelling infrastructure.
The role of natural gas

Natural gas will continue to play a major role in the UK energy system at least well into the 2030s (see figure 3.8).

• Natural gas is likely to continue to heat around 80% of **UK households** well into the 2030s, regardless of carbon target ambitions, although the overall gas requirements will reduce as energy-efficiency measures are installed.

• In the **industrial and commercial sectors**, more renewable technologies are likely to feature, such as biomass and heat pumps in larger businesses and public sector buildings. However, gas is still likely to make up a considerable proportion of heat demand in 2030.

• In the **power sector**, the amount of electricity generated from gas-fired power stations depends on the other technologies in the system. With a higher penetration of intermittent renewables, gas-fired power plants will be playing a back-up role. It should be remembered that in 2011, prior to the advent of cheaper imported coal, gas-fired generation amounted to nearly 50% of total electricity generation.

As **UK Continental Shelf** (UKCS) production declines, securing new international supplies of gas will be increasingly important and this will inevitably mean greater exposure to global commodity prices.

Figure 3.8: Forecasts for UK Gas demand in policy forecast and cost optimal (Bcf/d)
Indigenous onshore shale could play a useful role in offsetting the decline in UKCS production to some degree, and the environmental impact is potentially lower than that of LNG. However, it is unlikely that the North American experience – of significant falls in natural gas prices – will be replicated here. This is for a number of reasons: higher population density, a lack of a developed supply chain and the fact that private landowners do not participate in the mineral rights, are likely to slow development. In addition, well development and gas gathering costs are likely to be higher than the US.

‘Policy forecast’ does not appear to protect against commodity volatility.

One argument for delivering greater amounts of renewable generation is that it reduces exposure to high commodity prices – in effect insulating the UK consumer against international gas price increases. Under DECC base case commodity prices, ‘Policy forecast’ uses 22% less gas than the lowest-cost approach by 2030 (figure 3.8), largely because of the higher investment in low-carbon power generation, meaning gas-fired power generation is used less.

To test whether this investment paid off under high gas and oil prices, we simulated a shock change in commodity prices in 2025 from DECC’s central case to DECC’s high case. Despite the lower exposure to high gas prices, ‘policy forecast’ remained more expensive than ‘cost optimal’. This is because gas and oil remained dominant fuel sources by 2030 in both ‘policy forecast’ and ‘cost optimal’, and the expense of the policy forecast technology investments outweigh the savings they deliver when gas prices are high.

In addition, the ‘cost optimal’ approach was highly responsive to the sharp gas price increases by quickly reducing gas use in power generation and shifting to biomass, coal CCS, and by choosing to build more offshore wind after 2025. This response occurred only after the gas price shock, and led ‘cost optimal’ to use only 4% more gas than ‘policy forecast’ by 2030.
Chapter 4

targets

rationalising our targets
Carbon budgets offer a good framework for delivering emissions reductions. The UK is right to measure its progress in tackling climate change as total UK emissions over five-year periods (carbon budgets). This is because emission levels at shorter snapshots in time could be as much down to temporary factors such as the weather or the economy as to real policy impacts. Five year budgets enable policy-makers to focus on tackling the ‘structural’ drivers of greenhouse gas emissions.

The fourth carbon budget (covering 2023 to 2027) has provisionally been set at 1,950MtCO₂, equivalent to a c.50% reduction in greenhouse gas emissions compared to 1990 levels. In its 2013 review on the fourth carbon budget, the CCC indicated a potential fifth budget level of c.1,538MtCO₂. This is equivalent to a c.61% reduction in greenhouse gas emissions by 2030 compared with 1990 levels, and would imply an acceleration of decarbonisation beyond that necessary to meet the 2050 target. The 2030 energy system costs are highly sensitive to the level of the budget. This is because the fifth carbon budget period is a potential tipping point for the UK power system, as mentioned in chapter two.

A moderation in the ambition of the fifth carbon budget, to c.1,660MtCO₂, could reduce annual system costs in 2030 by some £2bn. Total savings could be as much as c.£10bn (cumulative). This carbon budget level would be consistent with a straight line in emissions reductions between the end of the fourth carbon budget and 2050, so there would be no back-loading of effort. Equally, it does not front-load effort (forcing earlier decarbonisation), which the CCC’s illustrative level appears to imply. This alternative 5th carbon budget level would be the equivalent of a c.57-58% reduction on 1990 levels by 2030.
Renewables deployment should be aligned to what is required to meet the carbon budgets.

Renewable energy has a major role to play in all pathways to the UK’s carbon targets. With carbon budgets alone, the UK will reach the renewables target – but slightly later than 2020 (see figure 4.1). Moderating the deployment of renewables such that the target is achieved in the mid-2020s, aligned with the carbon budget trajectory, could save the UK c.£17bn.

The UK has made progress in delivering the renewables target to date, but reaching it by 2020 will be challenging. Between 2008 and 2012, annual deployment rates of renewables averaged some 6TWh. Provisional data for 2013 suggests an increased renewables deployment rate of 12TWh, however this deployment rate will need to nearly double to c.20TWh a year to meet the target of delivering 15% of UK energy needs from renewables.

As well as the technical challenge of meeting this deployment trajectory, the focus on a sector-specific point-in-time target risks inflating supply chain costs and pushing overall costs up further.

While a slight delay in achieving the target would still signal a commitment to renewables consistent with carbon budgets, it could be argued to have a negative impact on confidence in the supply chain. Equally, though, delaying deployment might allow global economies of scale to reduce costs, which the UK could take advantage of – albeit at the possible expense of gaining an industry-leading position. There is some evidence that this is indeed happening in the solar industry. It is therefore not clear that forcing earlier large-scale deployment of certain technologies in the UK will necessarily result in a lower cost in the longer term.

Whatever the economic arguments, the UK cannot unilaterally change the target date, as it would be in breach of EU law by missing the 2020 deadline. This would probably initiate a legal process that could result in significant UK fines. However, the UK is not alone in finding the renewables target challenging. In March 2013 the European Commission published a report on member states’ progress. It warned that the outlook for 2020 was not optimistic: “In many member states currently implemented policies [...] risk being insufficient to trigger the required renewable energy deployment to reach the 2020 targets. [...] The financial crisis also affects these developments.” Discussions with other EU member states about the most appropriate timeframe for the target could therefore prove constructive.

The EU is currently debating a renewable energy target for 2030. Under current proposals an EU-wide renewables target would be imposed but there would be no national renewables targets. The UK government has previously stated a position resisting the implementation of future EU renewables targets: “We need a technology neutral approach to how individual countries meet their emissions targets. We want to maintain flexibility [...] A renewable energy target at an EU level is inflexible and unnecessary.”

This is borne out by our analysis, and the same economic reasoning applies to the 2020 renewables target.
A power sector carbon intensity target is unnecessary and adds cost.

A power sector carbon intensity target of 100gCO₂/kWh is likely to be unnecessary as there is a strong overlap with the fifth carbon budget. The fifth carbon budget largely sets the decarbonisation requirements of the power sector over the 2030 period, so it is unclear what an additional target would achieve. The main argument in favour of a CI target is that it is thought to encourage investor confidence. This is not borne out by discussions with investors, who are sceptical about the value of further targets. Industry groups such as the CBI have also questioned this, highlighting the importance of getting the right policy framework rather than additional targets.

A 50g target, as advocated by the CCC, forces a pathway that may not be needed (see figure 4.2), while adding up to £700m in 2030 annual costs.

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**Figure 4.1: Total UK renewable energy production (TWh)**

**Figure 4.2: Carbon intensity of the power sector under alternative fifth carbon budget scenarios (gCO₂/kWh)**

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42 E.g. widespread views given in evidence to the House of Commons Energy Bill committee http://www.parliamentlive.tv/Main/Player.aspx?meetingId=12322

Chapter 5

lowering costs and bills
Up to £96bn of the costs of decarbonisation could be avoided by 2030, without compromising the UK’s existing carbon budgets.

As described in the previous two chapters, we believe the UK could avoid up to £96bn of additional costs by investing in more cost-effective technologies and adopting a rationalised set of targets – but without compromising the UK’s existing carbon budgets or 2050 target. This represents an average of £2.5bn in avoided costs to British industry every year to 2030, while small businesses could be spared, on average, some £0.6bn a year. The average saving to households could be £2.4bn p.a. to 2030, or around £80 per household (see figure 5.1).

Figure 5.1 Savings in total energy system costs (£bn cumulative to 2030, real 2012)

How the additional costs break down by sector (£bn cumulative to 2030)

- Average of £2.5bn added cost to British businesses p.a.
- Average of £2.4bn added cost to households p.a.
- Average of £0.6bn added cost to SMEs
Under this approach, the cumulative costs of the energy system up to 2030 would still be some £51bn higher (£4bn higher in 2030 on a per annum basis), compared to a scenario with no targets or climate change policies – so decarbonisation will come at a cost. However, to put this in context, these additional costs represent just 2-3% of the total costs of the energy system in 2030, including fuel for transport and investment in infrastructure (from boilers and power stations to cars and power cables). We believe this is a price worth paying, given the significant costs and risks associated with climate change.

**Impact on household bills**

On the current trajectory, households could see their energy bills increase by some £180 by 2020 without energy-efficiency measures being taken into account (from 2012 levels, see figure 5.2). This is an increase of 15% in real terms, or 40% factoring in inflation, equivalent to a c.4.5% average price increase every year between now and 2020. However, bills need not rise as quickly as prices, because energy efficiency provides the most material way for consumers to mitigate this increase.

The continued uptake of energy efficiency measures between now and 2020 can help offset around £129 of bill increases (see figure 5.2).

A focus on more cost-effective measures could save customers an additional c.£10 in 2020, and adopting a rationalised set of targets could save a further c.£25. It is difficult to make substantial policy cost savings in the short term because most of the costs are the legacy of existing policy that are “locked in”. However, longer-term, our approach will lead to significantly more material bill savings – possibly greater than £100 p.a. by 2030 if the UK follows current policy forecasts.
These calculations are based on DECC cost assumptions. However, the reality may be that environmental policy costs are higher. For example, a recent study by CCC found that new evidence suggested solid wall insulation is significantly less cost-effective than previously thought, and our experience over the first 15 months of ECO aligns with this finding. Although DECC has recently reduced its near-term ambitions on this measure, it still forms a material component of the ECO scheme, meaning its cost estimates are at risk of being too low44.

The dual fuel price forecast masks a significant difference in policy impacts felt across gas and electricity. As an increasing proportion of the UK’s gas supplies are imported, costs will largely depend on global wholesale prices. However, there is a large opportunity for energy-efficiency savings in gas heating, which can more than offset the upward pressure on the gas bill.

In electricity, the primary driver for the increase is policy costs. This is a result of the current focus on the decarbonisation of the electricity sector, and the impact is large: a c.26% increase in real electricity prices by 2020 (compared to 7% for gas). The more limited opportunity for energy efficiency in electricity means this impact cannot be offset in the same way as it could in gas.

The impact of an electricity-biased policy approach on affordability is exacerbated for homes that use electricity, instead of gas, for heating. This poses a question of fairness, as the poorest in society are more likely to live in an electrically heated home than the richest45.

One way to address the disproportionate impacts on certain consumer groups would be to transfer all policy charges from the bill-payer to the taxpayer. This is because, unlike the tax system, energy bills take no account of the customer’s ability to pay.

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44 CCC: Fourth Carbon Budget review part 2: December 2013
45 English Housing Conditions Survey (2011) – 11% of lowest 20% income group have electrically heated homes, compared to 6% of the highest 20% income group.
Chapter 6

An alternative energy strategy for the UK
A more affordable, more adaptable alternative

**Affordability** must be at the heart of the UK’s energy strategy. Decarbonisation does come with costs, and public acceptance of these costs depends on them being minimised as much as possible.

In addition, the UK must set its energy strategy in the context of significant uncertainty, as described in chapter one. This means trying to define a precise, prescriptive pathway is challenging and could lead to a more expensive outcome. Therefore, the UK’s energy strategy must also ensure flexibility and adaptability in uncertain circumstances.

In practice this means:

1. **Prioritise the lowest-cost, least regret technologies**
   - Assess options to reduce emissions, focusing on deployment needs to 2030, and prioritise lowest-cost, least regret options.

2. **Set simple and cost-effective decarbonisation targets**
   - Emphasise carbon budgets, avoiding technology or sub-sector targets.

3. **Support those most impacted by the costs**
   - Put policies in place to minimise the burden on vulnerable customers and energy-intensive industries.

1. **Prioritise the lowest-cost, least regret technologies (with a focus on 2030)**

The UK must stay on course to deliver its 2050 target. A focus on the next two decades, combined with a vision for 2050, provides sufficient foresight for investors in large capital projects without locking us into a high-cost system too early.

We have developed a framework to help assess the various carbon abatement options available to the UK, and to identify the lowest-cost and least regret opportunities. This framework categorises technologies into three groups:

- a) Low-cost, least regret options
- b) Promising but currently uncertain options
- c) Uncompetitive or potentially high regret options

An illustration of how the measures could fit within the framework follows. For more information, see the analytical appendix.

a. **Identify, prioritise and maximise least regret carbon abatement measures**

A number of carbon abatement options appear consistently cost-effective under a wide range of scenarios. These are least regret opportunities and should be progressed now, not only because they are cost-effective, but also because they can be confidently regarded as necessary – despite the inherent uncertainties (see table 6.1).
b. Assess the currently uncertain options, and select and promote the more promising ones, as required

Policymakers will need to identify a number of less certain options to promote in order to ensure carbon budgets can be met (see figure 5.4). An independent and expert assessment of the most promising options should be made, based on cost expectations, scalability and the importance of the UK’s effort in bringing down costs. Each option comes with a different set of uncertainties or barriers. Policymakers must decide which of these options to pursue, as well as how and when to address the barriers – for example, with clear R&D priorities for the country (see table 6.2).

c. Deprioritise options that are uncompetitive and pose a high risk of regret in sunk costs

There are a number of options that appear uncompetitive prior to 2030 in a wide range of scenarios and could come with considerable lock-in risk if deployed too early. These options should be deprioritised by policymakers until their cost-effectiveness or need becomes clearer (see table 6.3).

2. Set simple and cost-effective decarbonisation targets

As outlined in the previous chapter, carbon budgets enable clear focus on the objective of reducing greenhouse gas emissions while also providing policymakers with sufficient flexibility to pursue the right mix of measures and technologies. In contrast, renewables targets force policymakers to adopt certain technologies over others, even if they are not the most cost-effective.

3. Support those most impacted by the costs

We have outlined how decarbonisation comes at a cost, even in a cost-effective approach. Vulnerable customers and energy-intensive industries are most likely to feel the impacts of these additional costs. Therefore, it is important that an affordable energy policy has clear measures to help mitigate this impact.
Table 6.1: Least regret carbon abatement options with illustration of scale and cost-effectiveness to 2030

<table>
<thead>
<tr>
<th>Measure</th>
<th>Sector</th>
<th>Scale in 2030</th>
<th>Carbon savings (MtCO₂ in 2030)</th>
<th>Cost (£/tCO₂)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Low</td>
<td>Mid</td>
</tr>
<tr>
<td>New nuclear</td>
<td>Power</td>
<td>3-8GW</td>
<td>11</td>
<td>24</td>
</tr>
<tr>
<td>Coal-to-gas switching</td>
<td>Power</td>
<td>c.20GW coal closures</td>
<td>37</td>
<td>49</td>
</tr>
<tr>
<td>Electrical product efficiency</td>
<td>Power</td>
<td>c.21TWh</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>Domestic heat pumps (core segments)</td>
<td>New build and large off gas grid homes</td>
<td>c.18-90TWh (700k-5m installs)</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Domestic gas boiler upgrades</td>
<td>On gas grid households</td>
<td>c.10-24m</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Loft and cavity wall insulation</td>
<td>Domestic properties</td>
<td>c.5m &amp; 3.5m installs respectively</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Domestic &amp; commercial district heating</td>
<td>New &amp; retrofit flats and city centres</td>
<td>c.30-50TWh (c.3-3.5m connections)</td>
<td>5</td>
<td>7</td>
</tr>
<tr>
<td>I&amp;C heat pumps</td>
<td>Non-domestic building space heat</td>
<td>c.70-120TWh</td>
<td>10</td>
<td>15</td>
</tr>
<tr>
<td>Industrial biomass</td>
<td>Industrial process heat</td>
<td>c.20-50TWh</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Fossil vehicle efficiency</td>
<td>Cars and vans</td>
<td>c.33-37M new cars</td>
<td>20</td>
<td>21</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>101</td>
<td>137</td>
</tr>
</tbody>
</table>

Note: at very high levels of deployment, some measures may not be least regret. We therefore consider the low to mid-range to be the scope of carbon abatement from least regret options.

*by 2030 all gas boilers should be upgraded to high efficiency systems. Therefore there are no additional savings to be made by replacing old boilers for new ones by this time.
Figure 6.4: The level of abatement achieved from least regret measures and the potential gap to 2030 that needs to be filled by other options (MtCO$_2$)

There is 137MtCO$_2$ of possible least regret opportunities to 2030 in the base case, and up to 185MtCO$_2$ in the high case.
<table>
<thead>
<tr>
<th>Measure</th>
<th>Sector</th>
<th>Scale (high)</th>
<th>Carbon savings (MtCO₂ in 2030)</th>
<th>Cost (£/tCO₂)</th>
<th>Uncertainty</th>
</tr>
</thead>
<tbody>
<tr>
<td>Onshore wind</td>
<td>Power</td>
<td>c.23GW</td>
<td>&lt;18</td>
<td>£0-170</td>
<td>What is the maximum acceptable deployment? Heavily contingent on fossil fuel prices</td>
</tr>
<tr>
<td>CCS</td>
<td>Power</td>
<td>c.20GW</td>
<td>&lt;113</td>
<td>£40-140</td>
<td>Will it be technically and commercially feasible? At what scale and cost?</td>
</tr>
<tr>
<td>Solid wall insulation (core segments)</td>
<td>Large off grid households</td>
<td>c.0.5m installs</td>
<td>&lt;1</td>
<td>£130-180</td>
<td>Will consumers be willing to retrofit their properties?</td>
</tr>
<tr>
<td>Offshore wind</td>
<td>Power</td>
<td>c. 25GW</td>
<td>29</td>
<td>£50-250</td>
<td>Heavily contingent on fuel prices and other technologies, such as CCS, remaining non-commercial</td>
</tr>
<tr>
<td>Maritime biofuels</td>
<td>Shipping</td>
<td>20Mboe p.a.</td>
<td>&lt;20</td>
<td>&lt;£0-10</td>
<td>Can enough biofuels be sourced sustainably and cost-effectively?</td>
</tr>
<tr>
<td>Gas HGVs</td>
<td>Heavy goods transport</td>
<td>c.70TWh c.0.5 M vehicles</td>
<td>&lt;9</td>
<td>&lt;£0-20</td>
<td>Can the infrastructure be put in place and businesses persuaded to adopt?</td>
</tr>
<tr>
<td>Electric vehicles</td>
<td>Private transport</td>
<td>19TWh c.7M vehicles</td>
<td>&lt;12</td>
<td>£100-400</td>
<td>Will electrification of transport be needed before 2030? Will significant power sector decarbonisation occur (leading to a drop in abatement costs)?</td>
</tr>
<tr>
<td>Bio jetfuels</td>
<td>Aviation</td>
<td>17-50mmboe</td>
<td>&lt;36</td>
<td>£0-10</td>
<td>Can enough biofuel be sourced sustainably?</td>
</tr>
</tbody>
</table>
Table 6.3: Uncompetitive technologies prior to 2030

<table>
<thead>
<tr>
<th>Measure</th>
<th>Sector</th>
<th>Scale</th>
<th>Carbon savings (MtCO₂ in 2030)</th>
<th>Cost (£/tCO₂)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solar PV</td>
<td>Power</td>
<td>23GW</td>
<td>9</td>
<td>£200-300</td>
<td>Not valuable to system as no generation during peak demand</td>
</tr>
<tr>
<td>Marine</td>
<td>Power</td>
<td>-</td>
<td>16</td>
<td>£100-300</td>
<td>Uncompetitive cost outlook to be deployed commercially</td>
</tr>
<tr>
<td>Biomass (non CCS)</td>
<td>Power</td>
<td>c.2GW</td>
<td>5</td>
<td>&gt;£300</td>
<td>Not a valuable use of limited biomass resources, especially by 2030 (i.e. low plant load factors and high relative abatement costs)</td>
</tr>
<tr>
<td>Solid wall insulation</td>
<td>On gas grid or smaller, newer properties</td>
<td>1.5m installs</td>
<td>2</td>
<td>&gt;£200</td>
<td>Most solid wall opportunities are not needed until after 2030 (significant cost variation across building sub-types)</td>
</tr>
<tr>
<td>Hydrogen bus/HGV</td>
<td>Transport</td>
<td>-</td>
<td>39</td>
<td>£0-100</td>
<td>High technology uncertainty (around both vehicle and hydrogen supply) and lock-in risk, given it may not be needed</td>
</tr>
</tbody>
</table>
Chapter 7

Policy to make it happen
In the previous chapter we set out a three part strategy for affordable and adaptable decarbonisation:

1. Prioritise the lowest-cost, least regret technologies,
2. Set simple and cost-effective decarbonisation targets,
3. Support those most impacted by the costs.

In this chapter we turn to what the implementation of such a strategy would look like.

It is clearly beyond the scope of this paper to set out detailed policy proposals across the energy sector, however some clear themes emerged from the modelling undertaken for this paper, which we have drawn on to provide practical guidance on an affordable and adaptable energy policy. The framework of energy policy has been fast-changing in the last decade or so, and will inevitably continue to evolve.

Prioritise the lowest-cost, least regret technologies (with a focus on 2030)

1. **Accelerate deployment of lower-cost domestic energy efficiency measures**

   As discussed in chapters three and five, the UK’s energy strategy should maximise the deployment of low-cost energy efficiency measures. The government’s Green Deal, which aims to enable a paid-for market for energy efficiency solutions, is a good vehicle for this. The underlying philosophy of the policy is sound, and by March 2014 around 190,000 customers had undertaken a Green Deal assessment.

   More generally, improving the energy efficiency of our homes can be a triple positive – helping to cut bills, improve energy security and cut emissions. However, policymakers should not lose sight of the cost of measures per tonne of carbon abated. Some efficiency measures have costs that run to several hundred pounds per tonne of carbon saved. Depending on how these are funded, they risk pushing up bills in an unjustifiable way and so should be deprioritised.

   Insofar as energy efficiency is delivered via an obligation placed on energy suppliers, a focus on cost-effective measures, with flexibility for suppliers to improve homes in the most efficient way possible is required. The inclusion of new technologies, such as smart enabled energy savings devices and remote heating controls, would also be helpful.

   The major challenge facing a paid-for market for energy efficiency remains demand. Incentives, such as the Green Deal Home Improvement Fund are welcome.
2. **Support greater business energy efficiency**

Opportunities for energy efficiency in the business sector have not received the same attention as those in the residential sector, as highlighted by the Carbon Trust and CBI. This needs to be addressed; firstly because energy-efficient businesses are more competitive, and secondly because of the importance of managing demand to reduce the costs of decarbonisation outlined in chapters one and three.

The current energy policy landscape for businesses is complex and overlapping (see figure 7.1). Businesses are paying a number of carbon taxes and although the cost is material, the price signal is often too weak to affect the majority of business investment decisions. Businesses respond better to incentives with a direct benefit, such as the RO, FITs and, potentially, demand-side response. Some of the tax receipts should be recycled back to business as incentives. In addition, the multiple reporting requirements businesses have to fulfil could be rationalised.

3. **Maintain momentum on the smart meter roll-out**

As highlighted in chapter three, smart meters offer a number of benefits to customers, the energy system, and efforts to tackle climate change. They enable the real-time transfer of information between customer and energy supplier, ensuring an end to estimated bills, faster switching between tariffs and suppliers, better customer service, and innovative new tariffs tailored to customers’ needs.

Increased use of smart meters can also help manage and reduce energy demand.

- Time-of-use tariffs help spread energy demand more evenly across the day or across the week, thus easing the stress on distribution networks, and balancing supply from intermittent renewable energy sources with demand.

- Data on customers’ consumption enables personalised energy efficiency advice, allowing customers to take greater control of their energy consumption and reducing overall demand.

Because of these potential benefits, the government has committed to ensuring every house has a smart meter by 2020. The government must ensure energy suppliers complete the roll-out as far as practically possible by 2020.
4. Retain support for renewable heat, with a few improvements

As seen in chapter three, renewable heat could be a sizeable and cost-effective source of carbon abatement and renewable energy potential, particularly for larger-scale installations such as non-domestic ASHP and biomass, and district heating. The Renewable Heat Incentive (RHI) is an important delivery tool for this purpose. However, the level and lack of certainty of the budget for the RHI risk limiting roll out.

The level of the budget needs to be sufficient for all cost-effective options to be delivered – this may mean it rising from £424m in 2014/15 to between £2-3bn in 2020/21. Greater budget foresight is also needed. Currently, developers have certainty neither of the total RHI budget beyond 2015/16 nor whether there will be any budget left for their project when it is complete. This undermines the ability to raise finance for such projects.
5. Promote and maintain a credible carbon price signal

Chapters three and five highlighted the potential carbon savings available in the near term by encouraging the shift from coal to gas power generation. An appropriate carbon price signal, such as through the CPF or the EU Emissions Trading System (EU ETS), can help enable this.

Ideally, the carbon price signal would be set on a pan-European basis through the EU ETS, but the scheme currently faces challenges (see box opposite). The UK government should push for reform of the EU ETS scheme to put it on a long-term sustainable footing. Until these challenges are addressed, the UK should maintain the Carbon Price Floor (CPF) to provide an effective carbon price signal to support decarbonisation.

6. Refocus power generation support

As outlined in chapter three, the costs of meeting the UK’s carbon targets could be reduced by refocusing the support for low-carbon power generation technologies.

CfDs potentially offer a solid framework within which low-carbon power generation projects can attract investment. However, policy should encourage the most cost-effective deployment mix as is practical. The UK government put forward a consultation in January 2014 with updated proposals for CfD allocation. Under these proposals CfD contracts will be allocated in auction rounds and first come first served allocation at fixed strike prices will no longer apply. In addition the CfD budget will now be divided between “established” and “less established” technologies, with the size of the budget for the more established technologies being set to ensure competition from the start of the CfD regime.

CCS appears to be a special case as it could have a profound impact on the energy system – not least because it can address emissions from industry as well as power. If CCS were available at scale, it could remove the need for large amounts of offshore wind. The viability and scalability of CCS needs to be established as a priority. The UK government is supporting the development of commercial scale CCS by making £1bn capital funding available through its current UK CCS Commercialisation Competition. The government has recently signed contracts to develop the next stages of two CCS projects – the Peterhead CCS project in Aberdeenshire and the White Rose CCS project in Yorkshire. Policymakers should continue to pursue these CCS demonstration projects but also consider whether current R&D spend is adequate, given the potential “game-changing” importance of CCS (see next recommendation).

Our analysis shows a need for gas-fired generation but there is significant uncertainty as to the load factor (usage), in part because it is uncertain how much and what type of less flexible low carbon generation will be built. A capacity mechanism is a sensible policy response to overcome this.
The current market structure is not encouraging new investment despite warnings on the security of electricity supply in the next few years. A capacity mechanism increases the prospect that investors will be able to recover the capital costs of building new plants and should in theory address the current lack of investment. The success of all new low carbon generation investment is dependent on the government of the day acknowledging that higher charges from consumers will be required to fund capacity payments.

7. **Accelerate investment in energy R&D to deliver the next generation of energy technologies**

Chapters one and three illustrated how technology developments, or the lack of them, could impact the costs of decarbonisation. Despite being more focused on low-carbon technologies than ever before, UK energy R&D levels are still low compared to other developed countries and historic levels *(see figure 7.2)*. The need for an energy R&D strategy is clear and we would propose directing some of the savings from a revised UK energy strategy to R&D.

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**The EU Emissions Trading System**

The EU Emissions Trading System (EU ETS) is a pan-European market created to enable reductions in carbon emissions. Policymakers set the total allowable carbon emissions within the EU ETS. In theory, these levels are set to create sufficient scarcity to drive an appropriate carbon price. Participants in the scheme must buy permits to cover their emissions from the carbon market, so have an incentive to reduce them (and avoid this cost). The price of these permits (carbon price) is likely to settle at the level at which it is more cost-effective to pay and buy permits than to reduce emissions. Unfortunately, a number of flaws in the original design, combined with the economic downturn reducing the EU’s emissions and depressing the price, mean the price signal is currently very weak and ineffective. As a short term solution to the oversupply of permits, a “backloading” scheme has been implemented which will withhold permits until 2019/2020.

This however is only a temporary solution. A sustainable solution to the imbalance between supply and demand requires structural changes to the EU ETS scheme. As part of the EU 2030 package, the European Commission has proposed to establish a market stability reserve for the ETS in 2021.

The EU ETS is a pan-European market created to enable reductions in carbon emissions. Policymakers set the total allowable carbon emissions within the EU ETS. In theory, these levels are set to create sufficient scarcity to drive an appropriate carbon price. Participants in the scheme must buy permits to cover their emissions from the carbon market, so have an incentive to reduce them (and avoid this cost). The price of these permits (carbon price) is likely to settle at the level at which it is more cost-effective to pay and buy permits than to reduce emissions. Unfortunately, a number of flaws in the original design, combined with the economic downturn reducing the EU’s emissions and depressing the price, mean the price signal is currently very weak and ineffective. As a short term solution to the oversupply of permits, a “backloading” scheme has been implemented which will withhold permits until 2019/2020.
Naturally this increased R&D spend should be targeted at priority technologies to maximise the value of the investment. We identify CCS as a clear priority for the power sector. In domestic heating, there are a number of promising technologies under development that could replace the gas boiler with a lower-carbon alternative. These include gas and electric heat pumps, hybrid boilers, district heating and Micro CHP.

8. **Support low-regret decarbonisation in the transport sector**: there are a number of cost-effective low-regret options in the transport sector. It is important these are fully pursued to avoid an undue cost burden on any one sector.

- **Ensure tighter efficiency standards in new cars and vans**: a significant increase in the average fuel economy of the UK’s car and van fleet could constitute one of the largest contributors to carbon emission reductions by 2030. High-efficiency diesel and petrol cars exist today, and their adoption is a priority.

- **Recognise and support the use of gas in heavy goods vehicles**: gas emits around 25% less carbon than diesel. Gas-fuelled trucks are already commercially available, as well as conversion kits for existing diesel trucks. Support for infrastructure requirements could accelerate adoption.

9. **Maintain recognition of natural gas given its continued importance**: almost all studies of the UK’s energy sector agree that natural gas will continue to play an important role in an affordable strategy. The UK should continue to maximise indigenous sources and seek out more import opportunities in order to maintain security of supply.

- **Maximise indigenous sources**: the UK still has strong indigenous resources, with up to 24 billion barrels of oil equivalent remaining to be produced from the UK Continental Shelf. Recovery of this depends on successful exploration and the right regime for the North Sea. The steps the government is taking to encourage the development of UK shale are welcome and should be continued. The recently announced review of the fiscal regime in the North Sea is also welcome and potentially very important.

- **Support import opportunities**: imports will make up an increasing proportion of the UK energy mix, often supported by long-term contracts with exporting countries. The government should look to ensure a stable economic and regulatory climate, to give counterparties confidence that they will be paid when they sign up to contracts with UK energy suppliers. A clear focus on securing an EU-USA free trade agreement is also vital.

- **Ensure that gas storage is adequate**: the UK has diverse sources of natural gas supplies and significant, but declining indigenous production. However, additional storage capacity will be needed. National Grid has forecast a requirement for almost twice the current levels by 2019\(^47\), and the geopolitical complexity of accessing gas supplies is increasing. Therefore, the government should keep under review the need for additional UK gas storage, particularly as ageing UK facilities require refurbishment.
Figure 7.2: UK energy R&D spend is lower than many countries... % of GDP, 2011

...and low in comparison with historic levels % of GDP, 2011

However, low carbon now dominates energy R&D £m (2011)

Set simple and cost-effective decarbonisation targets

10. Maintain the proposed fourth carbon budget and adopt a cost-effective fifth
Maintain the indicative fourth carbon budget level, on the provision that the EU follows a similar level of ambition. Adopt a fifth carbon budget consistent with a straight-line reduction in emissions to 2050.

11. Deploy renewables consistent with carbon budget requirements
Seek to align the deployment of renewables to that required to meet our carbon budgets, hitting our 15% target by around 2025. This will likely require negotiations at an EU level.

12. Resist a carbon intensity and 2030 renewables target
Focus on the policy landscape and setting the right fifth carbon budget rather than setting unnecessary additional targets, which risk additional costs and restricted flexibility.

Support those most impacted by the costs

13. Ensure supplier obligations focus on cost effectiveness
Energy efficiency obligations placed on suppliers have delivered significant results, but over time these have become increasingly complex and administratively burdensome.

Obligations funded through energy bills are paid for by all customers, including those on low incomes. To avoid socially regressive outcomes, we believe that the benefits of these obligations should be restricted to low income households.

A separate “able to pay” market should be developed with incentives to drive demand funded through general taxation (the Green Deal could provide the basis for this).

14. Better target the Winter Fuel Payment to ensure it goes to those who need it most
Existing support for vulnerable customers could be better targeted to maximise the impact. The Winter Fuel Payment (WFP) is currently valued at £2.2bn, and distributed tax-free to 12.6m claimants over 65. However, 90% of recipients are not fuel-poor.

If, for example, the WFP was targeted at fuel-poor households, it would amount to a £650 cash payment per household – greater than the average fuel-poverty gap of £438 (using the Low Income High Costs framework). Alternatively, better targeting would also enable the WFP to be paid not just to vulnerable pensioners but also to other vulnerable groups such as the disabled or terminally ill.

15. Adequately support energy intensive industries
If UK energy prices put energy-intensive industries at a significant and sustained competitive disadvantage, these industries will simply move overseas to a more benign price environment, and continue to emit carbon. This will lead to a UK economic disadvantage with no reduction in global emissions. Therefore, appropriate policies need to remain in place to support the energy-intensive sector. It is encouraging to see that the budget 2014 contained a number of packages to this effect.
16. Fund decarbonisation in a fairer way

The current approach of funding decarbonisation (and some fuel poverty measures) through energy bills unduly exposes vulnerable customers and the lower paid to higher costs. This conclusion was also reached by the Energy and Climate Change Select Committee, which identified that the increasing use of levies on bills is likely to hit hardest those least able to pay\(^5\). Without action this issue is set to get worse. The average bill levy will stand at £150 per household by 2020. Most of the costs will fall on electricity bills, disproportionately impacting the lower-income groups in society (see chapter five).

Furthermore, with policy costs levied on bills, energy-intensive industries are exposed to the rising costs too. As highlighted above, it is right to protect those industries for which rising policy costs would undermine international competitiveness, because it would be highly counterproductive if production of these goods – and the associated carbon emissions – moved abroad.

Shifting the costs of decarbonisation from the energy bill to public funding was noted by the Energy and Climate Change Select Committee to be a less regressive way of funding decarbonisation. Changing who pays for decarbonisation would help to ensure that the cost is borne by those who are able to pay, protecting households and industries most at risk of rising energy prices.

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The way forward

This report outlines our methodology, analysis and policy proposals. However, it is not intended to provide an answer, but to stimulate an informed and rational conversation about the future of the UK’s energy policy. It offers guiding principles to underpin policymaking – that of a ‘lowest-cost, least regret’ approach, and suggestions for how to implement that in practice.

Over the next few years we have a collective responsibility to ensure the UK’s sustainability and security obligations are met affordably. We hope the findings in this report help contribute to achieving that goal.

Analytical appendix
1. Analytical appendix

1.1 General methodology
The analytical approach for this study is based on Redpoint’s Energy System Optimisation Model (RESOM). This is a lowest-cost optimisation framework, similar in a number of respects to the basic MARKAL/TIMES framework or the ETI’s Energy System Modelling Environment (ESME) model.

It has been used primarily to understand the trade-offs between sectors and energy technology options as part of meeting the UK’s renewable energy and climate change targets, over the period to 2050. The model has been applied to a range of studies, including for:

- DECC (2012) and the CCC (2012), to inform their bioenergy strategy and review, respectively, with significant CCC input into the design of the model
- National Grid (2012) to inform its thinking around long-term heat decarbonisation
- DECC (2013) to help inform its low-carbon heat strategy.

The background to RESOM is discussed in more detail in the above reports.

Conceptually, the model is focused on optimising a complex set of technology and energy choices in five-year steps over the pathway to 2050, across the entire UK energy system from a ‘societal resource cost’ perspective. This covers choices across power, buildings, industry, transport and other conversion. To ensure that all future energy service demands and other constraints are met (accounting for annual, seasonal, within-day and peak-day supply-demand balancing), the model effectively decides:

- what resources to use
- what technologies to build (and when)
- how to operate this stock of technologies over time.

Other constraints include the Greenhouse Gas (GHG) emissions and Renewable Energy Directive (RED) targets, resource availability limits, security of supply, and technology build constraints.

The process of cost-optimisation effectively allows all possible trade-offs of technologies, their utilisation, and use of resources, over all time periods on the pathway to 2050, to be resolved simultaneously.

RESOM is designed to aid scenario analysis, particularly over the medium and longer term, rather than trying to establish short-term projections. It helps to provide an ‘engineering-style’ view of how the energy system should evolve to meet its targets in the lowest-cost manner. The wider policy environment would then be tailored to try to achieve this, subject to wider considerations that are harder to model endogenously, such as the role of R&D or supply chain development in bringing down costs.


53 http://www.eti.co.uk/technology_strategy/energy_systems_modelling_environment/

54 https://www.gov.uk/government/publications/uk-bioenergy-strategy

55 http://www.theccc.org.uk/publication/bioenergy-review/


58 Including the various RED accounting rules within the optimisation.
Cost-optimisation is fundamentally different from other modelling approaches such as macro-economic, econometric or agent-based models, which explore price-based impacts more (for example, on how investor behaviour responds to subsidy support in the near term).

As a result, the model has a relatively abstract representation of existing policy. It is focused primarily on meeting both the absolute GHG and RED targets in an optimal manner, and not the likely impact of incentive policies or subsidies such as the Renewable Heat Incentive (RHI) or Renewables Obligation (RO) on deployment of renewables, or the Green Deal in the uptake of energy-efficiency measures.

Calibration has, however, been undertaken in the relatively near term to impose minimum levels of new build in key sectors such as power, which are expected to be brought forward from the results of current policy support (e.g. the Renewables Obligation and Contracts for Difference).

1.2 Assumptions table

An overarching principle for this analysis has been to maintain consistency with published government data for key input assumptions, based on either those used in the aforementioned studies or more recent updates where available.

Our key assumptions are summarised in the table opposite.
<table>
<thead>
<tr>
<th>Area</th>
<th>Data</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Targets</td>
<td>GHG target</td>
<td>DECC carbon budgets to 2027 and fixed % decline from this to the 80% by 2050 target (CCC estimates for share of non-CO₂ GHGs which are outside of model scope). NB compared to the earlier DECC (2013) study the scope of energy/emissions has been expanded to include all CO₂ – including industrial process emissions</td>
</tr>
<tr>
<td>RED target</td>
<td>As earlier National Grid (2012)/DECC (2013) studies, 15% share in final energy consumption, 10% renewables in road transport, contribution based on underlying RED accounting rules</td>
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<tr>
<td>Demands</td>
<td>Energy service demands for domestic and non-domestic building heat, industry, transport and other electricity</td>
<td>As per DECC (2013) above, broadly calibrated to equivalent “Level 2/3 ranges” in the DECC 2050 pathways calculator[^60]</td>
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<tr>
<td>Resources</td>
<td>Fossil fuel prices</td>
<td>DECC Updated Energy Projections July 2013 (high, central, low cases)</td>
</tr>
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<td></td>
<td>Biomass</td>
<td>As per DECC Core Resource Scenario from DECC (2012) Equivalent to c.16% maximum share in primary energy by 2050, high (22% or unlimited imports) and low (10%) cases informed by CCC (2012) bioenergy review</td>
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<tr>
<td></td>
<td>Other conversion (bioenergy, hydrogen, etc)</td>
<td>As per earlier National Grid (2012)/DECC (2013) studies</td>
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<td></td>
<td>Transport</td>
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</table>
1.3 Summary of scenarios

A large number of scenarios and sensitivities were explored to support the analysis in the main body of the report. The most important are summarised in the table opposite.

It should be noted that the majority of the sensitivities were explored using the default RESOM model approach (i.e. a perfect foresight optimisation of the full pathway to 2050). However, for the ‘commodity shocks’ and ‘breakthrough’ sensitivities a two-stage process was applied.

• The model was first run to 2050 in perfect foresight mode under standard assumptions (i.e. without the price shock or technology breakthrough).

• The technology results up to the period of the shock (e.g. 2025) were then fixed and the remaining periods (e.g. 2030 to 2050) run with the shock in place.

This approach allowed us to understand the extent to which a pathway that has been optimised under a pre-supposed set of long-term conditions (e.g. continuing moderate fossil fuel prices) can adapt when these conditions change part through the pathway – for example, the extent to which system costs and technology costs are or can be altered given earlier infrastructure lock-in.
Table 2: Overview of key scenarios and sensitivities

<table>
<thead>
<tr>
<th>Group</th>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0) Core</td>
<td>COST OPTIMAL</td>
<td>Cost-optimised pathway with core publicly available “central” assumptions on key technology, fuel price, resource availability and demand data</td>
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<td></td>
<td>POLICY FORECAST</td>
<td>As per above but with higher forced minimum build quantities to 2025/2030 for • Renewables (on/offshore wind, solar, tidal, biomass, hydro), CCGT, nuclear, CCS as per the DECC EMR delivery plan • SWI – Energy bills analysis is aligned with current ECO proposals of a minimum of 100,000 installs by 2017, rising to lower end of Carbon Plan target by 2030 (see section 1.5 for more details)</td>
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<td></td>
<td>TECHNOLOGY PESSIMIST</td>
<td>As per COST OPTIMAL, but constraining • Maximum onshore wind to 15 GW (cf 30) and nuclear to 25 GW (cf 39) • No CCS before 2030 and no new nuclear before 2025 • Bioenergy availability by 2050 a maximum of 10% primary energy demand • 2020 RED target optional</td>
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<td></td>
<td>TECHNOLOGY PESSIMIST + LOWER FIFTH CARBON BUDGET</td>
<td>As per TECHNOLOGY PESSIMIST but constraining • Linear (less rapid) reduction in emissions from end of carbon budget 4 (CB4) to 2050 target</td>
</tr>
<tr>
<td>1) Counterfactuals</td>
<td>NO TARGETS</td>
<td>As per COST OPTIMAL but with no RED or GHG targets</td>
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<tr>
<td>2) Biomass sensitivities</td>
<td>PLENTIFUL BIOMASS</td>
<td>As per COST OPTIMAL but with unlimited biomass import availability</td>
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<td></td>
<td>LIMITED BIOMASS</td>
<td>As per COST OPTIMAL but with maximum bioenergy availability (both imports/domestic) constrained to c.10% of primary energy demand by 2050</td>
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<tr>
<td>3) Innovation importance</td>
<td>MATURE TECHNOLOGY ONLY</td>
<td>As per COST OPTIMAL but with no new CCS in all sectors, Bio-H2 gasification, SMR (Steam Methane Reforming), Distributed SMR, Electrolyser, Hybrid gas boiler, GASHP (heat pumps), Fuel cell CHP (combined heat and power), Tidal and Wave</td>
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<td></td>
<td>NO TECHNOLOGY COST REDuctions</td>
<td>As per COST OPTIMAL but with costs remain as per their 2015 or First of a Kind values</td>
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<tr>
<td>Group</td>
<td>Name</td>
<td>Description</td>
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<td>4) Commodity</td>
<td>GasOilUp-2025</td>
<td>As per COST OPTIMAL, but with commodity costs jumping from DECC central to DECC high in the year 2025</td>
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<tr>
<td></td>
<td>DECC-GasOilUp-2025</td>
<td>As per POLICY FORECAST, but with commodity costs jumping from DECC central to DECC high in the year 2025</td>
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<td>GasOilDown-2025</td>
<td>As per COST OPTIMAL, but with commodity costs jumping from DECC central to DECC low in the year 2025</td>
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<tr>
<td></td>
<td>DECC-GasOilDown-2025</td>
<td>As per POLICY FORECAST, but with commodity costs jumping from DECC central to DECC low in the year 2025</td>
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<td></td>
<td>HIGH GAS AND OIL PRICES</td>
<td>As per COST OPTIMAL, but using DECC’s UEP 2013 high gas and oil prices estimates</td>
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<tr>
<td></td>
<td>LOW GAS AND OIL PRICES</td>
<td>As per COST OPTIMAL, but using DECC’s UEP 2013 low gas and oil prices estimates</td>
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<tr>
<td>5) Target evaluation</td>
<td>NoRED</td>
<td>As per COST OPTIMAL, but with no 2020 RED target</td>
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<td></td>
<td>MODERATE FIFTH CARBON BUDGET</td>
<td>As per NoRED, but with a linear emissions glide path from the end of CB4 to 2050</td>
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<td></td>
<td>MODERATE FOURTH CARBON BUDGET</td>
<td>As per MODERATE FIFTH CARBON BUDGET, but with an increase of c.9% in the available CB4 per annum budget</td>
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<tr>
<td></td>
<td>COST OPTIMAL + 50g 2030 CARBON INTENSITY</td>
<td>As per COST OPTIMAL, but with a 50g/kWh carbon intensity target in the power sector from 2030 onwards</td>
</tr>
</tbody>
</table>
1.4 Categorisation of abatement measures

We have used sensitivity analysis to assess which measures are cost-effective across a wide range of future outcomes, based on 30 carefully selected ‘edge case’ scenarios.

The tables in chapter five provide an illustration, for each key abatement option, of both the scale of savings and the range of plausible abatement costs. It is important to note that whilst the range of abatement costs helps to provide context, it cannot by itself lead to a simple ranking of options.

- The cost range is driven by both the cost of the option itself and the cost of the counterfactual option it is being compared against.
- The system in 2030 still reflects legacy choices from 2020, driven primarily to meet the RED rather than to meet the carbon budgets. The year 2030 is also a transition point beyond which rapid change (e.g. electricity system decarbonisation) can take place, which indirectly affects the longer-term abatement costs of other measures such as electric heat pumps or electric vehicles.
- The system also ultimately needs to meet the demands for heat, transport and other electricity services and satisfy other constraints around security of supply. It is more appropriate to compare ‘broadly substitutable’ options.
- A wide variation in costs can exist within each high-level option presented (for example, energy efficiency and low-carbon heat supply options for different domestic building types).

The carbon saving values ultimately reflect the range in deployment of these technologies across the scenarios considered, implicitly reflecting their contribution to a lowest-cost solution for the energy system.

To attempt to prioritise the different options for abatement in the near to medium term, we first created a ‘waterfall-style’ chart of their individual impact on CO₂ emissions, by sector between 2015 and 2030, based on the model results for a given scenario.

- Each sector’s demand in 2030 is first compared to the demand and emissions intensity by sector in 2015; a change in demand between these years leads to a change in emissions using the average 2015 intensity.
- The emission intensity and outputs for each technology option in 2015 are then contrasted with their values in 2030 to determine the saving for each waterfall step. Where a low-carbon option declines between the two periods (e.g. retirement of existing nuclear as opposed to new nuclear) it is assumed that this leads to replacement by a fossil counterfactual and an increase in emissions on the waterfall.

The ‘cost optimal’ scenario forms the basis of the central steps on the waterfall. However, it is important to consider the range of uncertainty around each step within a ‘cost optimal’ solution when the wider scenario assumptions are changed. To this end we have run a further set of 30 edge case scenarios (in addition to those sensitivities described in 1.3), combining high and low values for a number of key input assumptions. We have then taken the maximum/minimum CO₂ saving seen across these scenarios for each step on the waterfall.
For flexible technologies, such as biomass power generation, the abatement costs also reflect the utilisation of the technology from within the scenario, rather than a stylised maximum availability (which can make the abatement costs appear artificially low).

The assessment of uncertainty has focused on two key groups of assumptions:

- **Key overarching drivers of technology deployment**
  - Fossil fuel prices (gas, oil, coal) – DECC UEP July 2013 – all high and all low
  - Demand (building heat, industry, transport) all either +/- c.15% by 2050
  - Bioenergy availability – max of 22% primary energy by 2050, min of 10%.

- **Technology costs**
  - Power sector costs for nuclear, CCS (including non-power) and wind (both on/offshore) – high-low from latest DECC generation cost update
  - End-use sector costs for electric heat pumps, district heat networks, electric road vehicles, hydrogen road vehicles. – high-low informed by range of data supporting the DECC-2050 calculator.

To make sure the number of edge cases is manageable we have explored all high and low combinations of the three key overarching drivers, but within these focused on the relative cost competition between electric and non-electric end-uses, when the conditions are more or less favourable for low-carbon power.

For example, we have examined high-electric heat pump costs and low-heat network costs (and vice versa) when low-carbon power costs are both high and low. We have also explored one further subset of conditions to understand the impact of lower wind costs versus high nuclear and CCS costs (again with the different permutations of the overarching drivers).

It is important to note that the edge cases do not cover all possible permutations; nor do the high and low values represent the absolute maximum or minimum possible. The aim is to help represent a wider plausible spectrum of energy system conditions, within which we can better understand the possible contribution from each technology option.

Abatement costs (in £/tCO₂) for each option are also calculated across the edge cases, by comparing their levelised cost and emissions relative to the counterfactuals mentioned above. These are intended to illustrate the range of uncertainty around the costs of abatement, rather than to inform a direct ranking. This is because the abatement costs can change significantly across different scenarios, both as a result of the cost of the option and the cost of the counterfactual (owing to changing fossil fuel prices, for example).

The edge cases are summarised in table 3 opposite.

Using the uncertainty ranges from the edge case analysis alongside the main ‘cost optimal’ scenario results we can begin to categorise each of the main options in the period up to 2030:

- **least regret** – measures with tangible CO₂ savings under the core scenario and limited uncertainty around this (at least up to a de minimis level of deployment)

- **promising but uncertain** – measures with high potential upside saving, but still with significant uncertainty around the minimum level of cost-effective deployment in the medium term (potentially even zero)

- **uncertain or high regret** – measures likely to lead to no savings (or even an increase in emissions under some conditions) or lock us into potentially inappropriate infrastructure by 2030, and with high uncertainty around this role.
Table 3: Overview of ‘edge cases’ explored (H = High cost/availability, L = Low, C = Central)

<table>
<thead>
<tr>
<th>ID</th>
<th>Fuel prices</th>
<th>Demand</th>
<th>Bioenergy availability</th>
<th>Nuclear</th>
<th>CCS</th>
<th>Wind</th>
<th>Electric Heat Pumps</th>
<th>District Heat Networks</th>
<th>Electric Vehicles</th>
<th>Hydrogen Vehicles</th>
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While this categorisation is still ultimately subjective, the analysis is intended to spur further debate about where these options fall, simultaneously considering other important factors (such as maturation of the supply chain) that are outside the direct scope of the modelling. Ideally, meeting the carbon budgets over the near term would focus first on the least regret options, before moving to those that are promising but uncertain.

1.5 Post Script on the timing of this analysis

The RESOM analysis described above, and presented in this report, was conducted in Summer 2013. Since this time there have been a number of policy changes and newly published data. Whilst the bills analysis described in Chapter 5 of this report has been updated accordingly, the overall system costs calculated in RESOM are less sensitive to these, and, following a series of checks, we concluded that the numerical analysis was still valid.

In particular the following areas of change were examined:

- **SWI:** The short term deployment of SWI will likely be lower as a result of proposed reforms to the ECO scheme. However the government has not made any public statements revising long term ambitions for SWI installations. We have therefore assumed deployment would still be in line with the UK government’s Carbon Plan report (see Figure A1 and box opposite) in our ‘policy forecast’ scenario.

- **Power generation capacity mix:** The government’s view of the future power sector capacity mix was updated in the EMR Final delivery plan document. However, a comparison of the capacity and generation mixes presented in the Draft and Final delivery plans for the 100g case (used for the ‘policy forecast’ scenario) suggested that the differences would not be material compared with the results presented in this report.

- **Demand:** Updated DECC UEP projections published in October 2013 showed higher domestic demand relative to the previous DECC UEP projections, while Service and Industry demands were lower. The net effect of this is relatively small in terms of differences in total system costs between our scenarios.

- **Heat Pumps:** In their review of the fourth carbon budget, the Committee on Climate Change reduced deployment of heat pumps in their updated scenario due to new evidence on capital costs, performance and durability. Whilst making similar changes in RESOM would correspondingly reduce deployment, again the impact on differences in total system costs between scenarios is relatively small.

Our conclusion was that, whilst there would be some changes to deployment levels for particular technologies in light of these changes, the impact on the total system cost differences presented for the scenarios would be small, and the key messages would remain unchanged. The numbers from the Summer 2013 RESOM modelling presented in this report have therefore been left unchanged.
Prior to the March 2014 changes to ECO that proposed a reduction in the near term ambition of SWI, the Carbon Plan 2011 outlined DECC ambition for this measure. At that point, DECC expected a roll-out of 1.5m SWI measures during the first 3 carbon budgets. An illustrative range of the potential for an additional 1.5-3.7m SWI installs to be rolled out by 2030 was also detailed. Although DECC have not been explicit about their latest ambitions for SWI post 2017 following their ECO proposals, it is clear that the short term ambition has been significantly reduced compared to the Carbon Plan. DECC do suggest that their long term goal remains “aligned with the Carbon Plan”, and so in ‘policy forecast’ we have prudently assumed c.1.5m SWIs by 2030. Any roll-out plan significantly higher than this would increase the costs of ‘policy forecast’, owing to the high costs associated with this measure.

Figure A1: Roll-out profiles of solid wall insulation, comparing policy forecast, cost optimal and DECC’s original roll-out ambitions as stated in the Carbon Plan 2011
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