HM Government

The Clean Growth Strategy

Leading the way to a low carbon future

Building our Industrial Strategy

The Clean Growth Strategy
Leading the way to a low carbon future

Presented to Parliament pursuant to Sections 12 and 14 of the Climate Change Act 2008

Amended April 2018 from the version laid before Parliament in October 2017

October 2017

The Clean Growth Strategy can be found on the BEIS section of GOV.UK:

https://www.gov.uk/government/publications/clean-growth-strategy

© Crown copyright 2017

You may re-use this information (not including logos) free of charge in any format or medium, under the terms of the Open Government Licence.

To view this licence, visit www.nationalarchives.gov.uk/doc/open-government-licence/ or write to the Information Policy Team, The National Archives, Kew, London TW9 4DU, or email: psi@nationalarchives.gsi.gov.uk.

Any enquiries regarding this publication should be sent to us at CleanGrowthStrategy@beis.gov.uk.

Amendments to the version laid before Parliament in October 2017

The following corrections have been made:

p122, p142: The unit label for the metric “Biodegradable waste sent to landfill” has been corrected to read “Million Tonnes”.

p156: The text “(in real 2016 prices)” has been removed.

p156: Three values in table 11 have been corrected.

A few other minor typographic errors have also been corrected.

Contents

Executive Summary **5**

Key Policies and Proposals in the Strategy 12

Chapter 1: UK Leadership and Progress **20**

Chapter 2: The Opportunities and Challenges **30**

Chapter 3: Our Clean Growth Strategy **46**

Chapter 4: Sectors **60**

Improving Business and Industry Efficiency and Supporting Clean Growth 61

Improving Our Homes 72

Accelerating the Shift to Low Carbon Transport 83

Delivering Clean, Smart, Flexible Power 93

Enhancing the Benefits and Value of Our Natural Resources 102

Leading in the Public Sector 113

Chapter 5: Next Steps **120**

Annexes **124**

Foreword from the Prime Minister

10 DOWNING STREET
LONDON SW1A 2AA

This Government is determined to leave our natural environment in a better condition than we found it. Clean growth is not an option, but a duty we owe to the next generation, and economic growth has to go hand-in-hand with greater protection for our forests and beaches, clean air and places of outstanding natural beauty.

There is no conflict between this aspiration and our plan to create an economy that works for everyone. But to do this we need a clear strategy that brings Government, business and society together. This Strategy sets out the action we will take to cut emissions, increase efficiency, and help lower the amount consumers and businesses spend on energy across the country.

The United Kingdom has a proud record in this field. Britain was one of the first countries to recognise the challenge posed by climate change and we have led the world in taking action to reduce carbon emissions. Our investment in green energy has seen Britain produce record amounts of renewably-generated electricity. On the world stage, we were instrumental in driving through the landmark Paris Agreement.

Protecting our environment for the next generation also benefits our wider economic prosperity. The UK has helped new green industries to develop which have brought jobs and growth, even as we have taken decisive action to protect the world around us.

In this document, we set out the actions we are taking to put clean growth at the centre of our modern Industrial Strategy: changing the way we heat our homes, power our cars, and run our electricity grid. But we cannot achieve this through Government action alone. We must harness the ingenuity and determination of all our people and businesses across the country if we are to build a better, greener Britain. The Government will help British businesses and entrepreneurs to seize the opportunities which the global low carbon economy presents, from electric vehicles to offshore wind.

Success in this mission will improve our quality of life and increase our economic prosperity. It will mean cleaner air, lower energy bills, greater economic security and a natural environment protected and enhanced for the future.

Seizing the clean growth opportunity

The move to cleaner economic growth is one of the greatest industrial opportunities of our time. This Strategy will ensure Britain is ready to seize that opportunity.

Our modern Industrial Strategy is about increasing the earning power of people in every part of the country. We need to do that while not just protecting, but improving the environment on which our economic success depends. In short, we need higher growth with lower carbon emissions. This approach is at the heart of our Strategy for clean growth.

The opportunity for people and business across the country is huge. The low carbon economy could grow 11 per cent per year between 2015 and 2030, four times faster than the projected growth of the economy as a whole.

This is spread across a large number of sectors: from low cost, low carbon power generators to more efficient farms; from innovators creating better batteries to the factories putting them in less polluting cars; from builders improving our homes so they are cheaper to run to helping businesses become more productive.

This growth will not just be seen in the UK. Following the success of the Paris Agreement, where Britain played such an important role in securing the landmark deal, the transition to a global low carbon economy is gathering momentum. We want the UK to capture every economic opportunity it can from this global shift in technologies and services.

Greg Clark
Secretary of State
for Business, Energy
and Industrial Strategy

Our approach to clean growth is an important element of our modern Industrial Strategy: building on the UK's strengths; improving productivity across the country; and ensuring we are the best place for innovators and new businesses to start up and grow.

A good example of this is offshore wind, where costs have halved in just a few years. A combination of sustained commitment – across different Governments – and targeted public sector innovation support, harnessing the expertise of UK engineers working in offshore conditions and private sector ingenuity, has created the conditions for a new industry to flourish, while cutting emissions. We need to replicate this success in sectors across our economy.

This Strategy delivers on the challenge that Britain embraced when Parliament passed the Climate Change Act. If we get it right, we will not just deliver reduced emissions, but also cleaner air, lower energy bills for households and businesses, an enhanced natural environment, good jobs and industrial opportunity. It is an opportunity we will seize.

Executive Summary

Clean growth means growing our national income while cutting greenhouse gas emissions[1]. Achieving clean growth, while ensuring an affordable energy supply for businesses and consumers, is at the heart of the UK's Industrial Strategy. It will increase our productivity, create good jobs, boost earning power for people right across the country, and help protect the climate and environment upon which we and future generations depend.

UK Leadership and Progress

Our Strategy for clean growth starts from a position of strength.

The UK was one of the first countries to recognise and act on the economic and security threats of climate change. The Climate Change Act, passed in 2008, committed the UK to reducing greenhouse gas emissions by at least 80 per cent by 2050 when compared to 1990 levels, through a process of setting five year caps on greenhouse gas emissions termed 'Carbon Budgets'. This approach has now been used as a model for action across the world, and is mirrored by the United Nations' Paris Agreement.

We have been among the most successful countries in the developed world in growing our economy while reducing emissions. Since 1990, we have cut emissions by 42 per cent[2] while our economy has grown by two thirds[3]. This means that we have reduced emissions faster than any other G7 nation, while leading the G7 group of countries in growth in national income over this period[4].

This progress has meant that we have outperformed the target emissions reductions of our first carbon budget (2008 to 2012) by one per cent[5] and we project that we will outperform against our second and third budgets, covering the years 2013 to 2022, by almost five per cent and four per cent respectively[6]. Our economy is expected to grow by 12 per cent over that time[7]. This will be a significant achievement.

We have made progress across every sector of our economy.

[1] There are several greenhouse gases (GHGs) that contribute to climate change, the most abundant of which is carbon dioxide. Because of this, we measure emissions of GHGs in terms of millions of tonnes of carbon dioxide equivalent (Mt). One tonne of carbon dioxide fills roughly the same space as a small house.

[2] BEIS (2017) BEIS provisional UK emissions statistics 1990-2016 https://www.gov.uk/government/statistics/provisional-uk-greenhouse-gas-emissions-national-statistics-2016

[3] ONS (2016) Quarterly National Accounts Statistical bulletins (Series ABMI. Seasonally adjusted chained volume measures) https://www.ons.gov.uk/economy/grossdomesticproductgdp/timeseries/abmi

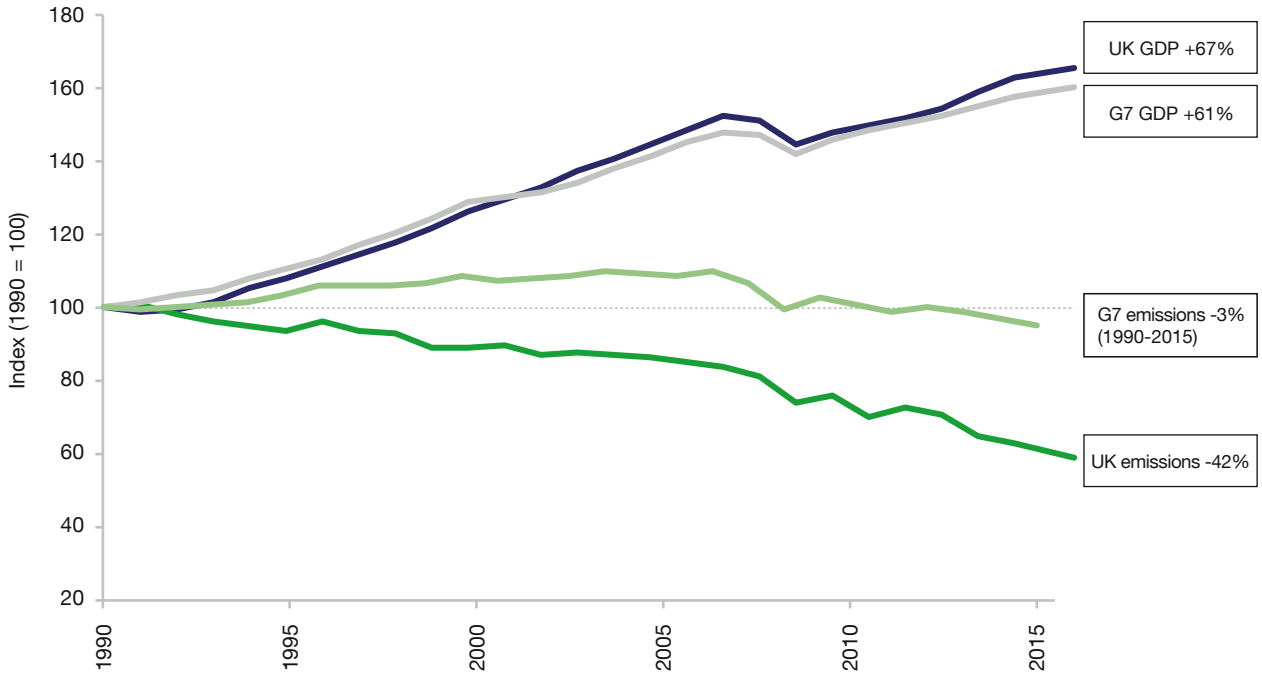
[4] Figures on per capita basis. OECD (retrieved September 2017) http://stats.oecd.org/index.aspx?DataSetCode=PDB_LV; World Resources Institute (2017) CAIT Climate Data Explorer http://cait.wri.org

[5] DECC (2014) https://www.gov.uk/government/statistics/final-statement-for-the-first-carbon-budget-period

[6] BEIS (2017) Energy and Emissions Projections 2016 https://www.gov.uk/government/publications/updated-energy-and-emissions-projections-2016

[7] OBR (March 2017) Economic and Fiscal Outlook http://budgetresponsibility.org.uk/efo/economic-fiscal-outlook-march-2017/; OBR (January 2017) Fiscal Sustainability Report http://budgetresponsibility.org.uk/fsr/fiscal-sustainability-report-january-2017/

Figure 1: UK and G7 economic growth and emissions reductions[8]



Source: UNFCCC; World Bank; BEIS

- In 2016, 47 per cent of our electricity came from low carbon sources, around double the level in 2010[9], and we now have the largest installed offshore wind capacity in the world. Our homes and commercial buildings have become more efficient in the way they use energy which helps to reduce emissions and also cut energy bills, for example average household energy consumption has fallen by 17 per cent since 1990[10]. Automotive engine technology has helped drive down emissions per kilometre driven by up to 16 per cent and driving a new car bought in 2015 will save car owners up to £200 on their annual fuel bill, compared to a car bought new in 2000[11]. England also recycles nearly four times more than it did in 2000[12].

[8] UNFCCC Data Interface (retrieved September 2017) http://di.unfccc.int/time_series; World Bank, World Development Indicators (retrieved September 2017) http://data.worldbank.org/indicator/NY.GDP.MKTP.PP.KD; BEIS (2017) Final GHG Emissions Inventory Statistics https://www.gov.uk/government/statistics/final-uk-greenhouse-gas-emissions-national-statistics-1990-2015

[9] BEIS (2017): Digest of UK Energy Statistics 2017 https://www.gov.uk/government/statistics/energy-chapter-1-digest-of-united-kingdom-energy-statistics-dukes

[10] BEIS (2017) Energy Consumption in the UK https://www.gov.uk/government/statistics/energy-consumption-in-the-uk Change in average consumption per household 1990-2016

[11] Annual average household saving from driving a car purchased new in 2015 (the latest year for which data is available) compared to driving a car purchased new in 2000. Fuel savings valued using 2015 prices. DfT (2017) National Travel Survey; DfT (2017) Vehicles Statistics; ICCT (2015) From Laboratory to Road; BEIS (2016) Green Book supplementary appraisal guidance

[12] Defra (2016) ENV18 - Local authority collected waste: annual results tables: https://www.gov.uk/government/statistical-data-sets/env18-local-authority-collected-waste-annual-results-tables

- This progress has been aided by the falling costs of many low carbon technologies: renewable power sources like solar and wind are comparable in cost to coal and gas in many countries[13]; energy efficient light bulbs are over 80 per cent cheaper today than in 2010[14]; and the cost of electric vehicle battery packs has tumbled by over 70 per cent in this time[15].
- As a result of this technological innovation, new high value jobs, industries and companies have been created. And this is driving a new, technologically innovative, high growth and high value "low carbon" sector of the UK economy. Not only are we rapidly decarbonising parts of the domestic economy, but thanks to our world leading expertise in technologies such as offshore wind, power electronics for low carbon vehicles and electric motors, and global leadership in green finance, we are successfully exporting goods and services around the world – for example, one in every five electric vehicles driven in Europe is made in the UK[16]. This progress now means there are more than 430,000 jobs in low carbon businesses and their supply chains, employing people in locations right across the country[17].

This progress has altered the way that we see many of the trade-offs between investing in low carbon technologies that help secure our future but that might incur costs today. It is clear that actions to cut our emissions can be a win-win: cutting consumer bills, driving economic growth, creating high value jobs and helping to improve our quality of life.

Of course, greenhouse gas emissions are a global problem and action is needed from all countries. The UK has played a key role in demonstrating international leadership on tackling climate change through its domestic action, climate diplomacy and financial support. The UK was among the first to recognise climate change as an economic and political issue as opposed to solely an environmental one and has used its world leading economic, science and technical skills to shape the global debate around climate change, for instance making the economic case for climate action in the landmark Stern Report in 2006[18]. The UK has also used its influence and resources to help developing countries with their own clean growth – and our actions to date are expected to save almost 500 million tonnes of carbon dioxide over the lifetime of the projects[19], more than the entire annual emissions of France[20]. While we do not count these results against our domestic targets, we can be proud of the impact of the UK's commitment to global climate action.

[13] New Climate Economy (2014) Better Growth, Better Climate http://newclimateeconomy.report/

[14] International Energy Agency (2016) Energy Efficiency Market Report https://www.iea.org/eemr16/files/medium-term-energy-efficiency-2016_WEB.PDF

[15] Bloomberg New Energy Finance (2016) 2016 lithium-ion battery price survey https://www.bnef.com/core/insights/15597

[16] European Alternative Fuels Observatory (2017) Top 5 selling BEV analysis: http://www.eafo.eu/vehicle-statistics/m1

[17] ONS (2016) UK Environmental Accounts: Low Carbon and Renewable Energy Economy Survey, Final estimates: 2015 https://www.ons.gov.uk/economy/environmentalaccounts/bulletins/finalestimates/2015results

[18] HM Treasury (2006) Stern Review on the Economics of Climate Change

[19] DfID (2017) 2017 UK Climate Finance Results https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/625457/2017-UK-Climate-Finance-Results.pdf

[20] UNFCCC 2015 data (retrieved September 2017) http://di.unfccc.int/time_series

The Opportunities and Challenges

The UK played a central role in securing the 2015 Paris Agreement in which, for the first time, 195 countries (representing over 90 per cent of global economic activity[21]) agreed stretching national targets to keep the global temperature rise below two degrees. The actions and investments that will be needed to meet the Paris commitments will ensure the shift to clean growth will be at the forefront of policy and economic decisions made by governments and businesses in the coming decades. This creates enormous potential economic opportunity — an estimated $13.5 trillion of public and private investment in the global energy sector alone will be required between 2015 and 2030 if the signatories to the Paris Agreement are to meet their national targets[22]. The decision by the US to withdraw from the Paris Agreement served to bring together and bolster action internationally on climate change with many countries underlining their commitment to the Paris Agreement in the days and weeks that followed.

The UK is well placed to take advantage of this economic opportunity. Our early action on clean growth means that we have nurtured a broad range of low carbon industries, including some sectors in which we have world leading positions. This success is built upon wider strengths – our scientific research base[23], expertise in high-value service and financial industries[24], and a regulatory framework that provides long-term direction and support for innovation and excellence in the design and manufacturing of leading edge technology.

Capturing part of the global opportunity while continuing to drive down carbon emissions from our own activities could provide a real national economic boost. The UK low carbon economy could grow by an estimated 11 per cent per year between 2015 and 2030 – four times faster than the rest of the economy[25] – and could deliver between £60 billion and £170 billion of export sales of goods and services by 2030[26]. This means that clean growth can play a central part in our Industrial Strategy – building on our strengths to drive economic growth and boost earning power across the country.

Action to deliver clean growth can also have wider benefits. For example, the co-benefit of cutting transport emissions is cleaner air, which has an important effect on public health, the economy, and the environment.

But hitting our carbon budgets and expanding the low carbon economy will not be easy. We have achieved significant results in the power and waste sectors and now need to replicate this success across the economy, particularly in the transport, business and industrial sectors. We also need to reduce the emissions created by heating our homes and businesses, which account for almost a third of UK emissions. If done in the right way, cutting emissions in these areas can benefit us all through reduced energy bills, which will help improve the UK's productivity, and improved air quality, while the innovation and investment required to drive these emissions down can create more jobs and more export opportunities.

[21] World Bank (retrieved September 2017) https://data.worldbank.org/indicator/NY.GDP.MKTP.CD

[22] International Energy Agency (2015) Climate pledges for COP21 slow energy sector emissions growth dramatically https://www.iea.org/newsroom/news/2015/october/climate-pledges-for-cop21-slow-energy-sector-emissions-growth-dramatically.html

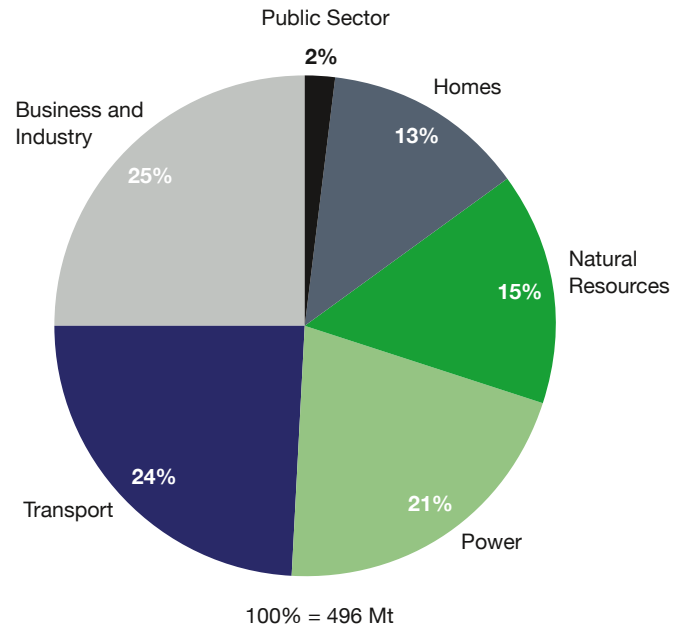
[23] BIS (2013) International Comparative Performance of the UK Research Base – 2013 https://www.gov.uk/government/publications/performance-of-the-uk-research-base-international-comparison-2013

[24] GreenAlliance (2016) Will the UK economy succeed in a low carbon world? http://www.green-alliance.org.uk/UK_low_carbon.php

[25] Ricardo Energy and Environment for the Committee on Climate Change (2017) UK business opportunities of moving to a low carbon economy https://www.theccc.org.uk/publication/uk-energy-prices-and-bills-2017-report-supporting-research/

[26] Ricardo Energy and Environment for the Committee on Climate Change (2017) UK business opportunities of moving to a low-carbon economy (supporting data tables) https://www.theccc.org.uk/publication/uk-energy-prices-and-bills-2017-report-supporting-research/

Figure 2: UK emissions by sector, 2015[27]



Heating in buildings and industry creates around 32% of total UK emissions

Source: BEIS

In order to meet the fourth and fifth carbon budgets (covering the periods 2023-2027 and 2028-2032) we will need to drive a significant acceleration in the pace of decarbonisation and in this Strategy we have set out stretching domestic policies that keep us on track to meet our carbon budgets. However, we are prepared to use the flexibilities available to us to meet carbon budgets, subject to the requirements set out in the Climate Change Act, if this presents better value for UK taxpayers, businesses and domestic consumers.

[27] BEIS (2017) UK Greenhouse Gas Inventory Statistics (1990-2015) https://www.gov.uk/government/collections/final-uk-greenhouse-gas-emissions-national-statistics; BEIS analysis

Every action that we take to cut emissions must be done while ensuring our economy remains competitive. As we set out in our Industrial Strategy Green Paper, we attach great importance to making sure our energy is affordable[28]. This is why the Government has commissioned an independent review into the cost of energy led by Professor Dieter Helm CBE. This review will recommend ways to deliver the Government's carbon targets and ensure security of supply at minimum cost to both industry and domestic consumers. Once Ministers have had the opportunity to consider the review's proposals, the Government will incorporate its recommendations into the further development of the Clean Growth Strategy as appropriate.

Another imminent challenge is to manage any impact of leaving the European Union as the Government fulfils its commitment to the British people. Leaving the EU will not affect our statutory commitments under our own domestic Climate Change Act and indeed our domestic binding emissions reduction targets are more ambitious than those set by EU legislation. The exact nature of the UK's future relationship with the EU and the long-term shape of our involvement in areas like the EU Emissions Trading System are still to be determined. There are also emerging opportunities to drive more action – for example by putting emission reductions and land stewardship at the heart of a post EU agricultural support policy. We will therefore carefully examine each area of common interest with our EU partners and work to deliver policies and programmes that are at least as beneficial as the current arrangements.

Our Clean Growth Strategy

This Strategy sets out a comprehensive set of policies and proposals that aim to accelerate the pace of "clean growth", i.e. deliver **increased** economic growth and **decreased** emissions.

Our Approach

In the context of the UK's legal requirements under the Climate Change Act, the UK's approach to reducing emissions has two guiding objectives:

1. To meet our domestic commitments at the lowest possible net cost to UK taxpayers, consumers and businesses; and,
2. To maximise the social and economic benefits for the UK from this transition.

In order to meet these objectives, the UK will need to nurture low carbon technologies, processes and systems that are as cheap as possible.

We need to do this for several reasons. First, we need to protect our businesses and households from high energy costs. Second, if we can develop low cost, low carbon technologies in the UK, we can secure the most industrial and economic advantage from the global transition to a low carbon economy. Third, if we want to see other countries, particularly developing countries, follow our example, we need low carbon technologies to be cheaper and to offer more value than high carbon ones.

We cannot predict every technological breakthrough that will help us meet our targets. Instead, we must create the best possible

[28] BEIS (2017) Building our Industrial Strategy https://www.gov.uk/government/consultations/building-our-industrial-strategy

environment for the private sector to innovate and invest. Our approach will maintain that of our Industrial Strategy: building on the UK's strengths, improving productivity across the UK and ensuring we are the best place for innovators and new business to start-up and grow. We are clear about the need to design competitive markets and smart regulation to support entrepreneurs and investors who will develop the new technologies at the scale we need. This will help our wider aim of improving the UK's earning power.

It is only through innovation – nurturing better products, processes and systems – that we will see the cost of clean technologies come down. That is why this Strategy sets out for the first time how over £2.5 billion will be invested by the Government to support low carbon innovation from 2015 to 2021. More broadly, the National Productivity Investment Fund will provide an additional £4.7 billion, with an extra £2 billion a year by 2020-21, representing the largest increase in public spending on UK science, research and innovation since 1979[29]. The UK is also working collaboratively as a core member of "Mission Innovation"[30], a group of leading countries which aims to drive forward clean energy innovation on a global scale.

In addition to supporting innovation, we are focused on policies that deliver social and economic benefits beyond the imperative to reduce emissions. Higher quality, more energy efficient buildings are healthier places to live and work. Reducing the amount of heat we waste will reduce bills. Accelerating the rollout of low emission vehicles contains a triple win for the UK in terms of industrial opportunity, cleaner air and lower greenhouse gas emissions. And crucially, many of the actions in the Clean Growth Strategy will enhance the UK's energy security by delivering a more diverse and reliable energy mix.

Actions taken by the Government on clean growth will be consistent with broader Government priorities, such as delivering clean air. All parts of the UK have a major role to play in delivering our ambitions on clean growth, and the Devolved Administrations have a range of plans and policies in place to deliver emission reductions. We will work closely with them, and with local leaders across the UK, as we develop the policies and proposals set out in this Strategy.

The changes to our infrastructure and the pace of innovation will require significant investment from the private sector. The first steps to support the growth of the green finance sector in the UK are set out in this Strategy. We are building on a position of global leadership in finance and investment. These steps will be followed by ambitious policy proposals to further accelerate investments to deliver our Clean Growth Strategy. To help develop this longer-term work, the Government has set up a new Green Finance Taskforce, comprising senior representatives from the finance industry and Government.

Key Policies and Proposals

The key actions that this Government will take as part of our Strategy are set out below. While these policies and proposals will drive emissions down throughout the next decade, our focus is on the areas where we need to do more to achieve the fifth carbon budget through domestic action in the UK.

Through preparing this Strategy, we have identified areas where we will need to see the greatest progress, both through technological breakthroughs and large-scale deployment, if we are to meet the fifth carbon budget through domestic action.

[29] HM Treasury (2016) Autumn Statement 2016 https://www.gov.uk/government/topical-events/autumn-statement-2016

[30] Mission Innovation http://mission-innovation.net/

Key Policies and Proposals in the Strategy

Accelerating Clean Growth

1. Develop world leading **Green Finance** capabilities, including by:
   - Setting up a **Green Finance Taskforce** to provide recommendations for delivery of the public and private investment we need to meet our carbon budgets and maximise the UK's share of the global green finance market
   - Working with the British Standards Institution to develop a set of **voluntary green and sustainable finance management standards**
   - Providing up to £20 million to support a new **clean technology early stage investment fund**
   - Working with mortgage lenders to develop **green mortgage** products that take account of the lower lending risk and enhanced repayment associated with more energy efficient properties

Improving Business and Industry Efficiency – 25% of UK Emissions

2. Develop a package of measures to **support businesses to improve their energy productivity**, by at least 20 per cent by 2030, including by:
   - Following the outcome of the independent review of Building Regulations and fire safety, and subject to its conclusions, we intend to consult on **improving the energy efficiency of new and existing commercial buildings**
   - Consulting on raising minimum standards of energy efficiency for **rented commercial buildings**
   - Exploring how **voluntary building standards** can support improvements in the energy efficiency performance of business buildings, and how we can improve the provision of information and advice on energy efficiency to SMEs
   - Simplifying the requirements for businesses to **measure and report on energy use**, to help them identify where they can cut bills
3. Establish an **Industrial Energy Efficiency scheme** to help large companies install measures to cut their energy use and bills
4. Publish **joint industrial decarbonisation and energy efficiency action plans** with seven of the most energy intensive industrial sectors
5. Demonstrate **international leadership in carbon capture usage and storage (CCUS),** by collaborating with our global partners and investing up to £100 million in leading edge CCUS and industrial innovation to drive down costs
6. Work in partnership with industry, through a new CCUS Council, to put us on a path to meet our ambition of having the option of **deploying CCUS at scale in the UK,** and to maximise its industrial opportunity

7. Develop our strategic approach to **greenhouse gas removal technologies,** building on the Government's programme of research and development and addressing the barriers to their long term deployment
8. Phase out the installation of high carbon forms of fossil fuel heating in new and existing businesses **off the gas grid** during the 2020s, starting with new build
9. Support the **recycling of heat** produced in industrial processes, to reduce business energy bills and benefit local communities
10. **Innovation:**
    - Invest around £162 million of public funds in research and innovation in **Energy, Resource and Process efficiency**, including up to £20 million to encourage switching to lower carbon fuels
    - Support innovative energy technologies and processes with £14 million of further investment through the **Energy Entrepreneurs Fund**

Improving Our Homes – 13% of UK Emissions

Improving the energy efficiency of our homes

11. Support around £3.6 billion of investment to **upgrade around a million homes** through the Energy Company Obligation (ECO), and extend support for home energy efficiency improvements until 2028 at the current level of ECO funding
12. We want all fuel poor homes to be upgraded to Energy Performance Certificate (EPC) Band C by 2030 and our **aspiration is for as many homes as possible to be EPC Band C by 2035** where practical, cost-effective and affordable
13. Develop a long term trajectory to improve the **energy performance standards of privately-rented homes**, with the aim of upgrading as many as possible to EPC Band C by 2030 where practical, cost-effective and affordable
14. Consult on how **social housing** can meet similar standards over this period
15. Following the outcome of the independent review of Building Regulations and fire safety, and subject to its conclusions, we intend to consult on **strengthening energy performance standards for new and existing homes** under Building Regulations, including futureproofing new homes for low carbon heating systems
16. Offer all households the opportunity to have a **smart meter** to help them save energy by the end of 2020

Rolling out low carbon heating

17. Build and extend **heat networks** across the country, underpinned with public funding (allocated in the Spending Review 2015) out to 2021
18. Phase out the installation of high carbon fossil fuel heating in new and existing **homes currently off the gas grid** during the 2020s, starting with new homes

Rolling out low carbon heating (continued)

19. **Improve standards** on the 1.2 million **new boilers** installed every year in England and require installations of control devices to help people save energy

20. Invest in **low carbon heating** by reforming the **Renewable Heat Incentive**, spending £4.5 billion to support innovative low carbon heat technologies in homes and businesses between 2016 and 2021

21. **Innovation:** Invest around £184 million of public funds, including two new £10 million innovation programmes to develop new energy efficiency and heating technologies to enable lower cost low carbon homes

Accelerating the Shift to Low Carbon Transport – 24% of UK Emissions

22. **End the sale** of new conventional petrol and diesel cars and vans by 2040

23. Spend £1 billion supporting the take-up of **ultra low emission vehicles (ULEV)**, including helping consumers to overcome the upfront cost of an electric car

24. Develop one of the best electric vehicle charging networks in the world by:

    - Investing an additional £80 million, alongside £15 million from Highways England, to support **charging infrastructure deployment**
    - Taking new powers under the **Automated and Electric Vehicles Bill**, allowing the Government to set requirements for the provision of charging points

25. Accelerate the uptake of low emission **taxis and buses** by:

    - Providing £50 million for the **Plug-in Taxi programme**, which gives taxi drivers up to £7,500 off the purchase price of a new ULEV taxi, alongside £14 million to support 10 local areas to deliver dedicated charge points for taxis
    - Providing £100 million for a national programme of **support for retrofitting and new low emission buses** in England and Wales

26. Work with industry as they develop an **Automotive Sector Deal** to accelerate the transition to zero emission vehicles

27. Announce plans for the **public sector** to lead the way in transitioning to zero emissions vehicles

28. Invest £1.2 billion **to make cycling and walking** the natural choice for shorter journeys

29. Work to enable cost-effective options for shifting more freight from **road to rail**, including using low emission rail freight for deliveries into urban areas, with zero emission last mile deliveries

30. Position the UK at the forefront of research, development and demonstration of **Connected and Autonomous Vehicle technologies**, including through the establishment of the Centre for Connected and Autonomous Vehicles and investment of over £250 million, matched by industry

31. **Innovation:** Invest around £841 million of public funds in innovation in low carbon transport technology and fuels including:
    - Ensuring the UK builds on its strengths and leads the world in the design, development and manufacture of **electric batteries through investment of up to £246 million in the Faraday Challenge**
    - Delivering trials of **Heavy Goods Vehicle (HGV) platoons**, which could deliver significant fuel and emissions savings

Delivering Clean, Smart, Flexible Power – 21% of UK Emissions

32. **Reduce power costs for households and businesses by:**
    - Implementing the **smart systems plan**, which will help consumers to use energy more flexibly and could unlock savings of up to £40 billion to 2050
    - Working with Ofgem and National Grid to create a more **independent system operator** to keep bills low through greater competition, coordination and innovation across the system
    - Responding to the forthcoming **independent review into the cost of energy** led by Professor Dieter Helm CBE
    - Publishing a draft bill to require Ofgem to **impose a cap** on standard variable and default tariffs across the whole market
33. **Phase out the use of unabated coal** to produce electricity by 2025
34. Deliver **new nuclear power** through Hinkley Point C and progress discussions with developers to secure a competitive price for future projects in the pipeline
35. Improve the route to market for **renewable technologies** such as offshore wind through:
    - **Up to £557 million for further Pot 2 Contract for Difference auctions**, with the next one planned for spring 2019
    - Working with industry as they develop an ambitious **Sector Deal for offshore wind**, which could result in 10 gigawatts of new capacity, with the opportunity for additional deployment if this is cost effective, built in the 2020s
36. Target a total **carbon price** in the power sector which will give businesses greater clarity on the total price they will pay for each tonne of emissions. Further details on carbon prices for the 2020s will be set out in the Autumn 2017 Budget
37. **Innovation:** Invest around £900 million of public funds, including around:
    - **£265 million** in smart systems to reduce the cost of electricity storage, advance innovative demand response technologies and develop new ways of balancing the grid
    - **£460 million** in nuclear to support work in areas including future nuclear fuels, new nuclear manufacturing techniques, recycling and reprocessing, and advanced reactor design
    - **£177 million** to further reduce the cost of renewables, including innovation in offshore wind turbine blade technology and foundations

Enhancing the Benefits and Value of Our Natural Resources – 15% of UK Emissions

38. As we leave the EU, design a new system of **future agricultural support** to focus on delivering better environmental outcomes, including addressing climate change more directly
39. Establish a **new network of forests** in England including new woodland on farmland, and fund larger-scale woodland and forest creation, in support of our commitment to plant 11 million trees, and increase the amount of **UK timber** used in construction
40. Work towards our ambition for **zero avoidable waste** by 2050, maximising the value we extract from our resources, and minimising the negative environmental and carbon impacts associated with their extraction, use and disposal
41. Publish a new **Resources and Waste Strategy** to make the UK a world leader in terms of competitiveness, resource productivity and resource efficiency
42. Explore new and innovative ways to manage **emissions from landfill**
43. Support **peatland** through a £10 million capital grant scheme for peat restoration
44. **Innovation:** Invest £99 million in innovative technology and research for agri-tech, land use, greenhouse gas removal technologies, waste and resource efficiency

Leading in the Public Sector – 2% of UK Emissions

45. Agree **tighter targets for 2020 for central government** and actions to further reduce greenhouse gas emissions beyond this date
46. Introduce a **voluntary public sector target of a 30 per cent** reduction in carbon emissions by 2020-21 for the wider public sector
47. Provide £255 million of funding for **energy efficiency improvements** in England and help public bodies access sources of funding

Government Leadership in Driving Clean Growth

48. Work with businesses and civil society to introduce a **"Green Great Britain"** week to promote clean growth
49. Reinstate a regular **Clean Growth Inter-Ministerial Group** responsible for monitoring the implementation of this Strategy and driving ambitious clean growth policies
50. Report annually on our performance in delivering GDP growth and reduced emissions through an **"Emissions Intensity Ratio"**

INVESTMENT IN INNOVATION FOR CLEAN GROWTH

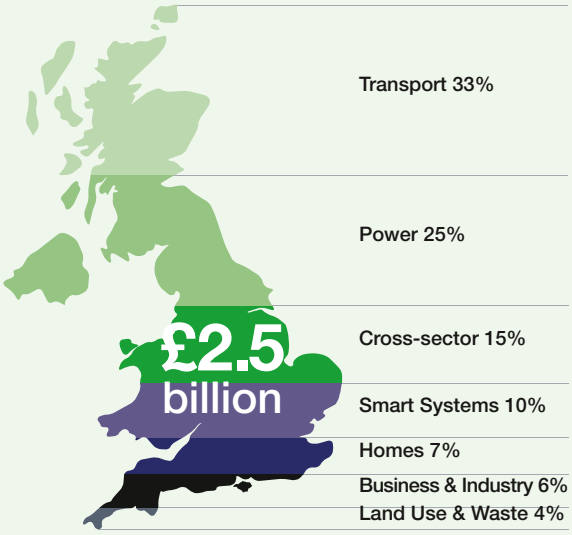
To achieve the clean growth we want, the UK will need to nurture low carbon technologies, processes and systems that are as cheap as possible.

It is only through innovation that we will see new technologies developed and the cost of clean technologies come down.

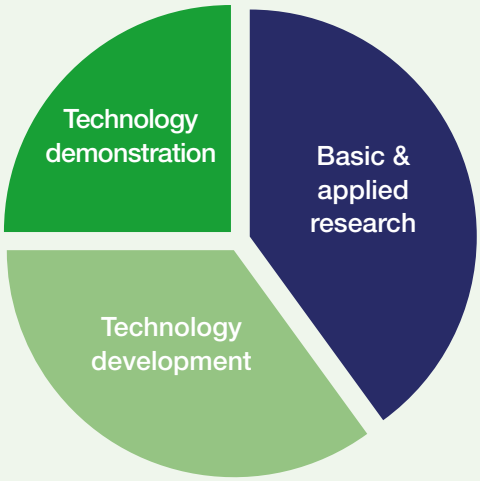
Government has significantly increased its investment in low carbon innovation

allocated
2015-2021

This strategy sets out, for the first time, where Government funding is targeted



Investment will be made at all stages of technology development: from basic research to pre-commercial trials



Innovation creates jobs and helps companies grow

The Energy Entrepreneurs Fund is a competitive funding scheme to support the development and demonstration of state of the art technologies, products and processes.

The impact of Phases 1-5 is:

109
Projects supported

£62 million
Private investment leveraged

296
Jobs supported

90
Patents applied for

42
Products launched

Tracking Our Progress

We want to deliver increased economic growth and reduced emissions. We have developed an Emissions Intensity Ratio (EIR) to measure our clean growth performance which we will publish each year so we can track progress. To reach our 2032 targets we will need to drive the emissions intensity of the economy down by an average of five per cent per year to 2032, an acceleration in the four per cent annual fall since 1990[31].

The Emissions Intensity Ratio (EIR)

This measures the amount of greenhouse gases (tonnes of carbon dioxide equivalent) produced for each unit of Gross Domestic Product (GDP) created. Currently the EIR is 270 tonnes/£ million and it was 720 tonnes/£ million in 1990. By 2032, we expect the EIR will need to be nearly as low as 100 tonnes/£ million to meet our ambitions.

Next Steps

This Strategy is not the end of the process. While this is an important milestone in our work to decarbonise the UK while growing our economy, our approach will develop and adapt to changing circumstances. We will update key elements of the Strategy in line with our annual statutory responses to the Committee on Climate Change's reports on progress, ahead of setting the sixth carbon budget by 30 June 2021.

We will also launch the following Government consultations during 2017 and 2018 on:

- The design of a new industrial heat recovery programme
- Making the private rented sector energy efficiency regulations more effective, and setting longer term energy performance standards across both the domestic private and social rented sectors
- A streamlined and more effective energy and carbon reporting framework for UK businesses to help them identify where they can cut bills
- A package of measures to support businesses to improve how productively they use energy
- Our strategic approach to the aviation sector in a series of consultations over the next 18 months.

A full list of the actions and milestones arising from this Strategy is set out at Annex B.

Many of the future actions the Government will be taking, expanding on the proposals above, will be set out in the 25 Year Environment Plan, which will be designed to be a sister document to this Strategy, and in a long term strategy for the UK's transition to zero road vehicle emissions. Taken together, these set out the Government's approach to fulfilling its commitment to leave the environment in a better state than it inherited. Along with the Industrial Strategy White Paper, to be published later in 2017, these will form a critical part of our future progress.

[31] BEIS analysis; ONS (2016) Quarterly National Accounts; BEIS (2017) UK Greenhouse Gas Inventory Statistics (1990-2015); OBR (March 2017) Economic and Fiscal Outlook; OBR (January 2017) Fiscal Sustainability Report

The Government cannot achieve the changes needed to our economy by itself. Outside action on public sector emissions, the Government's key role is to set the framework for action across the economy. Beyond that, clean growth has to be a shared endeavour between Government, business, civil society and the British people. Creating this supportive environment will help attract the domestic and international investment the UK wants. Therefore from 2018 we will work with private partners and NGOs to introduce a **Green Great Britain Week**.

We welcome views and comments on our approach and these should be sent to CleanGrowthStrategy@beis.gov.uk by 31 December 2017. Views received in response to both this Strategy and the detailed policy proposals which will follow it, will be considered as we update key elements of our Strategy before setting the sixth carbon budget by 30 June 2021.

Green Great Britain Week

An annual event to:

- Focus on climate and air quality issues across the UK
- Demonstrate our progress and successes on climate action
- Share the latest climate science
- Highlight and promote economic opportunities arising from clean growth especially to international investors.

Chapter 1:
UK Leadership and Progress

Our strategy for clean growth starts from a position of strength. The UK was one of the first countries to recognise and act on the threat of climate change and continues to play an important leadership role today.

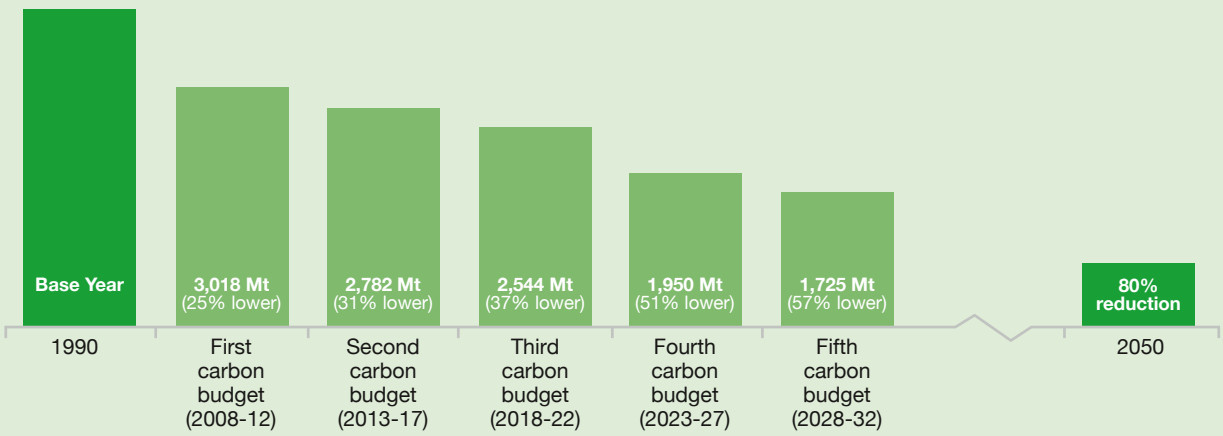
In 2008, we became the first country to set a legally binding emissions reduction target through the Climate Change Act.

This has driven significant progress in cutting emissions. In 2016 alone UK emissions fell by six per cent compared to the year before[32]. Overall, between 1990 and 2016, the UK reduced emissions by 42 per cent[33]. Today, the Climate Action Network ranks the UK third in the world for action on climate change[34].

What the Climate Change Act Requires

The Climate Change Act requires the UK to reduce its emissions by at least 80 per cent by 2050[35]. This means greenhouse gas emissions falling from around 14 tonnes per person in 1990 to around 2 tonnes per person in 2050. To ensure steady progress towards our 2050 goal, the Climate Change Act requires the Government to set intermediate targets – 'carbon budgets'. These are caps on the greenhouse gas emissions that can be emitted across the UK during a five-year period. Five carbon budgets have been set to date, putting in place caps on greenhouse gas emissions from 2008 out to 2032. In July 2016, we set the fifth carbon budget, which requires a 57 per cent average reduction in emissions over 2028-32 across the UK compared to a 1990 baseline.

Figure 3: UK carbon budgets and 2050 target[35]



Source: UK legislation; BEIS

[33] BEIS (2017) Provisional UK greenhouse gas emissions national statistics 2016 https://www.gov.uk/government/statistics/provisional-uk-greenhouse-gas-emissions-national-statistics-2016

[33] Ibid

[34] Climate Action Network (2017) Climate Change Performance Index Results 2017 http://www.caneurope.org/docman/climate-energy-targets/3015-climate-change-performance-index-2017/file

[35] On 1990 levels

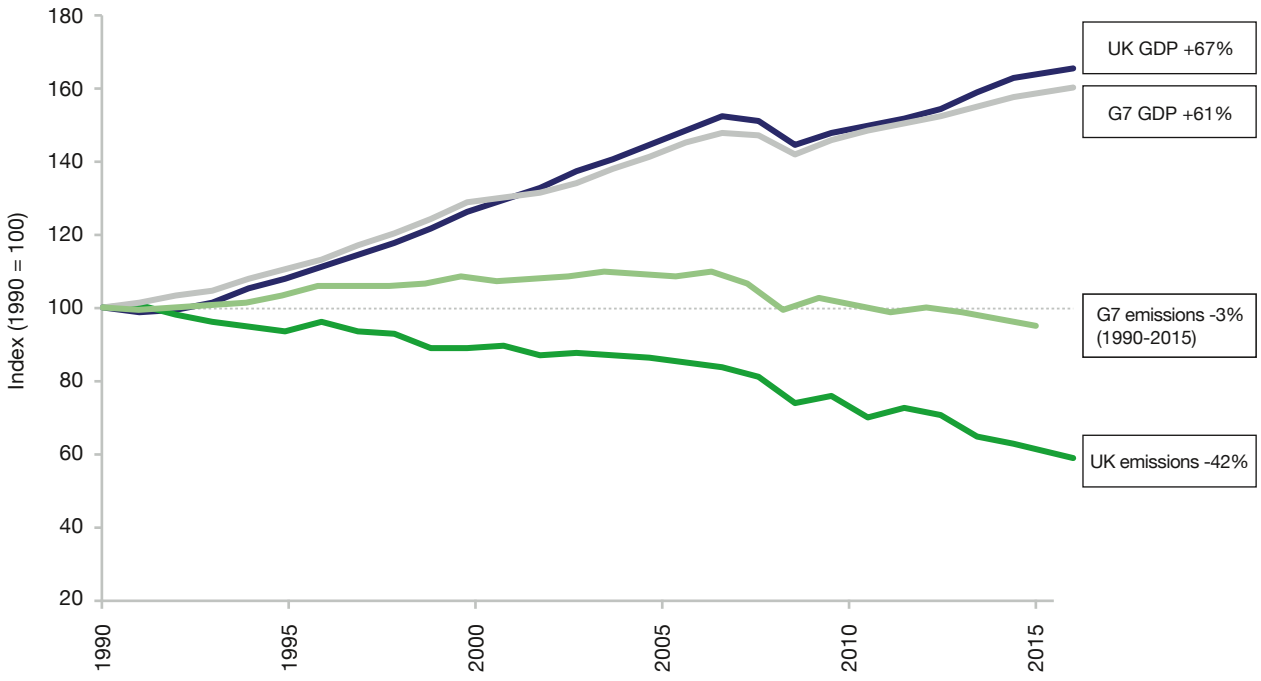
[36] 1990 base year emissions 803 Mt, equivalent to 4,013 Mt over a 5-year period, BEIS (2017) UK Greenhouse Gas Inventory Statistics (1990-2015) https://www.gov.uk/government/collections/final-uk-greenhouse-gas-emissions-national-statistics

This progress has not come at the expense of the economic growth we need to support our public services and invest in our future. Between 1990 and 2016, while the UK reduced its emissions by 42 per cent[37] the economy grew by 67 per cent[38]. The UK has reduced emissions per person faster than any other G7 nation (and indeed more than any other G20 nation[39]) while at the same time leading the G7 in GDP growth per capita since 1990[40]. PwC's Low Carbon Economy Index shows that the UK was the fastest of any country in the G20 to decarbonise in 2016[41].

Progress Has Been Made Across the UK Economy

Some of the largest falls in emissions since 1990 have been seen in the power sector, where emissions have fallen by almost half[43] as the UK has switched away from coal and increased the share of renewables and gas in electricity generation. In 2016 nearly one quarter of the UK's electricity generation was provided by renewables[44] and on 7 June this year renewable energy sources supplied over 50 per cent of UK electricity for the first time in history[45].

Figure 4: UK and G7 economic growth and emissions reductions[41]



Source: UNFCCC; World Bank; BEIS

[37] BEIS (2017) Provisional Greenhouse Gas Emissions Inventory Statistics 2016 https://www.gov.uk/government/statistics/provisional-uk-greenhouse-gas-emissions-national-statistics-2016

[38] ONS (2016) Quarterly National Accounts Statistical bulletins (Series ABMI. Seasonally adjusted chained volume measures) https://www.ons.gov.uk/economy/grossdomesticproductgdp/timeseries/abmi

[39] World Resources Institute (retrieved September 2017) CAIT Climate Data Explorer http://cait.wri.org Data to 2013

[40] World Bank (retrieved September 2017) World Development Indicators, International Comparison Program database http://data.worldbank.org/indicator/NY.GDP.MKTP.PP.KD. Data to 2015

[41] PwC (2017) Low Carbon Economy Index http://www.pwc.co.uk/services/sustainability-climate-change/insights/low-carbon-economy-index.html

[42] UNFCCC Data Interface, http://di.unfccc.int/time_series; World Bank, World Development Indicators, http://data.worldbank.org/indicator/NY.GDP.MKTP.PP.KD; BEIS (2017) Final GHG Emissions Inventory Statistics (1990-2015) https://www.gov.uk/government/statistics/final-uk-greenhouse-gas-emissions-national-statistics-1990-2015

[43] BEIS (2017) UK Greenhouse Gas Inventory Statistics (1990-2015) https://www.gov.uk/government/collections/final-uk-greenhouse-gas-emissions-national-statistics

[44] BEIS (August 2017) Energy Trends https://www.gov.uk/government/statistics/electricity-section-5-energy-trends

[45] BBC (2017) Renewables provide more than half UK electricity for first time http://www.bbc.co.uk/news/business-40198567

Table 1: Greenhouse gas emissions by sector, 1990-2015[46]

	Emissions (Mt)		
Sector	1990 base year[47]	2015	Percentage change 1990-2015
Business and industry	231	123	-47%
Transport	122	120	-2%
Power	204	104	-49%
Natural resources	152	77	-50%
Homes	80	64	-20%
Public sector	13	8	-40%
Total	**803**	**496**	**-38%[48]**

Source: BEIS

There have also been significant falls in emissions from waste and industry – driven partly by a change in the UK's economic structure from manufacturing to services but also by a large reduction in waste being sent to landfill. This has been driven by initiatives like the Landfill Tax which helped reduce the amount of taxable waste sent to landfill by 76 per cent between 1997 and 2016[49].

We have made progress in other sectors, including transport, where tighter regulations have helped drive down the average car's carbon emissions per kilometre by up to 16 per cent since 2000[50] while hybrid and ultra low emission vehicles (ULEVs), such as electric and hydrogen fuel cell cars, accounted for a record 5.5 per cent of sales in July 2017[51]. In our homes, average household energy consumption has fallen by over 17 per cent since 1990, in part due to tighter standards and obligations on energy suppliers to improve energy efficiency[52].

Falling Costs and Rapid Technology Uptake

This progress has been aided by the falling costs of many low carbon technologies globally, coupled with accelerating momentum in the deployment of the technologies we need to reduce emissions, as a result of early policy action by the UK, other governments and substantial public and private sector investment.

[46] BEIS (2017) UK Greenhouse Gas Inventory Provisional Statistics (1990-2016) https://www.gov.uk/government/statistics/provisional-uk-greenhouse-gas-emissions-national-statistics-2016

[47] In line with the Climate Change Act the base year is comprised of 1990 for carbon dioxide, methane and nitrous oxide, and 1995 for fluorinated compounds

[48] Provisional 2016 estimate: -42 change 1990-2016. BEIS (2017) UK Greenhouse Gas Inventory Statistics (1990-2015) https://www.gov.uk/government/collections/final-uk-greenhouse-gas-emissions-national-statistics

[49] HMRC Landfill Tax bulletin https://www.gov.uk/government/statistics/landfill-tax-bulletin

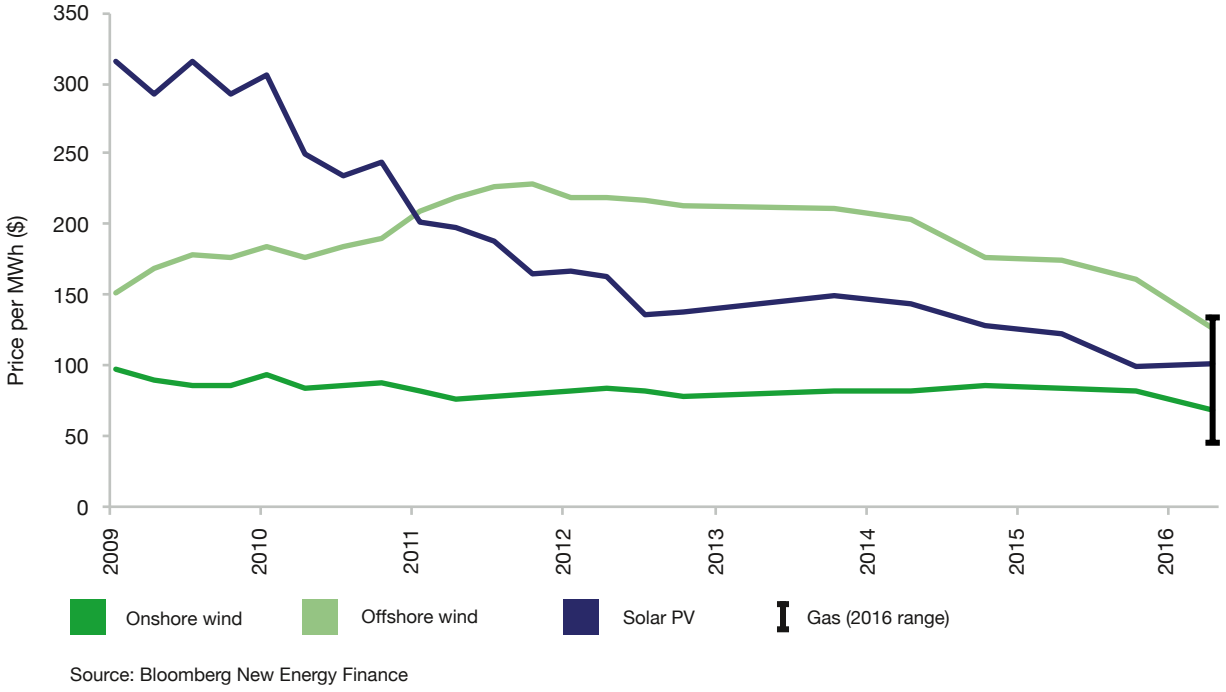
[50] Fuel efficiencies are from DfT modelling using DfT (2017) Vehicle statistics; ICCT (2015) From Laboratory to Road: A 2015 update http://www.theicct.org/laboratory-road-2015-update

[51] SMMT (2017) EV & AFV Registrations, July 2017 and Year-to-Date https://www.smmt.co.uk/vehicle-data/evs-and-afvs-registrations/

[52] BEIS (2017) Energy Consumption in the UK https://www.gov.uk/government/statistics/energy-consumption-in-the-uk Change in average consumption per household 1990-2016

For example, the power sector has seen dramatic falls in the price of renewable energy due to government policies, with global investment estimated at $2.8 trillion since 2007[53]. This has driven down the cost of solar cells by 80 per cent since 2008[54], meaning we are now beginning to see solar deploying in the UK without government support, and onshore wind power by 50 per cent since 2009[55]. The cost of offshore wind is falling even faster; in the UK, government investment has helped to deliver a 50 per cent drop in costs over just the last two years[56]. This means that wind and solar energy are increasingly cost competitive with coal and gas in many countries[57].

Figure 5: Change in global renewable energy costs[57]



Source: Bloomberg New Energy Finance

[53] Bloomberg New Energy Finance (2017) Clean Energy Investment Trends 2Q 2017 https://about.bnef.com/blog/clean-energy-investment-2q-2017-figures-2/

[54] Bloomberg New Energy Finance (2016) Summit keynote presentation http://www.bbhub.io/bnef/sites/4/2016/04/BNEF-Summit-Keynote-2016.pdf

[55] Ibid

[56] Gov.uk (2017) New clean energy projects set to power 36 million homes https://www.gov.uk/government/news/new-clean-energy-projects-set-to-power-36-million-homes

[57] New Climate Economy (2014) Better Growth, Better Climate http://newclimateeconomy.report/2014/

[58] Bloomberg New Energy Finance (2016), H2 2016 Global Levelised Cost of Electricity Update https://about.newenergyfinance.com/about/blog/h2-2016-lcoe-giant-fall-generating-costs-offshore-wind/

Global investment in energy efficiency is also growing, having already reached $221 billion in 2015, an increase of six per cent on the year before[59]. This included $12 billion of investment in improving the efficiency of appliances and has led to an improvement in the average efficiency of major appliance categories[60] of more than 16 per cent between 2005 and 2015[61].

The transport sector is seeing the beginnings of a rapid shift to clean technology. Between 2011 and 2016, the number of electric vehicles on the road globally increased thirtyfold[62]. This has been aided by the falling costs of the battery packs that power electric vehicles, which have come down by nearly 80 per cent since 2010[63]. In the future, the cost of electric vehicles is now forecast to fall below that of conventional vehicles in the early to mid-2020s[64].

A High Growth Low Carbon Economy

As a result of this technological innovation and investment, new high value jobs, industries and companies have been created. The UK low carbon economy – encompassing activities such as the design and building of low carbon power and heat projects, the manufacture of electric vehicles, the development of energy efficient products and systems for buildings, and green finance – already supports over 430,000 jobs directly and through supply chains[65]. We have developed world leading expertise in technologies such as offshore wind and power electronics for low carbon vehicles and electric motors, and we are a global leader in green finance.

This progress has altered the way that we see many of the trade-offs between investing in low carbon technologies that help secure our future but that might incur costs today. Actions to cut our emissions can be a win-win: cutting consumer bills, driving economic growth, creating high value jobs and helping to improve our quality of life.

[59] International Energy Agency (2016) Energy Efficiency Market Report https://www.iea.org/eemr16/files/medium-term-energy-efficiency-2016_WEB.PDF

[60] Refrigerators, freezers, washing machines, dishwashers, heating equipment, cooling equipment, water heating equipment and lighting (luminaires and lamps) and controls.

[61] International Energy Agency (2016) Energy Efficiency Market Report https://www.iea.org/eemr16/files/medium-term-energy-efficiency-2016_WEB.PDF

[62] International Energy Agency (2016) Global EV Outlook 2017 https://www.iea.org/publications/freepublications/publication/global-ev-outlook-2017.html

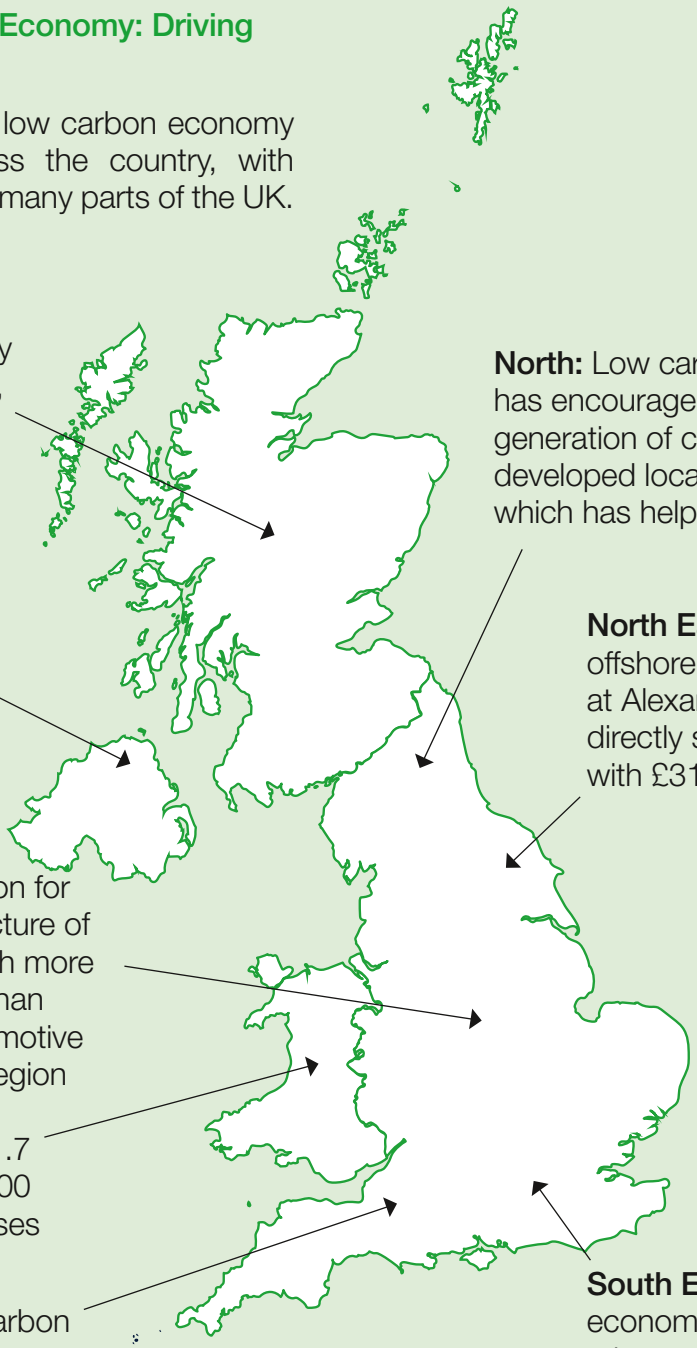
[63] McKinsey & Co (2017) Electrifying insights: How automakers can drive electrified vehicle sales and profitability http://www.mckinsey.com/industries/automotive-and-assembly/our-insights/electrifying-insights-how-automakers-can-drive-electrified-vehicle-sales-and-profitability

[64] OLEV analysis. This is based on the whole-life cost of electric vehicles. The up-front cost of these vehicles is expected to fall below that of conventional vehicles in the second half of the 2020s.

[65] ONS (2017) Low Carbon and Renewable Energy Economy Survey, final estimates: 2015 https://www.ons.gov.uk/economy/environmentalaccounts/bulletins/finalestimates/2015results

The UK's Low Carbon Economy: Driving Regional Growth

The growth in the UK's low carbon economy has taken place across the country, with centres of excellence in many parts of the UK.



Scotland: Turnover of the low carbon economy was £5.5 billion in 2015, supporting 31,000 jobs and 20,000 businesses

Northern Ireland: Turnover was almost £1 billion, supporting 5,000 jobs and 4,000 businesses

Midlands: Leading region for the design and manufacture of low carbon vehicles, with more than £1.5 billion (more than 60 per cent) of UK automotive R&D carried out in the region

Wales: Turnover was £1.7 billion in 2015 with 11,000 jobs and 4,500 businesses

South West: The low carbon sector in Bristol employs over 9,000 people and over 19,000 in the whole of the West of England, generating £2.4 billion

North: Low carbon investment has encouraged innovation and generation of clean energy, and developed local supply chains, all of which has helped drive regeneration

North East: The Siemens offshore wind blade factory at Alexandra Dock in Hull directly supports 1,000 jobs with £310 million investment

South East: The low carbon economy in Oxfordshire has a turnover of £1.15 billion supporting 8,800 jobs, and is 7 per cent of the local economy

Sources:
Scotland, Wales, Northern Ireland: ONS (2016): Low Carbon and Renewable Energy Economy Survey. Direct activity only - excludes supply chains.
North East: DECC published news story (2014) Siemens to build major offshore wind manufacturing site in the UK
South East: Low Carbon Oxford and the Environmental Change Institute at the University of Oxford (2014) Joining the crowd: Growing a new economy for Oxfordshire
South West: Bristol City Council (2015) State of Bristol - Key Facts
Midlands: DIT (2017) https://www.gov.uk/government/publications/midlands-engine-investment-portfolio/midlands-engine-investment-portfolio
North: Aldersgate Group Report (2016) Setting the Pace: Northern England's Low Carbon Economy

The UK's International Leadership and Actions to Reduce Emissions Overseas

Climate change is a global challenge requiring action from all countries. The UK has played a key role in demonstrating international leadership on reducing emissions and supporting other countries to do the same.

The UK was the first country in the world to introduce legally binding emissions reduction targets under the Climate Change Act, which has been used as a model around the world, including in France, Denmark, Sweden and Mexico. The UK was among the first to recognize that climate change is an economic and political issue not just an environmental one, and to put serious climate expertise in our embassies to influence and help countries to act.

We have used our world leading economic, science and technical skills to shape the debate around climate change and have been at the forefront of the debate through our world leading scientists at the Met Office, the landmark 2006 Stern Report[66] and the more recent New Climate Economy project[67], having one of the first Foreign Secretary Special Representatives on climate and arranging the first discussion of climate change in the UN Security Council.

We also played a critical role in securing the 2015 Paris Agreement, the first ever international climate change agreement where 195 countries (representing over 90 per cent of global economic activity[68]) made a commitment to reduce emissions with the long-term goal of limiting global temperature increases to "well below 2 degrees", and to review progress every five years, mirroring the UK's ground-breaking processes.

The Agreement puts pressure on all countries to bring forward long-term emissions reduction strategies by 2020. The Clean Growth Strategy, as the UK's long-term emissions reduction strategy, shows the UK is leading the world in response to this important step. The UK also led the way in pledging to phase down the use of hydrofluorocarbons (HFCs) by 79 per cent by 2030, and following this lead 197 countries agreed a global phase down of HFCs – delivering an 85 per cent phase down by 2036 - under the United Nations Montreal Protocol in October 2016.

[66] HM Treasury (2006) Stern Review on the Economics of Climate Change http://webarchive.nationalarchives.gov.uk/+/http://www.hm-treasury.gov.uk/sternreview_index.htm

[67] New Climate Economy (2014) http://newclimateeconomy.report/

[68] World Bank (retrieved September 2017) https://data.worldbank.org/indicator/NY.GDP.MKTP.CD

The UK's International Leadership and Actions to Reduce Emissions Overseas (continued)

The UK is among the largest contributors of climate finance, committing to provide at least £5.8 billion from 2016 to 2020, to help developing countries mitigate and adapt to the impacts of climate change, reduce deforestation and support cleaner economic growth. From 2011 we have used our International Climate Finance to install more than 400 megawatts of clean energy capacity, mobilised £2.7 billion of additional public and private finance, supported more than 34 million people in adapting to the impacts of climate change and helped resilient economic development in over 70 countries[69].

This support takes many forms, for instance investment in the Climate Investment Funds, through which the UK has helped support renewable energy, climate resilience and forestry projects in 72 countries[70]. The UK has also been at the forefront of global action to halt deforestation – helping negotiate international frameworks and mobilising partnerships to deliver on them – to meet shared goals such as ending forest loss by 2030, and eliminating deforestation from the production of key agricultural commodities by 2020. Together with Germany and Norway, we have collectively pledged $5 billion between 2015 and 2020 to incentivise ambitious governments, companies and communities to protect our largest natural global carbon sinks. This includes supporting a 30 per cent reduction in deforestation in Colombia's Amazon, improving livelihoods in conflict-affected areas[71].

Our actions to date are expected to save nearly 500 Mt over the lifetime of the projects[72], more than the entire annual emissions of France[73]. And while we do not count these results against our domestic budgets, we can be proud of the impact of the UK's commitment to global climate action.

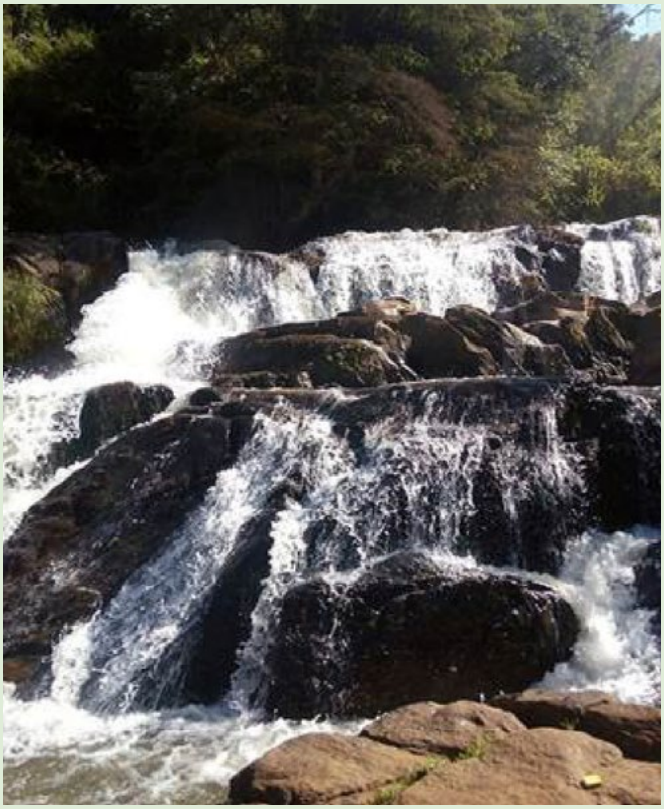
[69] DfID (2017) 2017 UK Climate Finance Results https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/625457/2017-UK-Climate-Finance-Results.pdf

[70] The Climate Invest Funds (CIFs) https://www.gov.uk/government/case-studies/the-climate-investment-funds-cifs

[71] BEIS assessment

[72] DfID (2017) 2017 UK Climate Finance Results https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/625457/2017-UK-Climate-Finance-Results.pdf

[73] UNFCCC (retrieved September 2017) http://di.unfccc.int/time_series,2015 data



The Renewable Energy Performance Platform supports small to medium-sized renewable energy projects throughout sub-Saharan Africa. In West Kenya, two mini-hydro power plants will provide electrification to local rural communities, helping to stimulate rural economic growth. Importantly, after 20 years of operation the project will be fully transferred to the local community.

Chapter 2:
The Opportunities and Challenges

The Size of the Clean Growth Opportunity

The commitments made in the Paris Agreement – shifting to cleaner, low carbon technologies in power, transport, heating and cooling, industrial processes and agriculture – will require enormous investment of public and private capital. An estimated $13.5 trillion of public and private investment will be required in the energy sector alone[74].

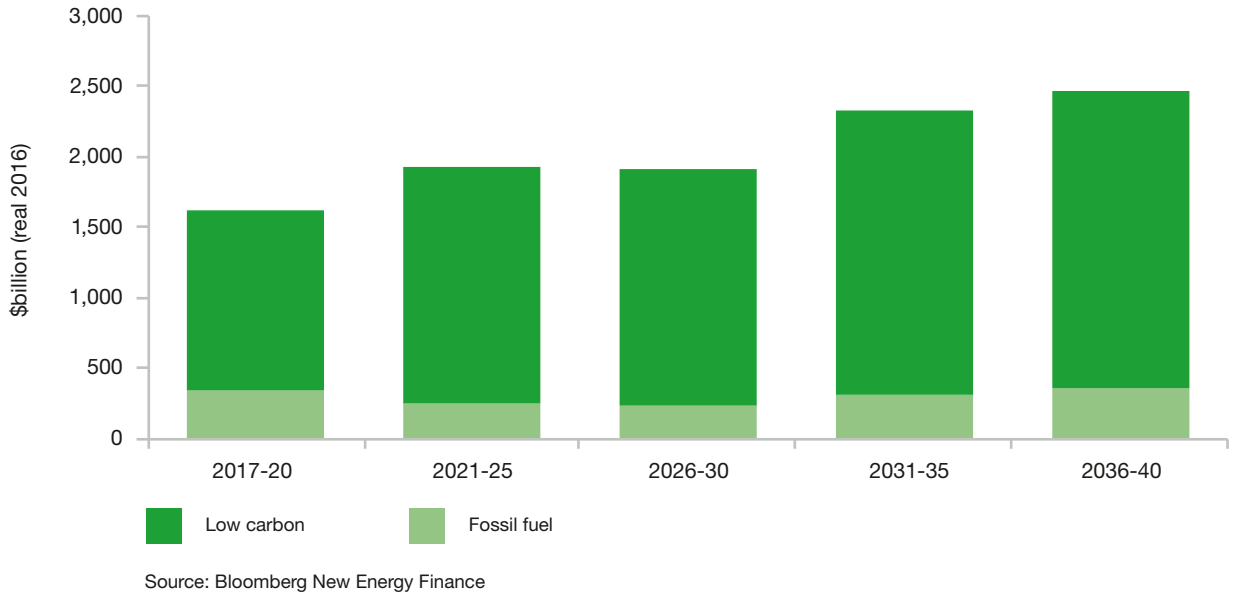
We have a high degree of confidence that these investments will be made given the scale of political support and the transformational impact of investment to date – indeed decarbonisation is cited as one of the 'megatrends' that will reshape the global economy over the years to come[75].

We are determined to ensure that this trend works to the advantage of the UK economy and that we embed it at the core of our Industrial Strategy.

Looking across sectors, to assess the size of the opportunity, highlights several key areas.

The **power sector** has seen some of the most significant early action on climate change, given its status as the largest source of emissions in most countries. Annual new global investment in renewable electricity grew more than threefold since 2005, reaching over $240 billion in 2016[76]. This trend is happening everywhere. In Europe, over 80 per cent of new power generating capacity built in 2016 was from renewables[77]. Globally, clean energy technologies are estimated to account for over 85 per cent of the $10.2 trillion investment in power generation projected between now and 2040[78].

Figure 6: Estimated global investment in power generation[79]



Source: Bloomberg New Energy Finance

[74] IEA (2015) Climate pledges for COP21 slow energy sector emissions growth dramatically https://www.iea.org/newsroom/news/2015/october/climate-pledges-for-cop21-slow-energy-sector-emissions-growth-dramatically.html

[75] World Economic Forum, OECD, World Bank, PwC, Ernst & Young

[76] FS-UNEP Collaborating Centre (2017) Global Trends in Renewable Energy Investment 2017 http://fs-unep-centre.org/sites/default/files/publications/globaltrendsinrenewableenergyinvestment2017.pdf

[77] REN21 (2017) Renewables 2017 Global Status Report http://www.ren21.net/wp-content/uploads/2017/06/170607_GSR_2017_Full_Report.pdf

[78] Bloomberg New Energy Finance (2017) New Energy Outlook 2017 https://about.bnef.com/new-energy-outlook/

[79] Bloomberg New Energy Finance (2017) New Energy Outlook 2017 https://about.bnef.com/new-energy-outlook/

Clean Growth in China and India

Both China and India are driving the global transition to the low carbon economy, supported by political will[80,81], falling technology costs[82] and a desire to seize the economic opportunity[83,84].

China has put 'Green Development' at the heart of its current five year economic strategy[85] and committed to reduce its level of carbon emissions per unit of economic activity by 60 per cent to 65 per cent by 2030 compared to 2005.

India's targets commit to reducing emissions by 33 to 35 per cent over the same period, and Prime Minister Modi has plans to make India a leader in solar and renewable energy[86].

These ambitions have translated into impressive plans. India plans to increase its renewable power fivefold to 175 gigawatts by 2022[87], including 60 gigawatts of wind and 100 gigawatts of solar; and China has committed to invest $360 billion in low carbon power by 2020[88], increasing its renewable energy capacity by around 40 per cent.

This ambition extends to the transport sector. China currently has an electric car market share close to 1.5 per cent[89] and is aiming for ten per cent of its manufacturing output in the country to be either low or zero emission from 2019, rising to 12 per cent in 2020. India has stated an aspiration for all new cars sold to be electric by 2030[90].

The **transport sector** is also seeing the acceleration of a rapid shift to clean technology supported by government leadership and global investment.

Between 2011 and 2016, the number of electric vehicles (EVs) on the road globally increased thirtyfold[91] and governments are announcing increasingly ambitious targets that are driving even more rapid changes. The Government has announced an end to the sale of all new conventional petrol and diesel cars and vans by 2040[92]. France has also announced the end of petrol and diesel car sales by 2040[93], Norway is aiming for 100 per cent ultra low emissions vehicle sales by 2025[94], and China has recently announced a requirement for at least 10 per cent of auto manufacturers' output in the country to be either low or zero emission from 2019, rising to 12 per cent in 2020[95].

Meanwhile auto manufacturers are rapidly expanding their plans for new ultra low emission vehicle models, from just ten in 2010 to more than 200 in 2020[96].

[80] LSE Grantham Institute (2015) China's "new normal": structural change, better growth, and peak emissions http://www.lse.ac.uk/GranthamInstitute/publication/chinas-new-normal-structural-change-better-growth-and-peak-emissions/

[81] Government of India (2017) Draft National Energy Policy

[82] Bloomberg New Energy Finance (2017) LCOE Comparison and Visualisation database

[83] LSE Grantham Institute (2016) China's 13th Five-Year Plan http://www.lse.ac.uk/GranthamInstitute/law/13th-five-year-plan/

[84] Government of India (2017) Draft National Energy Policy

[85] LSE Grantham Institute (2016) China's 13th Five-Year Plan http://www.lse.ac.uk/GranthamInstitute/law/13th-five-year-plan/

[86] Government of India (2017) Draft National Energy Policy

[87] Government of India Ministry of New and Renewable Energy (2016) Draft National Wind-Solar Hybrid Policy: http://tinyurl.com/mwfgwyp

[88] Reuters (2017) China to plow $361 billion into renewable fuel by 2020 https://www.reuters.com/article/us-china-energy-renewables/china-to-plow-361-billion-into-renewable-fuel-by-2020-idUSKBN14P06P

[89] International Energy Agency (2017) Global EV Outlook 2017 https://www.iea.org/publications/freepublications/publication/global-ev-outlook-2017.html

[90] Financial Times (2017) India power minister promotes renewables and 'cleaner' coal https://www.ft.com/content/a106c468-3567-11e7-99bd-13beb0903fa3

[91] International Energy Agency (2017) Global EV Outlook 2017 https://www.iea.org/publications/freepublications/publication/global-ev-outlook-2017.html

[92] Defra, DfT (2017) Air quality plan for nitrogen dioxide (NO2) in UK (2017) https://www.gov.uk/government/publications/air-quality-plan-for-nitrogen-dioxide-no2-in-uk-2017

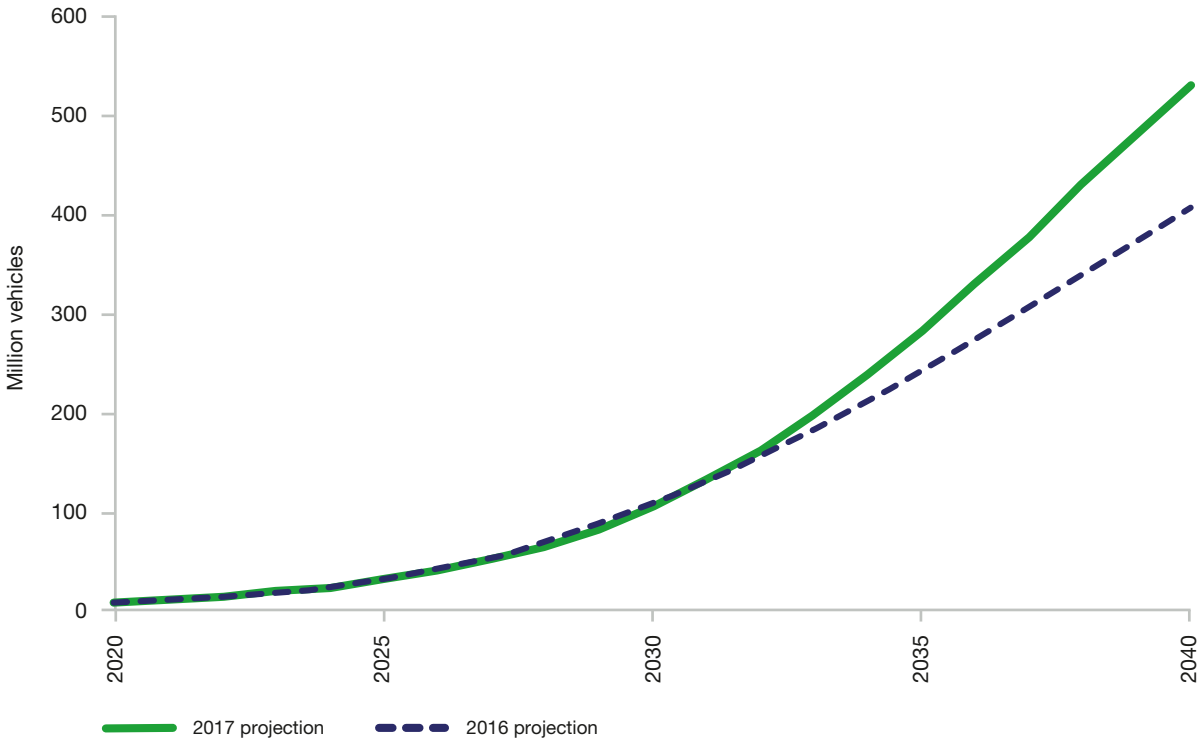
[93] Financial Times (2017) France plans to end sale of petrol and diesel cars by 2040 https://www.ft.com/content/af2fccb0-a29e-3347-bd0f-7597186b5a2a

[94] Norsk Elbilforening (2017) Norwegian EV Policy http://elbil.no/english/norwegian-ev-policy/

[95] Bloomberg (2017) https://www.bloomberg.com/news/articles/2017-09-28/china-to-start-new-energy-vehicle-production-quota-from-2019

[96] Bloomberg New Energy Finance (2017) Global EV and charging policy support database

Figure 7: Global deployment forecasts for electric vehicles have been improving over time[97]



Source: Bloomberg New Energy Finance projections

Globally, sales of EVs are expected to be five times higher in 2020 compared to 2015[98] and to take a rapidly increasing share of the market in an industry whose revenue in 2016 was more than $2 trillion[99].

The global **construction** sector will also be boosted by investment in sustainable infrastructure to meet decarbonisation goals.

Global markets for energy efficient buildings, and for low carbon heating and cooling, are already growing and the market for investment in buildings that reduce emissions and are resilient to climate change in just six key emerging economies in Asia has been estimated at more than $15 trillion up to 2030[100].

There is also a significant expansion in the use of innovative **green finance** to support the investment needed to realise these opportunities with the global markets for green bonds growing rapidly from $7.2 billion in 2012 to over $80 billion in 2016 and expected to break these records in 2017[101].

[97] Bloomberg New Energy Finance (2017) Comparison of Long-Term EV Adoption Forecasts https://www.bnef.com/core/insights/16595

[98] Bloomberg New Energy Finance (2017) Annual long-term forecast of the world's electric vehicle market. https://data.bloomberglp.com/bnef/sites/14/2017/07/BNEF_EVO_2017_ExecutiveSummary.pdf

[99] IBISWorld (2017) Global Car & Automobile Manufacturing: Market Research Report https://www.ibisworld.com/industry-trends/global-industry-reports/manufacturing/car-automobile-manufacturing.html

[100] International Finance Corporation (2016) Climate Investment Opportunities in Emerging Markets

[101] Climate Bonds Initiative https://www.climatebonds.net/

Opportunities for the UK

Just as the UK has led the world diplomatically in addressing climate change, we are also well-placed to take advantage of the global shift to a clean energy economy as we benefit from significant economic competitive advantages, including:

- The most productive science base[102] of the G7 countries – a critical asset, given the extensive innovation required for decarbonisation in many sectors;
- World leading expertise in high-value services[103], with strengths in areas such as finance, law, consultancy, software and data services – all important to enabling the low carbon transition;
- Excellence in the design and manufacture of products based on advanced technologies as in the automotive and aerospace sectors[104]; and
- A policy and regulatory environment that provides long-term direction and supports innovation, with some of the most liberalised gas and electricity markets; a long-term policy framework set by the Climate Change Act and carbon budgets; and an energy regulator which is pioneering in its approach to encouraging companies to innovate[105] with programmes like the 'regulatory sandbox'[106].

We have already capitalised on these strengths to take a leadership position in some important emerging low carbon sectors:

- **Power:** The UK has the most offshore wind generation built anywhere in the world, with around 40 per cent of the global installed capacity[107]. British companies are now benefiting from exports in areas such as cable installation, repairing equipment, construction work and consulting[108].
- **Electric vehicles:** In 2016, one in five battery electric cars driven in Europe was built in the UK[109] and low emission vehicle exports were estimated to be worth nearly £2.5 billion in 2015[110].

[102] BIS (2013) International Comparative Performance of the UK Research Base – 2013 https://www.gov.uk/government/publications/performance-of-the-uk-research-base-international-comparison-2013

[103] Green Alliance (2016) Will the UK economy succeed in a low carbon world? http://www.green-alliance.org.uk/UK_low_carbon.php, citing : World Trade Organisation (2015) World trade report 2015 https://www.wto.org/english/res_e/booksp_e/world_trade_report15_e.pdf (Data table, 'Leading exporters and importers of commercial services, 2014', p28); ONS (2016) International trade in services 2014 ('Total trade in services, all industries (excluding travel, transport, and banking) analysed by product 2014')

[104] BEIS (2017) Building our Industrial Strategy https://www.gov.uk/government/consultations/building-our-industrial-strategy

[105] OECD (2002) Reviews of Regulatory Reform, Regulatory Reform in the United Kingdom, Regulatory Reform in Gas and Electricity and the Professions https://www.oecd.org/regreform/2766184.pdf

[106] Ofgem (2017) Innovation Link – Open Letter: https://www.ofgem.gov.uk/system/files/docs/2017/02/open_letter_regulatory_sandbox_6_february_2017.pdf

[107] IRENA (retrieved September 2017) http://www.irena.org/home/index.aspx

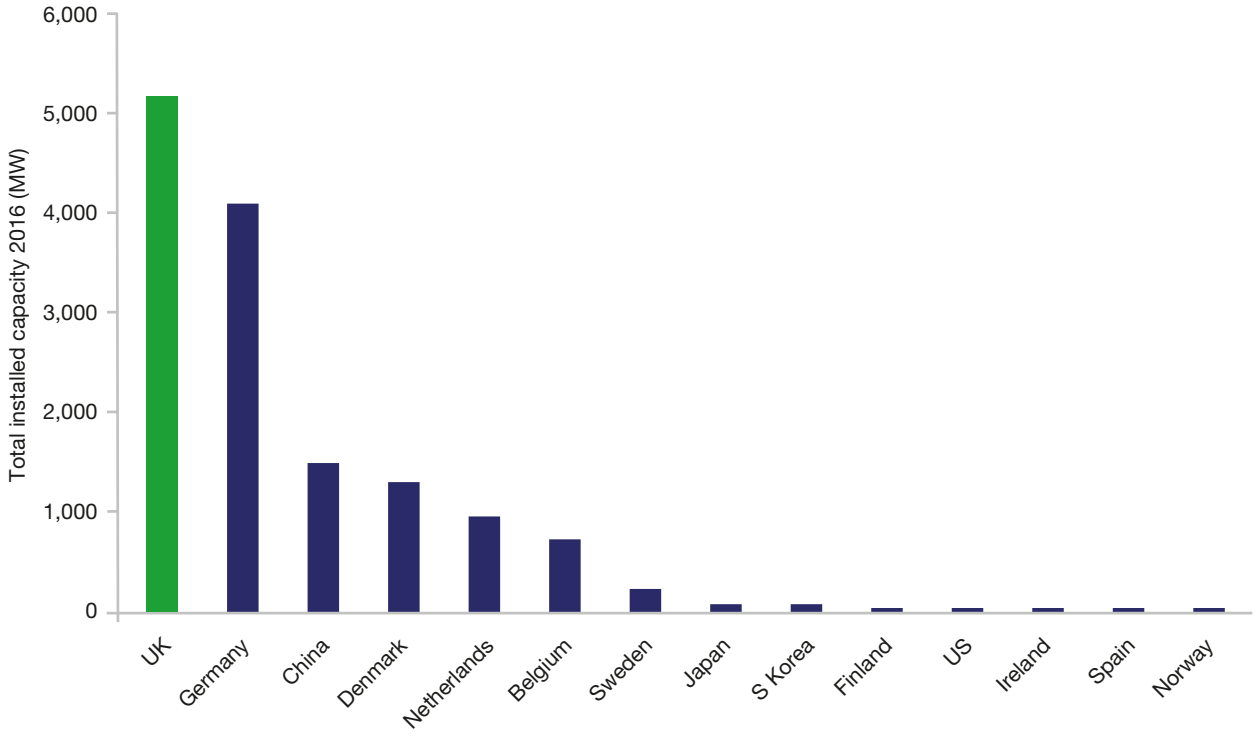
[108] Energy UK (2017) Response to Industrial Strategy consultation http://www.energy-uk.org.uk/press-releases/370-2017/6150-energy-uk-comments-on-the-industrial-strategy-consultation.html

[109] European Alternative Fuels Observatory (2017) Top 5 selling BEV analysis http://www.eafo.eu/vehicle-statistics/m1

[110] ONS (2017) Low Carbon and Renewable Energy Economy Survey, final estimates: 2015 https://www.ons.gov.uk/economy/environmentalaccounts/bulletins/finalestimates/2015results

- **Low carbon financial and professional services:** London is emerging as a leader in low carbon finance, the centre of global carbon trading, and with 50 green bonds listed on the London Stock Exchange, raising a combined $14.8 billion[111] across seven currencies. It has been estimated that UK legal and finance advice was behind a third of new clean energy projects globally between 2007 and 2012[112]. The UK is home to the largest speciality insurance market in the world[113], and is a leading provider of insurance cover for climate-related risks and for large-scale low carbon infrastructure projects.

Figure 8: Offshore wind installed capacity by country[114]



Source: International Renewable Energy Agency

[111] London Stock Exchange 2017

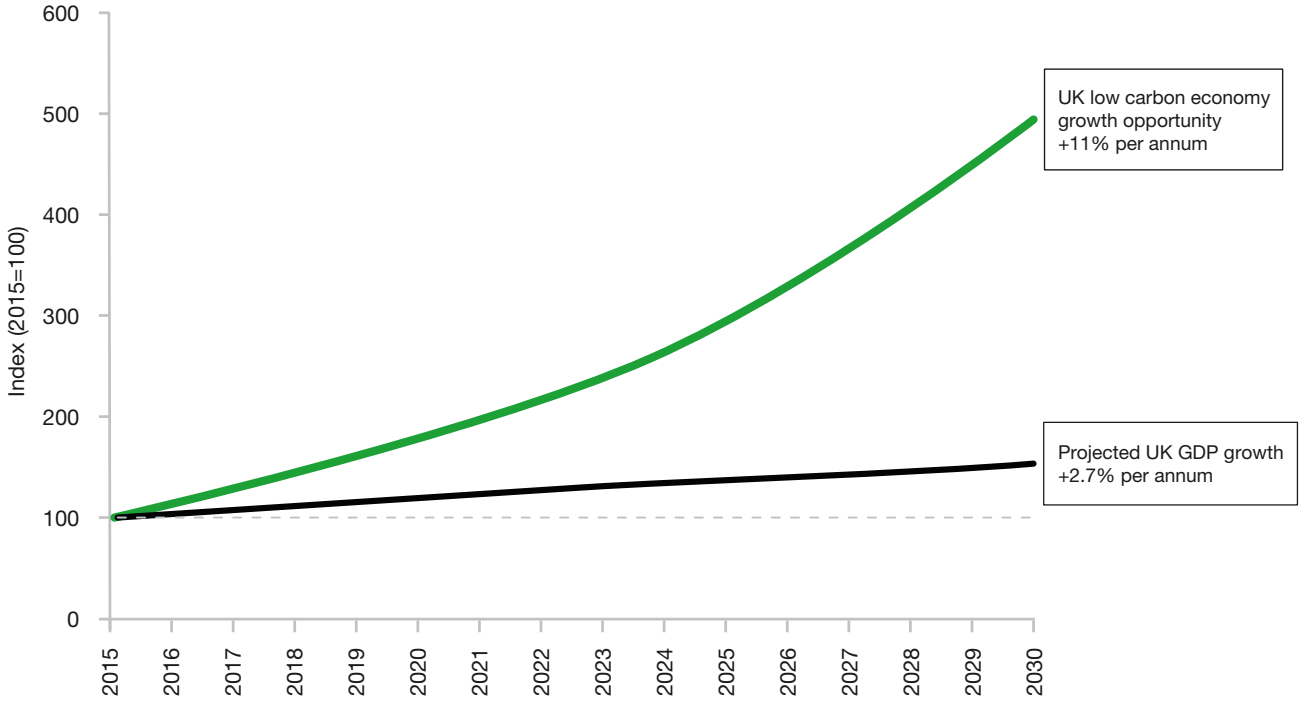
[112] Green Alliance (2016) Will the UK economy succeed in a low carbon world? http://www.green-alliance.org.uk/resources/UKeconomy_lowcarbonworld Bloomberg New Energy Finance (2017) Clean energy and energy smart technologies league tables, 2007-2012 https://about.bnef.com/blog/2016-league-tables-clean-energy/

[113] Boston Consulting Group (2017) London Matters: The competitive position of the London Insurance market https://www.londonmarketgroup.co.uk/lm-2017

[114] IRENA (retrieved September 2017) http://www.irena.org/home/index.aspx

Analysis for the Committee on Climate Change has suggested that if we continue to develop and build on our strengths we can capture significant economic benefits from these decarbonising trends. The UK's low carbon economy could grow at around 11 per cent a year between 2015 and 2030, some four times faster than the average growth rate for the UK economy overall which would mean the low carbon economy would increase from around two per cent of the UK's total output at present to around eight per cent by 2030[114]. The same study estimates that UK exports of low carbon goods and services could be worth between £60 billion and £170 billion by 2030.

Figure 9: Potential growth in UK low carbon economy[116]



Source: Ricardo-AEA for the CCC; OECD

[115] Ricardo Energy and Environment for the Committee on Climate Change (2017) UK business opportunities of moving to a low carbon economy https://www.theccc.org.uk/publication/uk-energy-prices-and-bills-2017-report-supporting-research/

[116] Ricardo Energy and Environment for the Committee on Climate Change (2017) https://www.theccc.org.uk/publication/uk-energy-prices-and-bills-2017-report-supporting-research/; OECD Long-term GDP forecast https://data.oecd.org/gdp/gdp-long-term-forecast.htm

Clean Growth and the UK Industrial Strategy

As we form our Industrial Strategy, we will aim to maximise the UK industrial advantages from the global shift to a low carbon economy. We will build and link together the strengths we already have, while nurturing new ones, so that our whole economy can seize the opportunities presented by this global economic trend.

We have already committed to the **largest increase in public spending for investment in science, research and innovation** in almost 40 years[117]. We will ensure that this is invested to catalyse low carbon innovation across multiple sectors of the economy.

We have also committed to **upgrading our digital, energy, transport, housing, water and flood defence infrastructure**, including through investment in the National Productivity Investment Fund, with annual central government infrastructure investment rising each year from around £2 billion in 2016/17 to over £5 billion in 2020/21[118]. We will ensure that these investments strengthen market demand for the innovative new clean energy technologies and services that our businesses are creating.

We have announced **significant reforms to technical education**, with the creation of new qualifications (T-levels), high-quality work placements, and Institutes of Technology to deliver higher education in STEM subjects. We will ensure that these reforms help train our innovators of the future and provide businesses with the skilled professionals they need to thrive in the clean energy economy[119].

We have welcomed early work on **sector deals** in nuclear, auto manufacturing and industrial digitalisation, all of which are central to productivity in the low carbon economy, and we will challenge businesses in all sectors to increase their competitiveness in relation to the shift to clean energy.

In return, and to maximise the domestic and international opportunities for the UK, we will **strengthen our support for businesses** as part of the transition to the low carbon economy. We have added billions of pounds in potential support for UK exporters, doubling the capacity of UK Export Finance and increasing available cover for individual markets by up to 100 per cent[120], and will dedicate resources within the Department for International Trade to promote investment into the UK renewable energy landscape, develop this supply chain further and support UK exports. So far this has helped to secure investments across the country: into a turbine blade manufacturing plant in Hull[121], a transition pieces yard in Teesside[122] and an MHI Vestas investment into the Isle of Wight[123], which collectively support over 1,400 new jobs.

[117] HM Treasury (2016) Autumn Statement 2016 https://www.gov.uk/government/topical-events/autumn-statement-20161

[118] Ibid

[119] HM Government (2016) Post-16 skills plan and independent report on technical education https://www.gov.uk/government/publications/post-16-skills-plan-and-independent-report-on-technical-education

[120] HM Government (2016) Autumn Statement 2016 https://www.gov.uk/government/publications/autumn-statement-2016-documents/autumn-statement-2016

[121] Siemens http://www.siemens.co.uk/en/wind/hull.htm

[122] 4C Offshore (2015) Offshore Structures (Britain) opens its doors http://tinyurl.com/m3yn5px

[123] MHI Vestas Offshore Wind commences hiring for over 200 jobs on the Isle of Wight, UK http://tinyurl.com/l5nrs25

We are committed to **making the most of the diverse strengths of all of Britain's cities and regions**, to grasp the opportunities that could drive faster growth and increased earning power in each of them. To support this, we have allocated an additional £1.8 billion from the Local Growth Fund for a new set of Growth Deals between Government and Local Enterprise Partnerships (LEPs)[124]. Each region of the UK differs in its local energy resources, its industrial and domestic energy needs, and its expertise. We will ensure that local communities and LEPs are empowered to make the best use of their local skills and resources, so that through the clean energy economy they can drive productivity, job creation and growth.

And we will set out our plans to build on this progress in the Industrial Strategy White Paper, to be published later in 2017, positioning the UK as a leader in the low carbon economy, investing in the foundations required for economic success and ensuring our industries succeed in an economic transition that we are helping to shape and lead.

[124] HM Government (2016) Autumn Statement 2016 https://www.gov.uk/government/publications/autumn-statement-2016-documents/autumn-statement-2016

The Challenges to Delivering Clean Growth

We have high aspirations and are committed to delivering clean growth. But we face three significant challenges that we must overcome if we are to continue progress: ensuring we deliver affordable energy for households and businesses; decarbonising "harder to reach" parts of the UK economy; and establishing a post-EU emissions and environmental framework that is at least as beneficial as current arrangements.

Decarbonising Harder to Reach Sectors and the Use of Flexibilities

As a result of our actions so far we have already driven emissions per head down by nearly half since 1990. This progress meant that we exceeded the target emissions reductions of our first carbon budget (2008 to 2012) by one per cent[125] and we project that we will outperform against our second and third budgets covering the years 2013 to 2022 by almost five per cent and four per cent respectively[126]. This will be a significant achievement.

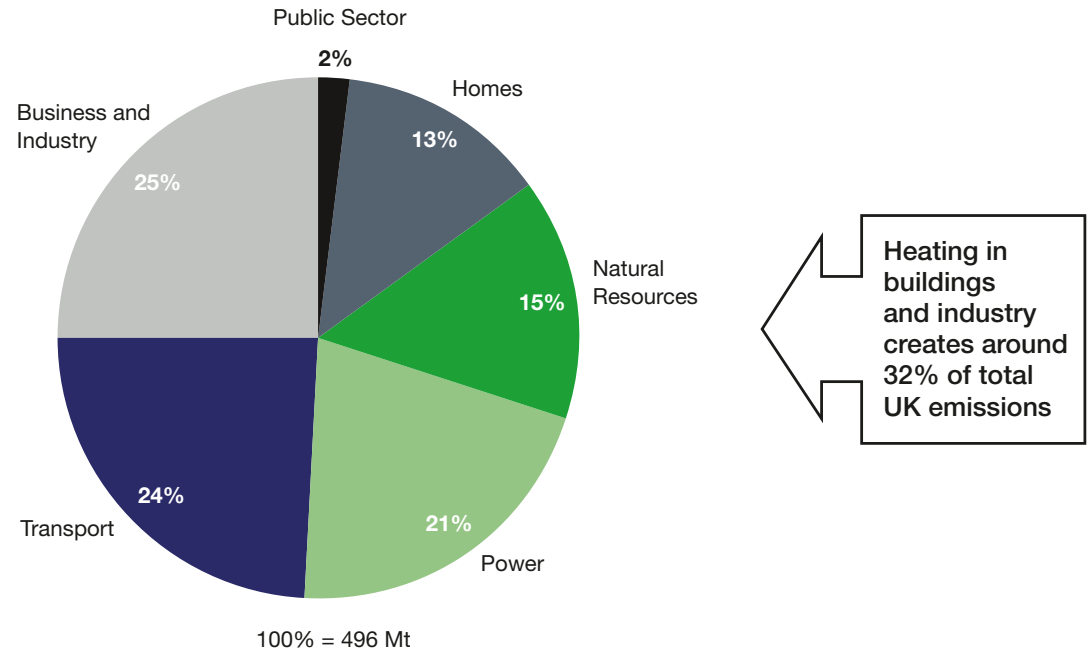
Our achievements to date have been substantially driven by significant decarbonisation of the power and waste sectors and we now need to replicate this success across the economy, particularly in the transport, business and industry sectors which account for almost half of current emissions. And we need further action on heating across key sectors, which is responsible for around a third of emissions.

These are the "harder to reach" parts of the economy requiring more investment, concerted joined up working between government, industry and consumers, or big technological breakthroughs to drive substantial shifts down in carbon emissions. This Strategy sets out how we plan to address some of these difficulties, including how we will target our innovation investment. Cutting emissions in these areas can benefit us all through cleaner air and reduced energy bills which will help improve the UK's productivity. In addition, the innovation and investment required to drive these emissions down can create more jobs and more export opportunities.

[125] DECC (2014) Final statement for the first carbon budget period https://www.gov.uk/government/statistics/final-statement-for-the-first-carbon-budget-period

[126] BEIS (2017) Energy and Emissions Projections 2016 https://www.gov.uk/government/publications/updated-energy-and-emissions-projections-2016

Figure 10: UK emissions by sector, 2015[127]



Source: BEIS

Our approach is pragmatic. Given how much uncertainty underlies projections, we need an approach that is flexible in response to shifting evidence, not least about the impact of policies. It is also right, in our economic circumstances, to be rigorous in examining the costs and benefits of action to reduce emissions, and the right pace of change. The Climate Change Act permits us to use "flexibilities", such as surplus from previous carbon budgets or the purchase of good quality international carbon credits[128], to meet carbon budgets. We are prepared to use the flexibilities available to us to meet carbon budgets, subject to the requirements set out in the Climate Change Act, if this presents better value for UK taxpayers, businesses and domestic consumers.

Our current estimated projection for the fourth and fifth carbon budgets suggests that we could deliver 94 per cent and 93 per cent of our required performance against 1990 levels – for carbon budgets which will end in ten and fifteen years' time respectively[129]. While we have the option to use flexibilities to fully meet our carbon budgets, the ambitious policies and proposals set out in this Strategy, and the rapid progress and accelerating pace of changes in low carbon technologies so far, suggest that we may not need to use this option. We will decide whether to use flexibilities following consultation with the Devolved Administrations, and having obtained and taken into account advice from the Committee on Climate Change.

[127] BEIS (2017) UK Greenhouse Gas Inventory Statistics (1990-2015) https://www.gov.uk/government/collections/final-uk-greenhouse-gas-emissions-national-statistics; BEIS analysis

[128] A good quality carbon credit is one with its emission reduction and sustainability credentials assured.

[129] This includes an initial estimate of 30 Mt and 80 Mt of additional savings in the fourth and fifth carbon budgets respectively from the more advanced policies and proposals in the Clean Growth Strategy. As we move forward and develop the full range of policies and proposals, we will publish individual impact assessments as appropriate with updated analysis.

Table 2: Performance against carbon budgets[130]

		Carbon Budget				
		1 2008-12	2 2013-17	3 2018-22	4 2023-27	5 2028-32
Budget, cumulative emissions, Mt		3,018	2,782	2,544	1,950	1,725
Average reduction vs 1990 emissions, %		-25%	-31%	-37%	-51%	-57%
Existing policies	Projected emissions, cumulative emissions, Mt	2,982 actual	2,650 E	2,453 E	2,096 E	1,972 E
	Result vs. Budget,%	-1.2%	-4.7%	-3.6%	+7.5%	+14.3%
Existing and new policies and proposals[131]	Projected emissions, cumulative emissions, Mt	2,982 actual	2,650 E	2,453 E	2,066 E	1,892 E
	Result vs. Budget, cumulative emissions, Mt	-36	-132	-91	+116	+167
	Result vs. Budget,%	-1.2%	-4.7%	-3.6%	+6.0%	+9.7%
	Cumulative surplus (+) or deficit (-), Mt		+132	+223	+107	-60

The Cimate Change Act 2008[132]

The Act allows Government some flexibility on when and how to reduce UK emissions on route to 2050 but before doing so the Government must obtain and take into account the advice of the Committee on Climate Change and consult the Devolved Administrations. There are three options:

1. **Carry forward over-achievement from earlier budgets:** The Act allows for Government to carry forward over-achievement from one carbon budget to the next, so that early action to reduce emissions increases the following budget[133].
2. **Carry back from later carbon budgets:** The Act allows for the Government to increase the carbon budget in one period with a corresponding tightening of the next carbon budget. This 'borrowing' is limited to one per cent of the later carbon budget.
3. **Use international carbon credits:** The Act allows for the purchase of good quality international carbon credits to contribute to meeting carbon budgets but with a limit on the use of these credits set 18 months in advance of the relevant carbon budget.

[130] BEIS (2017) Energy and Emissions Projections 2016 https://www.gov.uk/government/publications/updated-energy-and-emissions-projections-2016

[131] BEIS initial estimates of a subset of new early stage policies and proposals show an additional potential reduction of up to 30 Mt and 80 Mt over the fourth and fifth carbon budget periods respectively; these and other policies will be developed building on the proposals outlined in the Strategy.

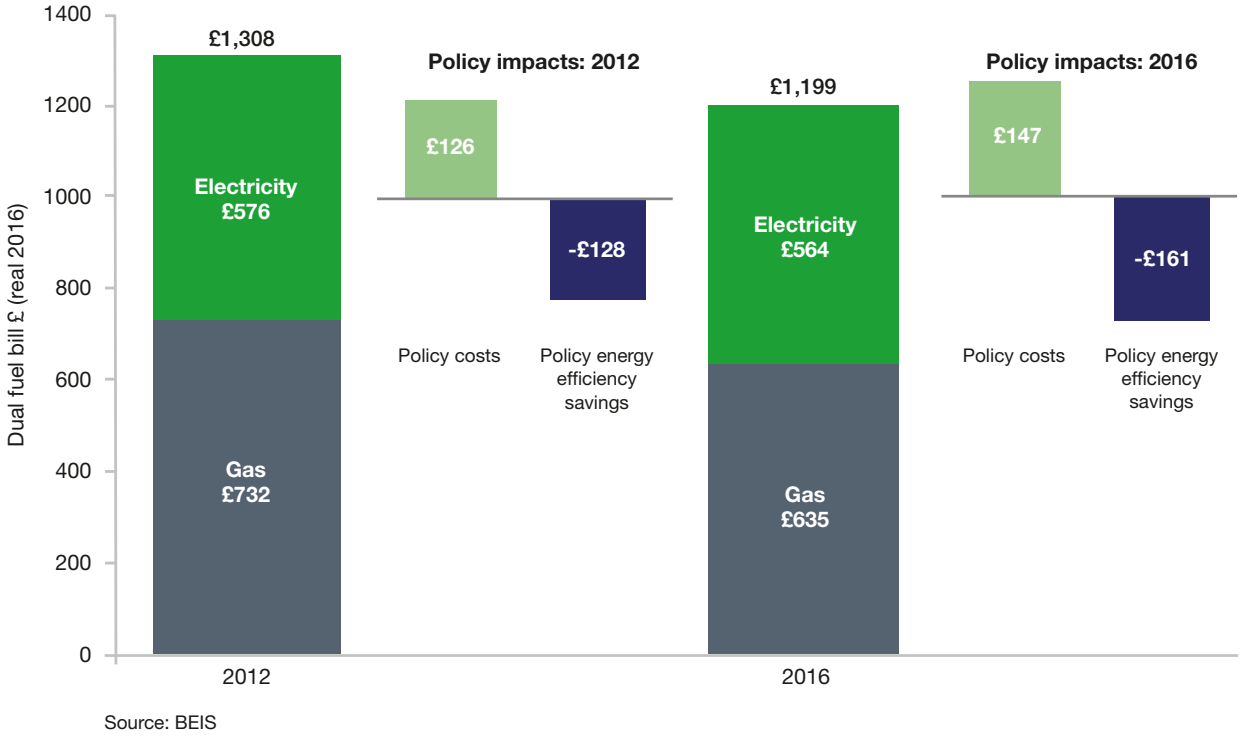
[132] The Act sets out specific requirements to follow before deciding to use a particular flexibility (such as seeking advice from the Committee on Climate Change before banking) or when creating a framework for a decision to be taken within (such as setting a limit on the amount of carbon units which can be used to meet carbon budgets). Any use of flexibilities needs to be consistent with keeping the UK on track to meet its long term target in 2050 having regard to domestic action.

[133] Government will take a decision on whether to bank any surplus from the second to third carbon budget by May 2019 and from the third to the fourth carbon budgets in May 2024. The decision will be made after taking into account advice from the Committee on Climate Change and consulting with the Devolved Administrations.

Delivering Affordable Energy

Actions taken to tackle emissions have helped to reduce average energy bills for households as efficiency savings have more than offset the cost of financial support provided for developing low carbon technologies. The cost of policies delivering cleaner energy, support for vulnerable households and investing in upgrading our buildings accounts for around 12 per cent of an average gas and electricity bill. However, these costs are on average more than offset by savings from improvements to the energy efficiency of people's homes, delivering a saving of £14 on average in 2016 (see figure 11).

Figure 11: Average annual household dual fuel bill, 2012 and 2016



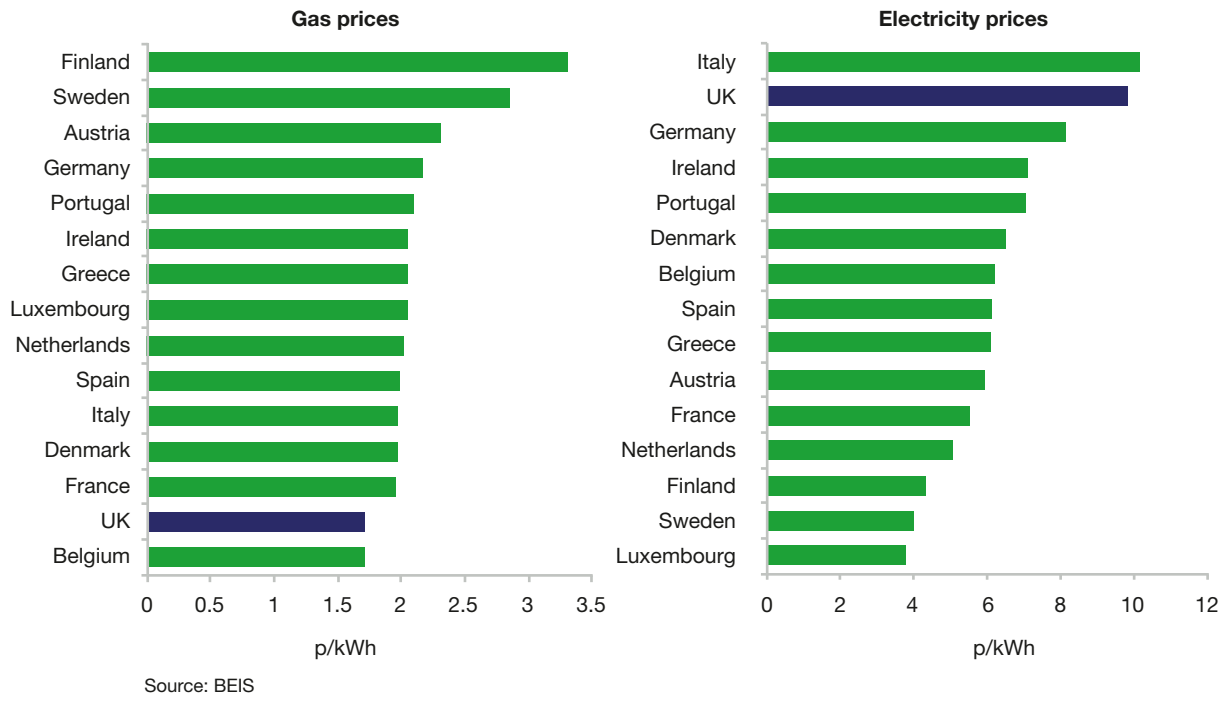
Source: BEIS

Going forward, our efforts to decarbonise will require increased investment across the energy system. However, our focus on innovation will ensure we minimise the costs of this investment as much as possible and further improvements in energy efficiency will continue to drive down bills. We have already seen the costs of offshore wind projects fall 50 per cent since 2015 and we are now seeing investment in solar without government support. We will also make sure that those least able to pay are protected through our work on fuel poverty, and are publishing a draft bill to require Ofgem to impose a cap on standard variable and default tariffs across the whole market.

On industrial energy, there is more to be done. The UK has some of the lowest gas prices in the EU, including for industry. However, our electricity prices are less competitive for large industrial users.

Every action to cut emissions must be taken while ensuring our economy remains competitive. As we have set out in our Industrial Strategy Green Paper, we attach great importance to making sure our energy is affordable. The Government has already supported UK businesses to help them with energy costs through various programmes. For instance the Government has taken steps to reduce the cumulative impact of energy and climate change policies on industrial electricity prices for key Energy Intensive Industries (EIIs) in sectors such as steel, plastics, cement and chemicals. This includes a package of relief for EIIs worth £260 million in 2016 and over £500 million since 2013[134].

Figure 12: Industrial electricity and gas prices for large consumers in the EU15 in 2016, including taxes[135]



Source: BEIS

[134] BEIS analysis. Figure includes compensation for indirect costs from EU Emissions Trading System, Carbon Price Support, Renewables Obligation, and Feed in Tariffs

[135] BEIS (2017) Quarterly Energy Prices https://www.gov.uk/government/collections/quarterly-energy-prices. Notes: Large gas consumers are those consuming 27,778 - 277,777 MWh per annum; large electricity consumers are those consuming 20,000 - 69,999 MWh per annum.

But we want to continue to do everything we can to ensure our energy prices are competitive. This is why the Government has commissioned an independent review into the cost of energy led by Professor Dieter Helm CBE which will recommend ways to deliver the Government's carbon targets and ensure security of supply at minimum cost to both industry and domestic consumers. The review will report on the full supply chain of electricity generation, transmission, distribution and supply, and consider the opportunities to reduce costs in each part. It will set out options for a long term roadmap for the power sector. Once Ministers have considered the review's proposals, the Government will incorporate its recommendations into the further development of the Clean Growth Strategy as appropriate.

Leaving the EU

The British people have voted to leave the European Union and the Government is working to get the best deal for the UK. Leaving the EU offers a unique opportunity to shape our environment and economy for the benefit of all – to have the freedom to make our own decisions on a whole host of matters.

And whatever our future relationship with the EU, the UK's commitment and leadership role in tackling climate change remains undimmed and working closely with the EU on this global challenge will remain important. Leaving the EU will not change any of our statutory commitments to reduce our emissions according to our Climate Change Act – indeed those targets are more ambitious and challenging than those set by EU legislation. There is also no need to change our domestic targets under the Act as a result of leaving the EU, as these targets are rooted in climate science. The UK remains strongly committed to the Paris Agreement and whatever the form of our future partnership with the EU we will satisfy our international obligations under the Agreement.

But there are extremely important current arrangements between the UK and the EU that bring material benefits for all the countries involved and it is critical that we get the detail of our exit negotiations right.

There are four main areas where the UK's current emissions policies rely on EU mechanisms:

- The EU Emissions Trading System (EU ETS) covering the "traded sector" (power, heavy industry and intra EEA aviation) which collectively account for around 40 per cent of UK emissions under carbon budgets. We remain committed to reducing emissions in these sectors and the UK already has a range of domestic policies in place to support this. We will seek to ensure that our future approach is at least as ambitious as the existing scheme and provide a smooth transition for the relevant sectors.
- For sectors not covered by the EU ETS, two sector policies operate at EU rather than UK level and are particularly important for driving emissions reductions – new car and van CO_2 regulations, and EU fluorinated gas quotas. We remain committed to reducing emissions in these areas and will offer certainty to industry as soon as possible on our future relationship with the EU. We will seek to ensure our future approach is at least as ambitious as the current arrangements.
- EU products policy which sets minimum standards for a range of products such as white goods and lighting, which improve energy efficiency. We continue to support these policy measures, which cut energy bills, increase energy security, reduce emissions and help customers make informed choices, and we will keep step with equivalent standards wherever possible and appropriate, or even exceed them where it is in the UK's interest to do so. This may include products not yet covered by European legislation, such as smart appliances.

- Non-energy and climate EU frameworks and policies which affect the UK, such as the Common Agricultural Policy. For instance, we will take the opportunity of leaving the Common Agricultural Policy to address climate change more directly by designing a new system to support the future of farming and the countryside, with a strong focus on delivering better environmental outcomes, including tackling climate change.

Detailed future policies will emerge as we negotiate the exact form of the UK's exit from the EU but while the UK is a member of the European Union, existing rules still apply and we will continue to engage constructively on new and existing EU legislation. Our Clean Growth Strategy therefore uses existing policy as the basis for the UK's emissions projections.

Carbon Pricing and Emissions Trading

Pricing emissions provides a cost-effective and technology neutral way of reducing carbon emissions and mobilising the private sector and in the UK pricing policies like Carbon Price Support (CPS), and the EU Emissions Trading System (EU ETS) have already helped to drive a switch from coal to gas generation in the power sector.

The UK is a pioneer in developing carbon pricing. In 2002 the UK launched the UK ETS, which served as a pilot for the EU ETS, giving businesses early experience of emissions trading and establishing London as its global centre.

The EU ETS is the largest cap-and-trade system for carbon emissions in the world. Each year, every participant must surrender one allowance for each tonne of carbon dioxide (or equivalent) emitted, and allowances are auctioned or allocated between participants. The cap on allowances is reduced annually in line with the EU's climate ambition.

However, a surplus of allowances in the EU ETS has caused the price to fall and it currently provides little incentive for low carbon investment. As a result the UK introduced CPS in April 2013 which acts as a top up to the EU ETS price in the power sector. The UK also supports measures to strengthen the EU ETS, with notable success in recent negotiations. We will continue to drive for ambitious reform for the next phase of the system.

The Government is considering the UK's future participation in the EU ETS after our exit from the EU and we remain firmly committed to carbon pricing as an emissions reduction tool whilst ensuring energy and trade intensive businesses are appropriately protected from any detrimental impacts on competitiveness.

Specifically in relation to the power sector and CPS, starting in 2021/2022, the Government will target a total carbon price which will give businesses greater clarity on the total price they will pay for each tonne of emissions, and we will set out more detail on carbon prices for the 2020s in the 2017 Autumn Budget.

Chapter 3:
Our Clean Growth Strategy

Our Approach

In the context of the UK's legal requirements under the Climate Change Act, our approach to reducing emissions has two guiding objectives:

1. To meet our domestic commitments at the lowest possible net cost to UK taxpayers, consumers and businesses.
2. To maximise the social and economic benefits for the UK from this transition.

In order to meet these objectives, the UK will need to nurture low carbon technologies, processes and systems that are as cheap as possible. We need to do this for several reasons. First, we need to protect our businesses and households from high energy costs. Second, if we can develop the low cost, low carbon technologies in the UK, we can secure the most industrial and economic advantage from the global transition to a low carbon economy. Third, if we want to see other countries, particularly developing countries, follow our example, we need low carbon technologies to be cheaper and to offer more value than high carbon ones.

We cannot predict every technological breakthrough that will help us meet our targets. Instead, we must create the best possible environment for the private sector to innovate and invest. Our approach will mirror that of our Industrial Strategy: building on the UK's strengths (see Chapter 2 and below on green finance); improving productivity across the UK; and ensuring we are the best place for innovators and new business to start up and grow. We are clear about the need to design competitive markets and smart regulation to support entrepreneurs and investors who will develop the new technologies at the scale we need. It is only through innovation – nurturing better products, processes and systems – that we will see the cost of clean technologies come down. This Strategy sets out how more than £2.5 billion will be invested by the Government to support low carbon energy innovation from 2015-2021. These actions will help our wider aim of improving the UK's earning power.

In addition to supporting innovation, we are focused on policies that deliver social, environmental and economic benefits beyond the imperative to reduce emissions. Better buildings are healthier places to live and work. Reducing the amount of heat we waste will reduce bills. High ambition on electric cars and other low emission vehicles contains a triple win for the UK in terms of industrial opportunity, cleaner air and lower greenhouse gas emissions. Crucially, many of the actions included here will enhance the UK's energy security.

Alongside these actions, we are laying the groundwork for major decisions in the areas where we face greatest uncertainty and challenge: in how we reduce the emissions that result from heating our homes and businesses; how we decarbonise our transport system; and how we work with industry to make carbon capture, usage and storage (CCUS) a viable future option. This has been shaped by our analysis of plausible pathways out to 2050, reflecting the huge uncertainties. In every section of the Strategy, we also explore the opportunity to shape new commercial opportunities for the UK that can help improve skills and create good jobs.

Building on the UK's Strengths: Green Finance

Private sector investment in low carbon technology and infrastructure will be key to meeting our carbon budgets and realising the economic opportunities from the low carbon transition. Around £180 billion of investment is already in the pipeline to build the power stations needed in the UK to produce clean and secure supplies of electricity and the networks to deliver this to homes and businesses[136].

To meet our decarbonisation challenge we will need to mobilise more private capital in sustainable projects and develop more innovative risk sharing financial structures for investment in domestic and commercial low carbon technology. This is a major business and export opportunity for the UK and could cement the UK's position as the leading hub for global low carbon investment.

UK Leadership in Green Finance

We already demonstrate global leadership on green finance around the world through initiatives like the G20 Green Finance Study Group, which we co-chair; the Green Finance Initiative, a partnership between the financial and professional services sector, academics and civil society, which promotes the UK as a leading global centre for green finance; and through participation in senior global multilateral fora such as the Financial Stability Board's Task Force on Climate-related Financial Disclosures (TCFD), which recently published its final recommendations.

The first offshore green bond issued by an Indian entity and the first green bond issued by a Chinese bank were listed on the London Stock Exchange and 50 green bonds denominated in seven currencies with a value of $14.8 billion are now listed in the UK[137].

On 31st July 2017, Anglian Water released the first ever public utility Sterling Green Bond on the London Stock Exchange.

Improving the energy performance of homes is vital in decarbonising our economy. Mortgage lenders have a significant financial stake in these properties, their future value, and their customers' ability to make their repayments. This is why the Government supported the LENDERS[138] project with funding from Innovate UK. We want to see the project recommendations implemented, including improving mortgage affordability assessments on energy bills, and lenders to develop a range of innovative new "green mortgage" products to encourage consumers to purchase more efficient homes, or improve their efficiency.

[136] Figure is total for electricity generation, electricity distribution and electricity transmission. Real 2015/16 prices. Gov.uk (2016) National Infrastructure and Construction Pipeline https://www.gov.uk/government/publications/national-infrastructure-and-construction-pipeline-2016

[137] London Stock Exchange 2017

[138] UKGBC (2017) Lenders core report https://www.ukgbc.org/ukgbc-work/lenders-core-report/

To capture and exploit this opportunity we need to go further. This is why we have set out in this Strategy a series of policies and proposals to develop our expertise in, as well as the opportunity from, new green finance solutions. These include:

- Setting up a Green Finance Taskforce[139], comprising senior representatives from the finance industry and Government, to develop ambitious policy proposals which could further accelerate private sector investments to deliver our Clean Growth Strategy.
- Endorsing the recommendations put forward by the Financial Stability Board's Task Force on Climate-related Financial Disclosures and encouraging publicly-listed companies to implement these recommendations.
- Working with the British Standards Institution (BSI) to develop a set of voluntary green and sustainable finance management standards to promote responsible investment practices globally. The BSI will have completed the necessary standards scoping exercises and have the first standard in production by the first half of 2018.
- Providing up to £20 million of new investment to support clean technology early stage funding, alongside creating an online platform to showcase UK businesses which have received innovation support from the Government. This will make this information easily accessible for early stage investors to help increase the flow of investment into innovative businesses in the UK.
- Working with mortgage lenders to develop green mortgage products that take account of the lower lending risk associated with more efficient properties and the reduced outgoings for customers living in more efficient homes.

Ensuring the UK is the Best Place for Low Carbon Innovators

Our Industrial Strategy Green Paper made clear that, for the UK economy to flourish, it must do things other advanced economies cannot do, or do them in better ways. This is the essence of innovation. This is a core part of our approach to decarbonising the UK's economy where investment in innovation will help us to:

- Drive down the cost of key technologies, systems and processes and increase the value they deliver to consumers (such as with batteries and electric vehicles);
- Lay the groundwork for decisions where the right technology choices are currently less clear (such as how we will heat our homes and businesses in the future); and
- Nurture technologies and businesses where the UK is a global leader, leveraging private sector investment and building international partnerships to create export opportunities.

Innovation involves incremental improvements, cross-sector knowledge sharing, and "breakthroughs". It results from competition within the private sector and from collaboration between the private sector and Government, as well as other organisations; each has a role in producing, spreading and adopting novel technologies and approaches. The Government is often more active at earlier stages of innovation, through investment in research, education and skills. Later on, private firms play a bigger role, bringing new technologies to market. However, there is no single, linear route for innovations to progress from concept to commercialisation and often innovation in one area has applications in others.

We want to use the power of Government to support innovation in a low carbon economy using all the tools available to us, including market design, taxation and regulation, as well as investment in our education system, our

[139] The list of members can be found at https://www.gov.uk/guidance/green-finance

science base and innovative companies. Our aim is to become one of the best places in the world for low carbon innovation. We understand the need for Government funding that is accessible to private, public and community sector organisations with all playing key roles in supporting and harnessing innovation.

Government funding can be key to stimulating private sector investment from the UK and overseas, both through direct leverage and by creating confidence in the potential to attract follow-on investment for particular innovations. Public investment brings in around 30 per cent additional private funding over the short term, with this increasing in the longer term[140].

The Government has significantly increased its investment in low carbon innovation. Between 2015 and 2021 we expect to invest more than £2.5 billion in research, development and demonstration of low carbon energy, transport, agriculture and waste. This includes:

- Up to £505 million from BEIS's Energy Innovation Programme[141], which aims to accelerate the commercialisation of innovative clean energy technologies and processes.
- Up to £1.2 billion of funding from the combination of UK Research Councils and Innovate UK – now being brought into one organisation with the creation of UK Research and Innovation. These investments include funding for the Energy Systems Catapult and the Offshore Renewable Energy Catapult.
- Up to £246 million for the Faraday Challenge, which will ensure the UK builds on its strengths and leads the world in the design, development and manufacture of electric batteries[142].
- Up to £620 million from a range of Departments, including BEIS, DfT, DfID and Defra and additional Industrial Strategy Challenge Fund (ISCF) support.

In addition to this Government funding, Ofgem is making up to £720 million of regulated expenditure available to gas and electricity network companies in Great Britain, to support smarter, more flexible, efficient, and resilient networks. The Government is also stimulating industry-academia collaboration, for example through the Agri-tech catalyst, which will help improve agricultural productivity and contribute to more environmentally sustainable agricultural systems.

BEIS Energy Innovation Programme

New projects announced as part of the BEIS Energy Innovation Programme in the Clean Growth Strategy include:

- Up to £10 million for innovations that provide low carbon heat in domestic and commercial buildings
- Up to £10 million for innovations that improve the energy efficiency of existing buildings
- An extra £14 million for the Energy Entrepreneurs Fund, including a new sixth fund
- Up to £20 million in a carbon capture and utilisation demonstration programme
- Up to £20 million to demonstrate the viability of switching to low carbon fuels for industry
- Up to £7 million to develop further the capability of nuclear regulators who support and assess advanced nuclear technologies
- Up to £20 million to support clean technology early stage funding

[140] BIS (2014) Analysis Paper 04 Estimating the effect of UK direct public support for innovation https://www.gov.uk/government/publications/innovation-effect-of-public-support

[141] The £505 million BEIS Energy Innovation Programme will invest around £70 million in smart systems, around £90 million in the built environment (energy efficiency and heating), £100 million in industrial decarbonisation and carbon capture, usage and storage (CCUS), around £180 million in nuclear innovation, around £15 million in renewables innovation, and around £50 million in support for energy entrepreneurs and green financing.

[142] BEIS press release (2017) https://www.gov.uk/government/news/business-secretary-to-establish-uk-as-world-leader-in-battery-technology-as-part-of-modern-industrial-strategy

Last November, the Prime Minister announced £4.7 billion of additional research and development funding[143] – a bigger increase than in any Parliament since 1979. This funding aims to kick start the development of disruptive technologies, including low carbon technologies, that have the potential to transform the UK economy[144]. It includes the Faraday Challenge and £93 million for Robotics and Autonomous Systems, and we are exploring the scope to fund further clean growth innovation challenges.

Internationally, governments around the world are investing around $15 billion a year in low carbon innovation, and this figure is set to rise significantly[145]. A key component of our innovation strategy is identifying opportunities for global partnership. In particular, the UK is committed to clean energy innovation as a member of 'Mission Innovation'. This initiative aims to reinvigorate and accelerate global clean energy innovation and to make clean energy widely affordable. As part of our commitment within Mission Innovation, the UK will invest at least £100 million in 2020-21 on projects that will help to address the clean energy needs of developing countries[146].

How we spend money is just as important as how much we spend. To ensure a strategic approach, a new Energy Innovation Board was launched in 2016[147], to bring together senior representatives from across the Government, Innovate UK, Research Councils, and Ofgem, to align public investments in low carbon innovation. The Board aims to co-ordinate the UK's domestic and international clean energy and low carbon innovation activities to maximise their impact, and to ensure that those investments leverage increased private sector investment.

Energy Entrepreneurs Fund

The Government is also launching a sixth round of the Energy Entrepreneurs Fund, which has been running since 2012, and aims to support, through capital grants, the development and demonstration of innovative energy technologies and processes, with a particular focus on assisting small and medium sized enterprises. This sixth round will offer up to £10 million in funding. Alongside this, a further £4 million has been offered to companies who applied for the fifth funding round, bringing the total to £14 million across the projects supported[148].

Over phases one to five of the Energy Entrepreneurs Fund, we have invested £47.2 million in 102 companies, which leveraged a further £35 million from the private sector. For those companies that have completed their projects, over £63 million in follow-on private investment has been secured.

For instance Vantage Power in West London retrofit buses to a low carbon standard. This is done at a fraction of the cost of purchasing new hybrid buses, and means that operators can reduce their fuel consumption and emissions. Vantage Power were beneficiaries of the Energy Entrepreneurs Fund, and the buses they have retrofitted have reported up to 40 per cent lower fuel consumption and 92 per cent lower emissions of nitrogen oxides.

[143] HM Treasury (2016) Autumn Statement 2016: https://www.gov.uk/government/publications/autumn-statement-2016-documents/autumn-statement-2016 Section 4.1

[144] BEIS press release (2017) https://www.gov.uk/government/news/business-secretary-announces-industrial-strategy-challenge-fund-investments Investment subject to business case approval.

[145] Mission Innovation website, Baseline and Doubling Plans: http://tinyurl.com/mkgyvlx

[146] DECC press release (2015) UK joins international clean energy initiative: https://www.gov.uk/government/news/uk-joins-new-international-clean-energy-initiative

[147] Further information on the Energy Innovation Board available here: https://www.gov.uk/government/groups/energy-innovation-board

[148] The Energy Entrepreneurs Fund is funded through the £505 million BEIS Energy Innovation Programme

Table 3: Government investments in clean growth technology 2015-2021[149]

	Forecast Clean Technology Innovation Spend £ million (across Innovate UK, Research Councils, BEIS, DfT, DfID, Defra)			
	Basic & Applied Research	Technology Development	Technology Demonstration	Total
Innovation in Smart Systems (including energy storage)	175	43	47	**265**
Innovation in the Power Sector (including renewables)	209	276	154	**638**
Innovation in Homes (including heat and energy efficiency)	100	31	53	**184**
Innovation in the Transport Sector (including electric vehicles and batteries)	296	413	132	**841**
Innovation for Business and Industry, including carbon capture, usage and storage (CCUS)	57	47	58	**162**
Innovation in Natural Resources	69	30	0	**99**
Cross-sector Clean Tech Innovation (including for entrepreneurs)	234	62	91	**387**
Total (£ million)	**1,140**	**902**	**534**	**2,576**

NB All figures are indicative and are subject to competitive bidding processes across sectors and value for money tests.

[149] Final spending commitments are subject to competitive bidding processes across sectors and value for money tests. Excludes £720 million of regulated expenditure being made available by Ofgem to support innovation in gas and electricity networks.

Clean Growth Innovation Challenges

To get the clean growth we want, we need breakthroughs in clean technologies. Government funding and innovations in universities are crucial, but such breakthroughs also need the creativity and energy of the private sector. We have identified the key challenges we believe need to be overcome if we are to meet future carbon budgets:

Hydrogen and bioenergy

Clean fuels such as hydrogen and bioenergy could be used for transport, industry, and to heat our homes and businesses. We need to test how they work in the existing gas network, whether they can fire industrial processes, and how they could be used in domestic appliances. These options need to work as well and as cheaply as current technologies.

Homes

We need energy efficiency and heat technologies that are less costly and easier to install, and commercial innovation to ensure retrofits are attractive for homeowners. To build lower cost, lower carbon homes, we need to use innovative construction methods including factory production and off-site manufacturing.

Batteries

To rapidly decarbonise transport, including rail and EVs, we need innovation in batteries: to extend their range and lifetime, bring down their cost, and ensure they can be disposed of sustainably. New methods for charging are needed to make electric vehicles easier to use, including super-fast charge points, wireless charging and dynamic charging.

Smart energy system

Clean technologies such as electric vehicles, batteries, fuel cells and renewable energy are all falling in cost. We need to ensure these technologies can integrate smoothly in the energy system, including finding local solutions, so that consumers benefit from lower energy and transport costs.

Power

We need to bring down the costs of nuclear power through developing new materials and manufacturing processes, and exploring the opportunities of new fuels and reactor designs. To further reduce the cost of offshore wind, we need to deliver larger turbines, extend existing asset life, optimise performance and reduce operational maintenance.

Industry

We need to find alternatives to industrial fuels which are energy intensive to produce, without increasing cost or reducing performance. The cost of CCUS technologies will need to fall.

Waste

We need to minimise the impacts of anaerobic digestion, particularly in relation to air quality. This includes developing improved digestion and ammonia and phosphate extraction technologies and reducing methane emissions. Innovative techniques are also needed to reduce the impact of landfills at the end of their use.

Land use

To support greater productivity of agricultural land, we need to: increase carbon storage through fertilising crops more effectively, develop new animal and plant breeding technologies, use precision farming technologies on smaller scale farms, and develop robotics and new sensor technologies. We also need to reduce plant and tree disease and investigate methods to improve soil health and carbon stocks.

Getting to 2032

We cannot predict the exact technological changes that will help us deliver on the fourth and fifth carbon budgets (and beyond). Some technologies will develop faster than expected, making it easier to reduce emissions in particular sectors. Some technologies may develop less quickly than we hope.

To explore this uncertainty, we test different potential versions of the future based on current knowledge. These are not firm predictions of the future and should not be taken as sectoral targets. However, they allow us to identify areas where progress is most needed to meet our future carbon budgets, especially the fifth carbon budget, and where action now is unlikely to be wasted. The policies and proposals set out in this Strategy reflect that understanding.

Our Clean Growth Strategy sets out in detail a possible pathway for meeting the fifth carbon budget through domestic action, including many of the policies and proposals set out here. The route we ultimately take to meeting our targets will depend on a range of factors, in particular ensuring we are mindful of any impact on energy costs for households and businesses, and changes in costs as a result of innovation.

The approach could involve[150]:

- Emissions from business and the public sector falling by 30 per cent on today's levels, through significant improvements in energy efficiency, reducing energy use per unit of output as well as reducing the carbon content of industrial energy use by at least 14 per cent through switching to cleaner fuels. Our proposals will contribute to this, for example improving business energy efficiency and standards for commercial buildings, and agreeing tighter targets to reduce central government emissions.
- Emissions from homes falling by 19 per cent from today, with household energy use falling nine per cent, through a combination of switching low-carbon heating and greater energy efficiency which in turn will help to reduce bills. We will also need to bring down the cost of low carbon alternatives to the gas boiler. This is supported by the proposals set out in this Strategy, including investments in upgrading homes and proposals to improve energy performance standards across the housing sector.
- Emissions from transport falling by 29 per cent from today, largely achieved by accelerating the shift to electric and other low emission vehicles. This transition could involve reducing the energy and emissions intensity of road transport[151] by 30 per cent and 44 per cent respectively. Our proposals, such as those to encourage uptake of ULEVs, will contribute to this.
- Emissions from power falling by 80 per cent on today's levels, by increasing the share of clean electricity generation to over 80 per cent of demand and moving to a smarter, more flexible system and reducing demand by improving the efficiency of appliances. The proposals set out in this Strategy, for example providing further funding for Contract for Difference auctions for renewable technologies, will help to deliver this.
- Emissions from land use and agriculture falling by 26 per cent on today's levels. This could mean that woodland cover increases by up to 16 per cent and the emissions intensity of agricultural outputs could improve by 27 per cent. Emissions from waste and F-gases fall to around 14 Mt by 2032, 53 per cent lower than today. This could mean that the amount of biodegradable waste sent to landfill in 2032 is around 45 per cent lower than that seen in 2015. This is supported by the proposals in this Strategy, such as those to reduce emissions from waste and to establish a new network of forests.

[150] Total sector emissions reductions are compared against estimated 2017 levels. Supplementary metrics, where relevant, compared the 2032 pathway with 2015 official statistics. See Table 4 in Annex D, and Table 6 in the Technical Annex for details.

[151] Covering cars, van and freight

BBOXX

BBOXX was formed by students at Imperial College London in 2010. In addition to $2 million in private funding, since 2013 BBOXX received £1.2 million, including from the EPSRC and DfID, to tackle the challenges and opportunities arising from unreliable electrical supplies in rural Africa. By providing households with off-grid electric lighting, children can do their homework and families can run a business without incurring threats to their health from paraffin smoke. Since 2006, BBOXX has created a sustainable non-subsidised business model. Rapidly expanding from three founders to a global staff of 140, BBOXX products have already saved energy worth over $2 million and offset over 40,000 tonnes of CO_2. BBOXX aims to provide up to 20 million people with electricity by 2020.

Innovation can deliver dramatic results, as we have seen with the rapid falls in the costs of some clean technologies over the past ten years, and this Strategy sets out ambitious proposals on funding innovation to further reduce costs. We take a cautious approach towards quantifying the contribution of current and future innovation to emissions savings. As we cannot say precisely how our investments today will impact on the UK's emissions in the future, we have omitted any estimates from this analysis.

We estimate the combination of existing policies and new measures in this Strategy that can be quantified could deliver 93 per cent of the required level of emissions savings for the fifth carbon budget, against our 1990 baseline. As well as setting out policies within this Strategy, we identify areas where we will need to drive further progress through future consultations, innovation spend and policy design. This is set out in more detail at Annex A.

Beyond the Fifth Carbon Budget, Towards 2050

There is even greater uncertainty about which technologies will help us reduce emissions by at least 80 per cent by 2050[152]. It is even more challenging to predict what the UK economy will look like in 2050 than in 2032. However, exploring the plausible potential pathways to 2050 helps us to identify low-regrets steps we can take in the next few years common to many versions of the future, as well as key technologies and uncertainties. To demonstrate this, we present three illustrative long-term pathways in this Strategy:

[152] On a 1990 baseline.

- **Electricity pathway:** Under this pathway, electricity is the main source of energy in 2050. There are many more electric vehicles (EVs), we replace our gas boilers with electric heating and industry moves to cleaner fuels. Altogether this means we use around 80 per cent more electricity than today, and virtually all of it comes from clean sources (renewables and nuclear). In this pathway, CCUS is not used in the UK by 2050.
- **Hydrogen pathway:** Under this pathway, we use hydrogen to heat our homes and buildings, as well as to fuel many of the vehicles we drive in 2050 and power the UK's industry. We adapt existing gas infrastructure to deliver hydrogen for heating and a national network of hydrogen fuelling stations supports the use of hydrogen vehicles. A large new industry supports hydrogen production using natural gas and capturing the emissions with CCUS.
- **Emissions removal pathway:** Under this pathway, sustainable biomass power stations are used in tandem with CCUS technology. Carbon is removed from the atmosphere by plants (biomass) as they grow and, when the biomass is used to generate electricity, emissions are captured and stored instead of returning to the atmosphere. There is still a significant clean transition in other sectors but successful innovation in emissions removal allows more time for some of these changes.

These illustrative pathways should not be seen as predictions, as we are continuing to build our understanding of the best approach. The ultimate way forward might in fact be some combination of these, or another approach that builds on further innovation. This approach will also be consistent with Government's commitments on clean air out to 2050.

The purpose of these illustrations is to demonstrate a range of practical ways in which emission reduction aims can be delivered with technology known today, and to underline some of the steps common to all. These include:

- making our homes and commercial buildings more energy efficient;
- shifting to low carbon sources of heating, such as through more district heating;
- continuing to decarbonise electricity;
- ensuring our electricity system is smart and flexible to respond to changes in demand and decarbonise at least cost;
- increasing the number of ultra low emission vehicles in the UK; and
- working with industry on how to improve efficiency and transition to clean fuels.

Greenhouse Gas Removal Technologies

As the UK approaches 2050, its remaining emissions will likely be in the sectors where it is the most difficult to cut them – in industry, agriculture, aviation and shipping. Under the Paris Agreement, as well as seeking to limit warming to well below 2 degrees, and to pursue 1.5 degrees, the UK is committed to working with other countries to achieve global net zero emissions in the second half of the century[153]. This will require a step change in action to tackle climate change and has strong links to how the Sustainable Development Goals will be achieved.

[153] This means that global GHG emissions will not be greater than the amount of GHGs which are absorbed through natural processes or technology.

As highlighted by the Committee on Climate Change[154], greenhouse gas removal (GGR) technologies are likely to have an important role to play in offsetting difficult-to-cut emissions, by removing greenhouse gases from the air. As we learn more about how GGRs could be developed and deployed, we want the UK's entrepreneurs, universities and engineering industries to be well placed to exploit the advantages of global demand for these new technologies.

There is a diverse set of GGR technologies with varying potential scale and at varying stages of development. These include afforestation, bio-energy with carbon capture and storage (BECCS), direct air capture (capturing carbon dioxide from the air and storing it), enhanced weathering (crushing suitable rocks that react with carbon dioxide and spreading over land), and methods for storing carbon in the oceans, such as ocean liming.

We are therefore taking active steps to strengthen our understanding of these technologies and, where appropriate, move forward with deployment. The Government's strategic approach to GGR has two main elements:

- **A Government programme of research and development,** which aims to improve our understanding of GGR technologies, to help overcome the uncertainties around their costs, deployment potential, and impacts on the environment. We have been working with the Research Councils, who launched a new £8.6 million research programme looking at all GGR technologies in April 2017. We will also develop robust estimates of sustainable biomass resource available to the UK, reporting during 2018, and consider Royal Society scientific views on GGR.
- **The Government will consider the scope for removing barriers and strengthening incentives to support the deployment of GGR**, to position the UK at the leading edge of GGR development. This includes, for example, considering options for developing a carbon offset market and exploring how UK timber could be used in construction. We are also considering how best to take forward CCUS, as set out in 'Improving Business and Industry Efficiency and Supporting Clean Growth'. We will conduct a study on how GGR activity can be incentivised, in the UK and in other countries, which will help us develop policy and accounting frameworks fit for the future. And we will also consider how legal, financial and regulatory frameworks could support the rollout of GGR technologies at scale.

We will develop our strategic approach for GGR technologies, including consideration of whether to reprioritise existing innovation spend, in light of these pieces of work.

Global Net Zero Emissions

As well as seeking to limit warming to well below 2 degrees, and to pursue 1.5 degrees, the Paris Agreement includes an aim of achieving net zero global greenhouse gas emissions in the second half of the century. Our obligations under the Climate Change Act only take us to 2050, and the Government agrees with the Committee on Climate Change that now is not the right time to set a post-2050 net zero goal. We need to understand more about the global path to net zero emissions, and believe that our focus should be on meeting our existing targets. However, the Government believes the UK will need to legislate for a net zero emissions target at an appropriate point in the future, to provide legal certainty on where the UK is heading.

[154] Committee on Climate Change (2016) UK climate action following the Paris agreement: https://www.theccc.org.uk/publication/uk-action-following-paris/

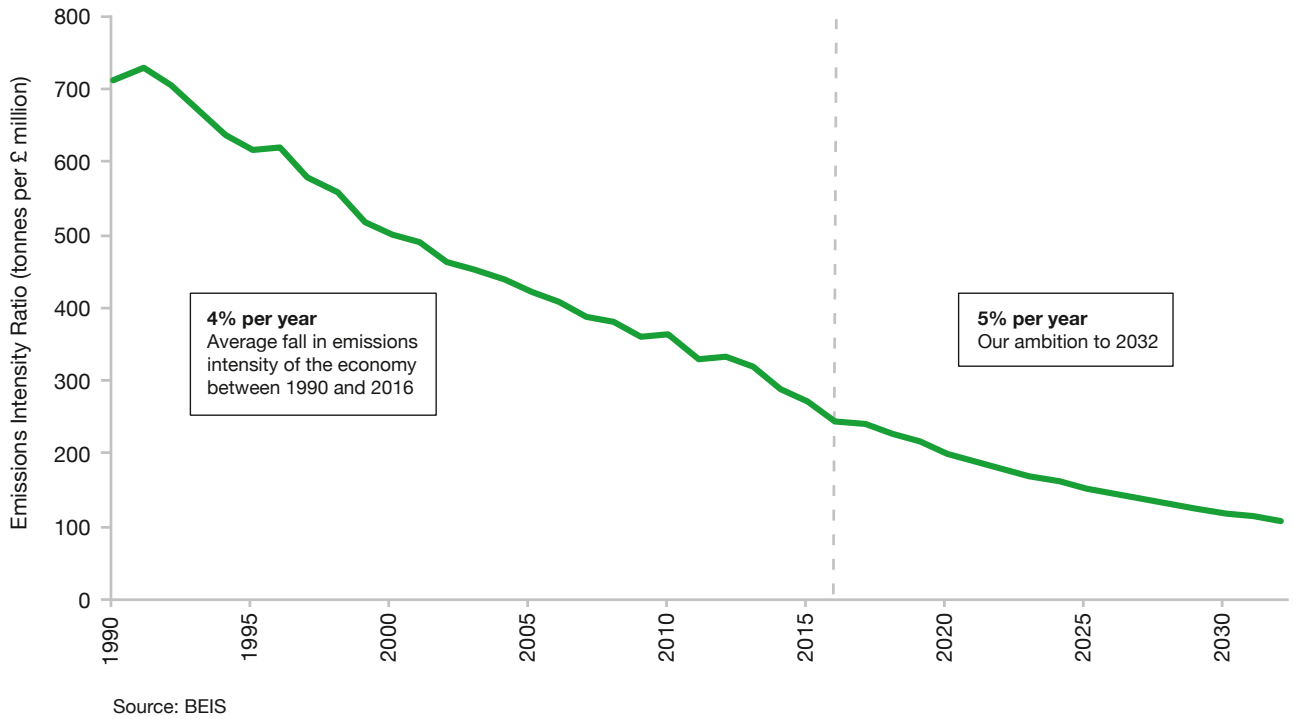
Measuring the Delivery of the Clean Growth Strategy

This Strategy sets out a comprehensive set of policies and proposals that will allow us to accelerate the pace of clean growth. We want to continue the UK's strong economic growth while achieving that growth in a way that sees emissions fall. Between 1990 and 2016 emissions fell by 42 per cent whilst GDP grew by 67 per cent which meant that the "emissions intensity" of our economy – the amount of carbon emitted for each pound of national income generated - fell by four per cent per year on average. We want to build on this success and accelerate clean growth. To reach our targets, the emissions intensity will have to fall by an average five per cent per year to 2032. We will therefore introduce a new measure of progress, the Emissions Intensity Ratio (see below) and publish our performance against this intensity ratio on an annual basis.

The Emissions Intensity Ratio (EIR)

This will measure the amount of greenhouse gases (tonnes of carbon dioxide equivalent) produced for each unit of Gross Domestic Product (GDP) created. Currently the EIR is 270 tonnes/£ million and it was 720 tonnes/£ million in 1990. By 2032, we expect the EIR will need to be nearly as low as 100 tonnes/£ million to meet our ambitions.

Figure 13: Historic and projected Emissions Intensity Ratio (EIR)



Source: BEIS

Government Leadership

To maintain cross-Government progress on clean growth, we will reinstate a regular Clean Growth Inter-Ministerial Group, which will be responsible for monitoring the implementation of this Strategy and driving ambitious clean growth policies.

The Government cannot achieve the changes needed to our economy by itself. Outside action on public sector emissions, the Government's key role is to set the framework for action across the economy. Beyond that, clean growth has to be a shared endeavour between Government, business, civil society and the British people.

Creating this supportive environment will help attract the domestic and international investment the UK wants. Therefore, from 2018, we will work with private partners and NGOs to introduce a **Green Great Britain Week**, to engage as many people as possible in the importance of tackling climate change and improving air quality. A week of high profile activity, this will be an opportunity to both celebrate UK leadership on climate change and look ahead to explore how we can continue to drive ambitious action in the future. This annual event will be an important moment to bring together all parts of society, from business through to the general public, to better understand the different ways the UK can further harness clean growth to boost economic performance, reduce emissions and create a cleaner environment.

Green Great Britain Week

An annual event to:

- Focus on climate and air quality issues across the UK, demonstrating how all parts of the country and sectors of the economy are working towards a cleaner future.
- Demonstrate our progress and successes by showcasing how taking action on climate change and air quality can provide opportunities for UK businesses and citizens.
- Share the latest climate science, providing a platform for the latest research on the impacts of climate change and the importance of taking ambitious action.
- Promote UK leadership on tackling climate change and air quality across our economy, and how we are driving forward innovation to create economic opportunities from reducing emissions, especially to international investors.

Chapter 4:
Sectors

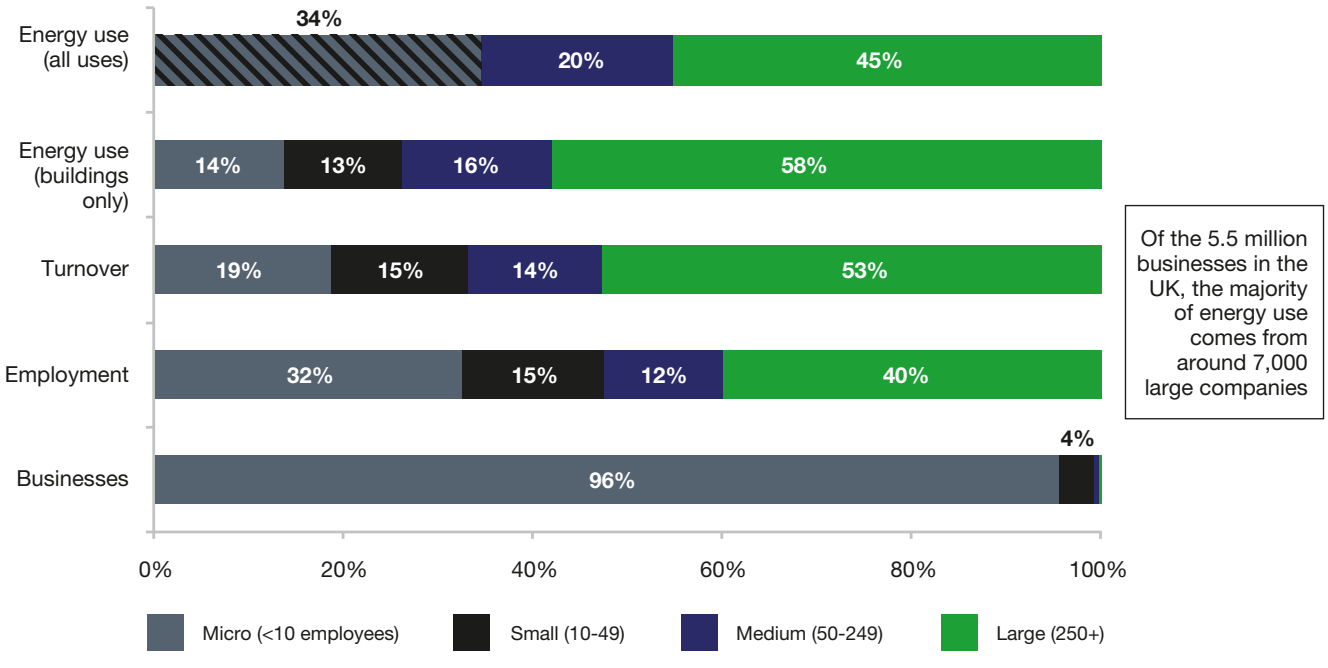
Improving Business and Industry Efficiency and Supporting Clean Growth

Progress

Since 1990, emissions from business and industry have almost halved, mainly due to efficiency gains and a shift in manufacturing to cleaner fuels, as well as changes to the industrial structure of the UK economy. Much of this reduction has taken place in the most energy intensive industries. For instance, each tonne of steel produced in the UK requires 40 per cent less energy to produce than 40 years ago[155].

In addition, we have also improved the energy efficiency of non-domestic buildings since 1990 with emissions 18 per cent lower in 2015[156]. The number of properties registering as having the lowest Energy Performance Certificates (EPC Bands F and G) has dropped from 19 per cent to 13 per cent between 2010 and 2016[157].

Figure 14: Distribution of energy use, turnover, and employment by business size (2016)[158]



Source: Derived from Business population estimates, Non-Domestic National Energy Efficiency Data-Framework and Business Energy Efficiency Survey

[155] WSP and Parsons Brinckerhoff & DNV GL (2015) Report prepared for DECC & BIS: Industrial Decarbonisation & Energy Efficiency Roadmaps to 2050 https://www.gov.uk/government/publications/industrial-decarbonisation-and-energy-efficiency-roadmaps-to-2050

[156] BEIS (2017) Final UK greenhouse gas emissions national statistics: 1990-2015 https://www.gov.uk/government/statistics/final-uk-greenhouse-gas-emissions-national-statistics-1990-2015

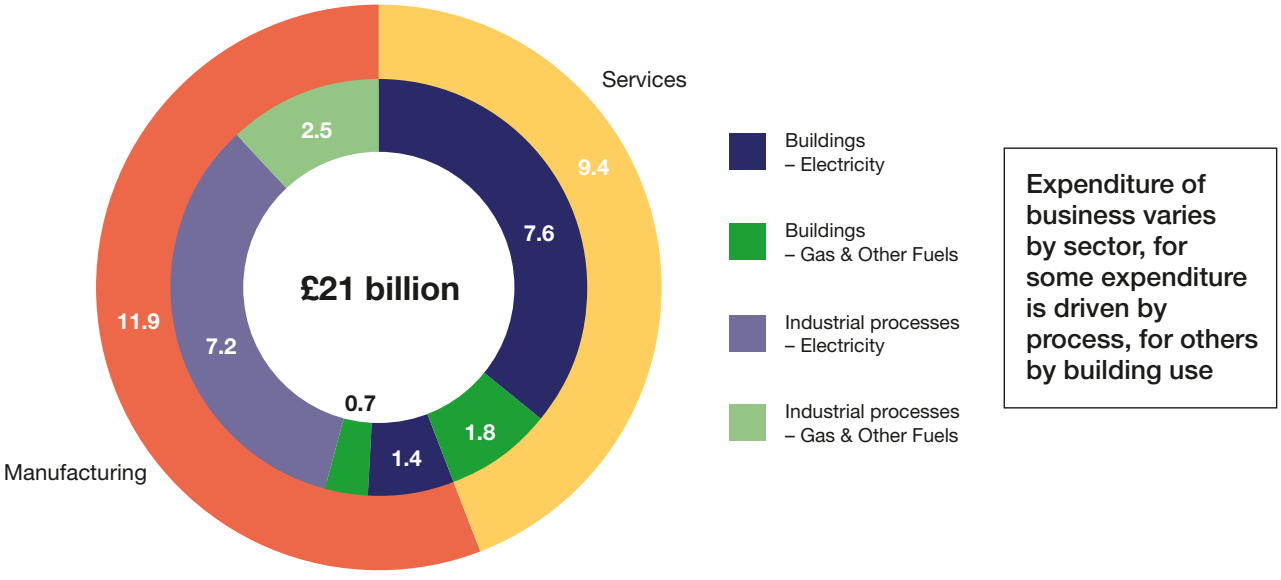
[157] DCLG (2017) Live tables on Energy Performance of Buildings Certificates https://www.gov.uk/government/statistical-data-sets/live-tables-on-energy-performance-of-buildings-certificates

[158] BEIS (2016) Business population estimates 2016 https://www.gov.uk/government/statistics/business-population-estimates-2016; BEIS (2014) Non-domestic National Energy Efficiency Data-Framework (ND-NEED) https://www.gov.uk/government/statistics/non-domestic-national-energy-efficiency-data-framework-energy-statistics-2006-12

Overall, business and industry now account for approximately 25 per cent of the UK's emissions (excluding fluorinated gases or F-gases)[159], with around two thirds of industrial emissions coming from a small number of energy intensive sectors (for example chemicals, iron and steel)[160]. Businesses and industry are also major users of electricity, accounting for over 50 per cent of electricity use[161].

We now have a much greater understanding of the potential for cost-effective energy efficiency in the commercial and industrial sector. Our analysis says that up to £6 billion[162] could be saved in 2030 through investment in cost-effective energy efficiency technologies. Roughly half of these savings are available through improving the efficiency of buildings and processes, including by fitting better insulation and smarter energy controls. The other half can be realised through eliminating electricity waste in business for example using better lighting and energy management systems. This is consistent with research from EEF, the manufacturers' trade association, which found that a 14 per cent reduction in electricity consumption could be made across the manufacturing sector, equivalent to over £1 billion a year in savings[163].

Figure 15: 2015 final energy expenditure[164] on energy by end use and fuel, £ billion, 2016 prices.



Source: Energy Consumption in the UK & Building Energy Efficiency Survey

[159] BEIS (2017) Final UK greenhouse gas emissions national statistics: 1990-2015 https://www.gov.uk/government/statistics/final-uk-greenhouse-gas-emissions-national-statistics-1990-2015

[160] BEIS (2017) Final UK greenhouse gas emissions national statistics: 1990-2015 https://www.gov.uk/government/statistics/final-uk-greenhouse-gas-emissions-national-statistics-1990-2015

[161] BEIS (2017) Digest of UK Energy Statistics 2017 https://www.gov.uk/government/statistics/energy-chapter-1-digest-of-united-kingdom-energy-statistics-dukes

[162] Total energy efficiency potential across business and Industry

[163] EEF (2016) Upgrading Power: Delivering a flexible electricity system https://www.eef.org.uk/resources-and-knowledge/research-and-intelligence/industry-reports/upgrading-power-report

[164] Excluding expenditure on energy used for raw material extraction or transformation to other fuels (e.g. oil extraction and refining) and excluding energy used for transportation

CRESS Systems

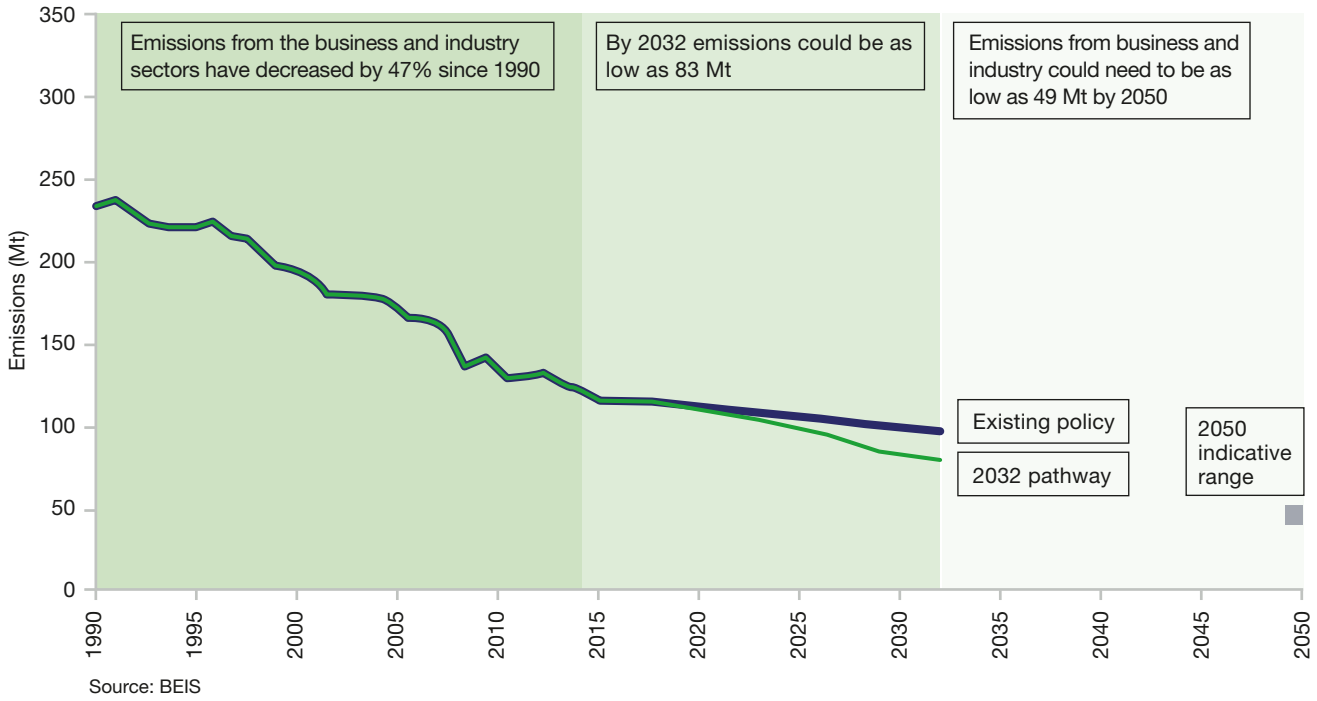
CRESS Systems, based in Darlington, have developed a flywheel to reduce the energy required to drive cranes at shipping ports. They received Energy Entrepreneurs Fund grants of £800,000 to build and test the first system at the Port of Felixstowe. Since then, they have secured investment from Enterprise Ventures' Northern Powerhouse Investment Fund and private investors to finalise the product and make first sales into the port market world-wide.

Ambition

The Government is determined to help businesses improve their productivity and competitiveness as part of our Industrial Strategy. This includes working together to unlock any potential energy savings to help keep bills as low as possible.

Our goal is to enable businesses and industry to improve energy efficiency by at least 20 per cent by 2030. This will contribute to overall economic growth by reducing the amount of energy required per unit of output. We will take a final decision on the level of this goal and how best to measure progress toward it in 2018, taking into account the recommendations of the independent review into the cost of energy, led by Professor Dieter Helm CBE.

Figure 16: Actual and projected emissions in business and industry, taking into account the clean growth pathway, 1990-2050

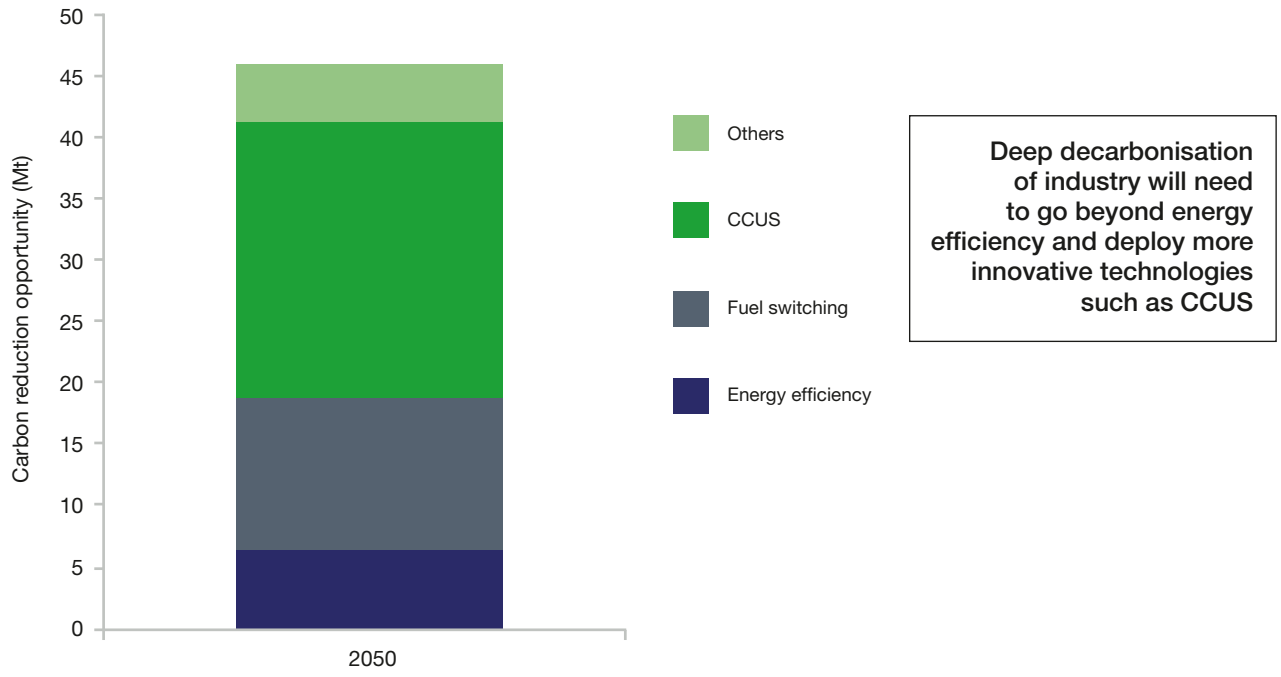


The Government will put in place a simpler, more ambitious and long-term policy and regulatory framework. This will:

- Make it easier for businesses to identify where they can save energy by simplifying the energy and carbon reporting framework.
- Ensure that those who lease premises to businesses, including in the service sector, continue to refurbish and improve the performance of their buildings. In parallel, all new commercial and industrial buildings should be more energy efficient.
- Help to understand how we can encourage greater investment in energy efficiency measures and technologies, including establishing an Industrial Energy Efficiency scheme to help large companies install measures to cut their energy use, and working with the financial sector to identify how such measures can be taken forward.

Energy intensive industries will require steps beyond energy efficiency. Out to 2030, this will require industry to make progress in switching from fossil fuel use to low carbon fuels such as sustainable biomass, in line with broader Government priorities on delivering clean air, and clean electricity. Beyond 2030, this switching will need to substantially increase in scale and be coupled with the deployment of new technologies, for example carbon capture, usage and storage (CCUS). Over the course of this Parliament, we will therefore also develop a framework to support the decarbonisation of heavy industry. Overall, one possible pathway to 2032 could involve emissions from business and industry falling by around 30 per cent on today's levels to as low as 83 Mt by 2032.

Figure 17: Carbon reduction opportunities across industry (2050)[165]



Source: 2050 Roadmaps Cross-Sector Summary report (2015). This illustrates the technical potential for emissions savings in the report's 'MAX TECH' pathway.

Opportunities

The UK energy efficiency sector already turns over £20.3 billion, employs 144,000 people and sells exports worth over £1 billion[166]. We know the potential for further energy efficiency in businesses and industry is significant - up to £6 billion could be saved by 2030 through investment in cost-effective energy efficiency technologies in buildings and industrial processes. As well as reducing bills across the UK, building the energy efficiency market would place UK businesses and industry in a prime position to further increase the export of knowledge, skills and products to other countries. It would also involve greater flows of external finance, a sector where the UK is already a market leader. For example, the UK energy services market is estimated to have a potential annual size of €1 billion per year and would require significantly more third party finance than we see currently[167].

[165] BIS, DECC (2017) Industrial Decarbonisation and Energy Efficiency Roadmaps to 2050 https://www.gov.uk/government/publications/industrial-decarbonisation-and-energy-efficiency-roadmaps-to-2050 'Fuel switching' includes a small amount of bioenergy used for feedstock

[166] ONS (2017) Low Carbon and Renewable Energy Economy Survey, final estimates: 2015 https://www.ons.gov.uk/economy/environmentalaccounts/bulletins/finalestimates/2015results

[167] EC (2014) The European ESCO Market Report 2013 https://ec.europa.eu/jrc/en/publication/eur-scientific-and-technical-research-reports/european-esco-market-report-2013

Policies and Proposals

Unlocking Business Energy Efficiency

1. The Government will develop a package of measures to support businesses to improve how productively they use energy and will consult on this in 2018, with the aim of improving energy efficiency by at least 20 per cent by 2030.
2. The Government will ensure incentives for investment in energy efficiency are regularly reviewed, for instance the list of products that qualify for enhanced capital allowances tax relief.
3. We will continue with plans to close the CRC Energy Efficiency Scheme following the 2018-19 compliance year. We will drive energy efficiency by implementing the previously announced increase to the main rates of the Climate Change Levy from 2019.
4. We will undertake an evaluation of the Climate Change Agreements to inform any successor scheme from 2023.
5. The Government will build on existing schemes such as the Energy Savings Opportunity Scheme (ESOS), undertaking a comprehensive assessment of its effectiveness and consider any future reforms.
6. The Government will work with stakeholders to improve the market for energy services, building confidence across commercial and industrial customers.
7. Alongside this Strategy, we are consulting on a new and streamlined energy and carbon reporting framework to replace some existing schemes, such as the reporting element of the CRC Energy Efficiency Scheme, and align with mandatory annual greenhouse gas reporting by UK quoted companies. This will improve the way in which businesses report their energy use, and provide businesses with the information needed to identify how they can reduce energy bills.
8. The Government will establish an Industrial Energy Efficiency scheme to help large companies install measures to cut their energy use and their bills.
9. We are consulting on the design of a new industrial heat recovery programme. This £18 million fund will encourage investment by manufacturers to recover and reuse heat from industrial processes that would otherwise be wasted.
10. The Government will explore with stakeholders how we can improve the provision of information and advice to SMEs to encourage the uptake of energy efficiency technologies.

Anglian Water

Anglian Water's 'Love Every Drop' campaign aims to significantly reduce carbon emissions, including in their supply chain, and encourage customers to be more resource efficient and cut down their carbon emissions. Their manifesto, published in 2015, aims to raise awareness about how essential water is to life, to people and the environment, and to a vibrant and growing economy too. This helped to save £2.5 million in energy costs in 2016. They have also issued the first ever public utility green bond this year, raising £250 million to finance a range of sustainable projects and support the company's vision of sustainability, carbon reduction, water efficiency and environmental stewardship.

More Energy Efficient Commercial and Industrial Buildings

11. The Government has commissioned an independent review of Building Regulations and fire safety, being led by Dame Judith Hackitt. The review will report in spring 2018. Subject to the conclusions of that review, the Government intends to consult on making improvements to Building Regulations requirements for new and existing commercial buildings where there are cost-effective and affordable opportunities, and it is safe and practical to do so. This will look to promote low carbon and higher energy efficiency heating, ventilation and air conditioning systems in new commercial buildings.

12. 42 per cent of business buildings' energy use is in the private rented sector[168]. We will consult in 2018 on how best to improve the energy performance of these buildings through tighter minimum energy standards.

13. The Government will explore how voluntary building standards can support future improvements in business building performance.

14. As we work to understand different options for the long term decarbonisation of heat, we will need to tackle the challenge of those business properties off the gas grid, particularly those heated by oil boilers and facing volatile costs. Beyond support through the Renewable Heat Incentive (RHI), our ambition is to phase out the installation of high carbon fossil fuel heating in new and existing business buildings off the gas grid during the 2020s, starting with new buildings as these lend themselves more readily to other forms of low carbon heating. We will involve businesses and industry in developing our new policy, in line with broader Government priorities on delivering clean air.

[168] BEIS (2016) Building Energy Efficiency Survey (BEES) https://www.gov.uk/government/publications/building-energy-efficiency-survey-bees

Transforming Manufacturing and Heavy Industry

15. Alongside this Strategy, we have published joint industrial decarbonisation and energy efficiency action plans with seven of the most energy intensive industrial sectors, building on three years of joint industry-Government co-operation. These action plans identify steps by industry and Government that can be taken now to support long term low carbon growth, energy efficiency and emissions reductions on a sector by sector basis. These include the sharing of best practice and innovation opportunities, including through a new online portal, facilitating dialogue to improve access to finance and cross-sector consideration of the best uses of biomass across industry.

16. The Government remains committed to using carbon pricing as an emissions reduction tool and will ensure that a clear price signal continues to incentivise industrial emissions reduction.

17. We will develop a framework to support the long term low carbon development of energy intensive industrial processes, such as CCUS and electrification.

Government Innovation Investment

The Government expects to invest around £162 million[169] of innovation funding out to 2021, in research, development and demonstration of energy, resource and process efficiency alongside better low carbon fuels and CCUS. This includes:

- Energy efficiency: We need to drive down the cost of new technologies to integrate them into existing processes and improve performance without affecting reliability. The Government is providing £9.2 million for an Industrial Energy Efficiency Accelerator, to help reduce the emissions from UK industry by increasing the commercially viable options available.

- Processes, resource and material efficiency: Over time we will need to replace materials which are energy intensive to produce with lower carbon ones at competitive prices, known as “advanced materials”. Government will work through Industrial Strategy sector deals and the Industrial Strategy Challenge Fund to stimulate innovation in advanced materials. We will also need to encourage more resource efficient business models, extend product life and reduce waste volumes. The Industrial Digitalisation Review will investigate how the design, development and deployment of digital technologies can drive increased national productivity.

[169] All figures are indicative and are subject to competitive bidding processes across sectors and value for money tests

- Fuel Switching: Firing industrial processes with low carbon fuels (such as hydrogen) is currently viewed as prohibitively expensive and disruptive. Innovation can prove the viability of these fuels without impacting operations. Government will invest up to £20 million in competitions from 2018, initially for research followed by competitions for demonstrator projects across industry.

Carbon Capture, Usage and Storage

There is a broad international consensus that carbon capture, usage and storage (CCUS) has a vital future role in reducing emissions. This could be across a wide range of activities such as producing lower-emission power, decarbonising industry where fossil fuels are used and/or industrial processes as well as providing a decarbonised production method for hydrogen which can be used in heating and transport. This makes CCUS a potentially large global economic opportunity for the UK. The International Energy Agency estimates there will be a global CCUS market worth over £100 billion - with even a modest share of this global market, UK GVA could increase to between £5 billion and £9 billion per year by 2030[170].

However, the current technology is expensive and there are only 21 large-scale plants operating, or in construction, across the world – of which 16 rely on revenue from providing carbon dioxide for enhanced oil recovery[171].

Our Clean Growth Strategy is underpinned by three commitments: to reduce our emissions in the most cost-effective way: to maximise innovation to develop world leading technologies and to seek the maximum possible benefits from investment for improving the productivity of the UK economy. While we have explored ways to deploy CCUS at scale in the UK since 2007, the lack of a technological breakthrough to reduce the cost of CCUS and the cost structures and risk sharing that potential large-scale projects have demanded has been too high a price for consumers and taxpayers. It is clear from the relative lack of deployment of the technology that other governments have reached a similar conclusion.

However, we have continued to invest in innovation and technology development both in the UK and overseas. To date we have invested over £130 million in R&D and innovation support to develop CCUS in the UK, supporting the development of technologies including NET Power's Allam cycle, Carbon Clean Solutions and C-Capture. We are also one of the leaders in providing aid support to CCUS internationally through our support to CCUS pilot projects in countries with a fossil fuel-intensive energy sector, such as Mexico, South Africa, and Indonesia.

[170] CCSA & TUC (2014) The economic benefits of carbon capture and storage in the UK http://www.ccsassociation.org/press-centre/reports-and-publications/

[171] Large-scale CCS facilities http://www.globalccsinstitute.com/projects/large-scale-ccs-projects

Carbon Capture, Usage and Storage (continued)

Investing in cutting edge technology to achieve global cost reductions in CCUS

As a global leader in supporting the development of cutting edge technologies, the Government provided £7.5 million for the early development support to the UK invented Allam cycle technology used by NET Power. This technology has the potential to capture 100 per cent of the carbon dioxide emitted at a cost similar to that of an unabated Combined Cycle Gas Turbine (CCGT).

This early support from the Government in a cutting edge technology has been critical to developing the technology and for the 8 Rivers NET Power project to reach demonstration scale. In March 2016, construction began on the NET Power pilot project, a 50 MWth first-of-its-kind natural gas-fired power plant located in Texas and the plant is expected to start operations in late 2017. The pilot project also includes significant UK content with two UK companies – Goodwins Steel Castings Ltd and Heatric involved in the project.

We now see a new opportunity for the UK to become the global technology leader for CCUS, working internationally with industry and governments to bring about global cost reductions. We will do this through:

Re-affirming our commitment to deploying CCUS in the UK subject to cost reduction:

We will build on the success of the Offshore Wind Cost Reduction Taskforce[172] and convene a CCUS Cost Challenge Taskforce to deliver a plan to reduce the cost of deploying CCUS. This will then underpin

a deployment pathway for CCUS in 2018, setting out the steps needed to meet our ambition of deploying CCUS at scale during the 2030s, subject to costs coming down sufficiently. This will include looking at the options for permanent storage of carbon dioxide domestically as well as elsewhere via international shipping.

Following the advice from the Parliamentary Advisory Group on CCUS the Government will review the delivery and investment models for CCUS in the UK to understand how the barriers to deployment can be reduced, and how the private and public sectors can work together to deliver the Government's ambition for CCUS.

We will work with the ongoing initiatives in Teesside, Merseyside, South Wales and Grangemouth to test the potential for development of CCUS industrial decarbonisation clusters.

We will set up a new Ministerial-led CCUS Council with industry to review our progress and priorities. Through the CCUS Council we will also monitor costs and deployment potential with the option of revising our deployment path accordingly.

[172] Offshore Wind Cost Reduction Taskforce https://www.gov.uk/government/groups/offshore-wind-cost-reduction-task-force

International collaboration: The Government will convene and lead a new international working group to drive down the cost and accelerate deployment of CCUS, including by:

- Participating in Mission Innovation and its Carbon Capture Challenge and working closely with private-sector led initiatives such as the Oil and Gas Climate Initiative;
- Developing closer collaborative working with countries such as Norway, the United States, Canada and Australia including joint working on innovation and carbon dioxide transport and storage solutions and working multi-laterally through the Carbon Sequestration Leadership Forum and North Sea Basin Task Force;
- Continuing to be a global leader in CCUS investments through the UK's £60 million international CCS programme which has been running since 2012, by investing a further £10 million in the programme. This will further strengthen international action on CCUS and draw on UK technical and commercial expertise; and
- Organising an international Global Carbon Capture Usage and Storage Conference in 2018 with international partners.

Innovation: The Government will spend up to £100 million from the BEIS Energy Innovation Programme to support Industry and CCUS innovation and deployment in the UK including £20 million of funding available for a carbon capture and utilisation demonstration programme to invest in new innovative technologies that capture and utilise carbon dioxide. The programme will also support next generation capture technologies, with an aim to lower the cost of capture compared to the current best performing technologies; and small-scale industrial capture demonstrations to reduce the risks associated with carbon capture on an industrial site. We also intend to support the application of CCUS in low carbon hydrogen production; develop our understanding of the role of GGR technologies, including bio-energy with carbon capture and storage; and support innovations that reduce the cost of transporting and storing carbon dioxide. The Government intends to set out further detail in 2018.

Investing in supporting new UK CCUS technologies and companies

The Government has provided over £4 million to support Carbon Clean Solutions Ltd, a UK headquartered company. This has supported the research, development and deployment of their novel carbon capture solvent technologies contributing to cost reductions in both the capital and operating costs of the technologies.

In early 2017, building on this early support from the UK Government, Carbon Clean Solutions launched an innovative carbon capture and utilisation project in India. In March 2017 Carbon Clean Solutions signed a partnership agreement with the global resource management company, Veolia, for a large-scale rollout of Carbon Clean Solution's carbon capture technology in a number of industrial processes.

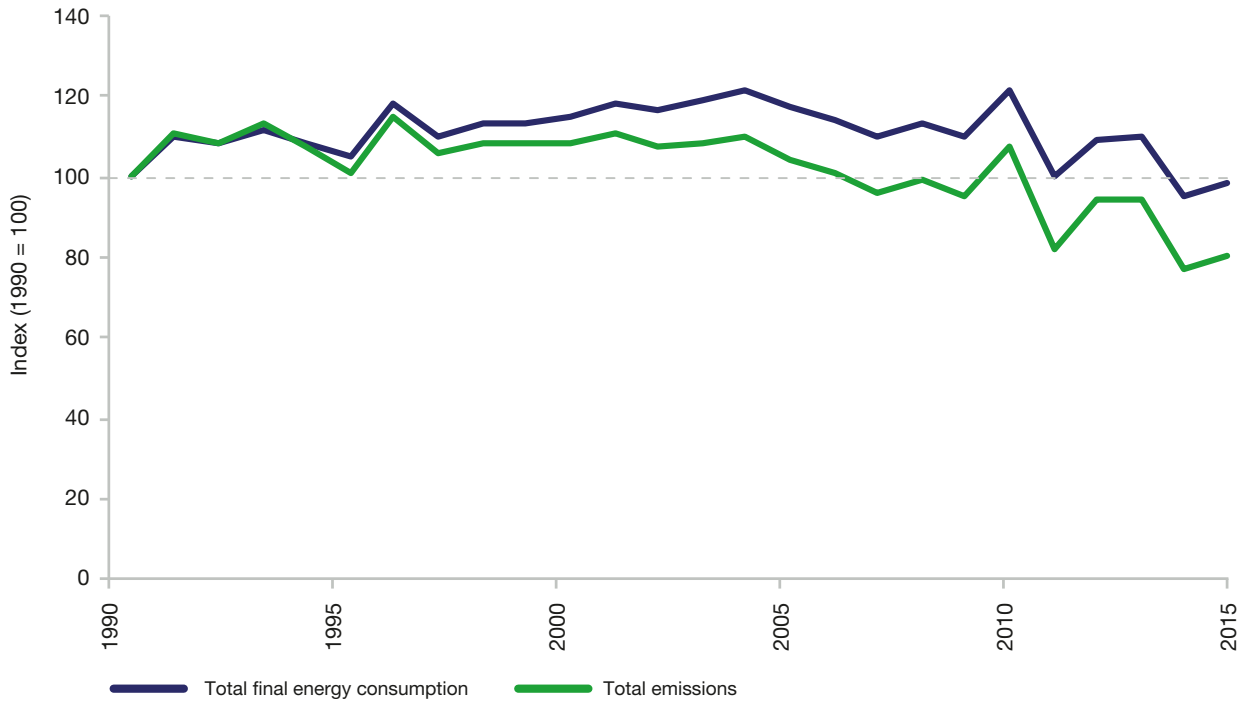
Improving Our Homes

Progress

Homes now account for 13 per cent[173] of the UK's emissions (rising to 22 per cent once electricity use is taken into account[174]). The average household's energy consumption has fallen by over 17 per cent since 1990[175]. This has been driven by a combination of: tighter building and products standards, in particular better boilers; the uptake of insulation and other energy efficiency measures, mainly delivered through obligations on energy suppliers; and greater awareness of potential energy savings.

While there are now approximately a quarter more homes than in 1990, the overall total of emissions from the sector has reduced by about a fifth over this period[176].

Figure 18: Total energy consumption and emissions of UK homes, 1990-2015



Source: BEIS Energy Consumption in the UK, 2017

[173] BEIS (2017) UK Greenhouse Gas Emissions https://www.gov.uk/government/statistics/final-uk-greenhouse-gas-emissions-national-statistics-1990-2015

[174] BEIS (2017) Annex 1990 – 2015 Final emissions by end user and fuel type https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/604354/Annex_1990-2015_Final_emissions_by_end_user_and_fuel_type.pdf A minor adjustment for fluorinated gases has been made, which are accounted with the Natural Resources sector

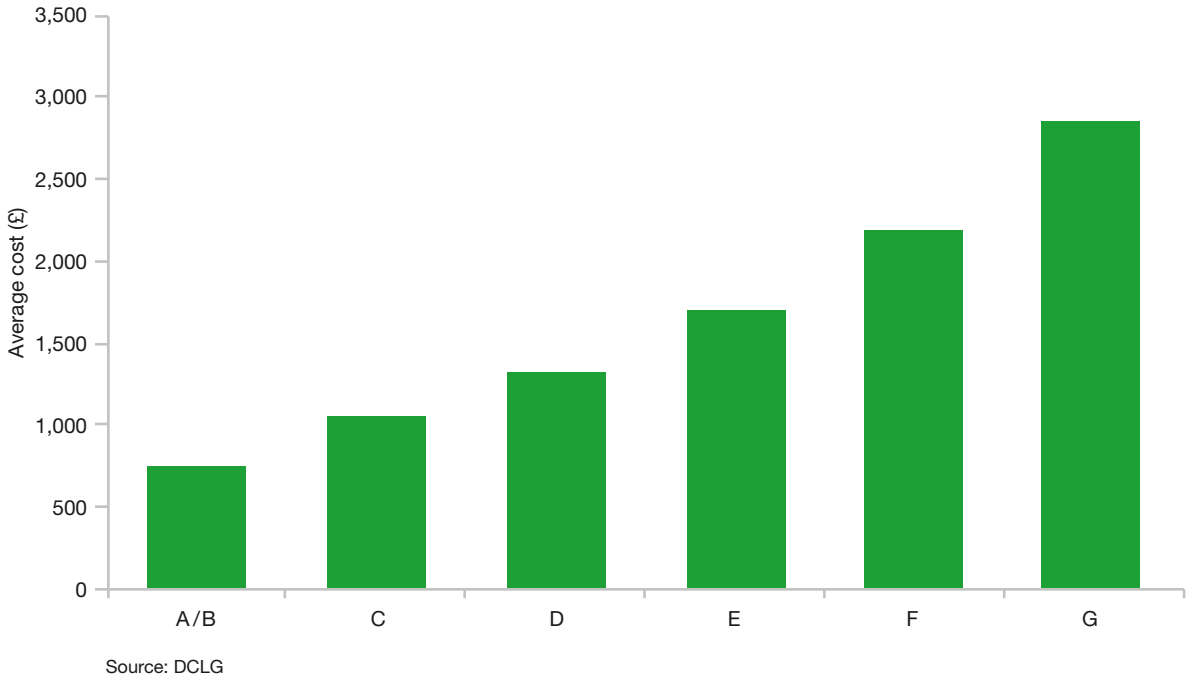
[175] BEIS (2017) Energy Consumption in the UK https://www.gov.uk/government/statistics/energy-consumption-in-the-uk Change in average consumption per household 1990-2016.

[176] BEIS (2017) UK Greenhouse Gas Emissions https://www.gov.uk/government/statistics/final-uk-greenhouse-gas-emissions-national-statistics-1990-2015

Reducing emissions through the measures listed above not only creates better quality homes but cuts the costs of heating them. Almost 79 per cent of homes in England in 2015 had an Energy Performance Certificate (EPC) rating of Band D or better compared to 39 per cent in 2005[177]. Upgrading energy efficiency from an EPC Band E to an EPC Band D reduces energy costs by £380 per year on average. For example, the annual running cost of a Band C rated home are £270 lower than the average Band D rated home and £650 less than the average Band E rated home[178].

Improved energy efficiency also offers substantial health benefits. There is a clear link between cold homes and ill-health, where existing conditions (such as respiratory illnesses or mental health conditions) are exacerbated. The Building Research Establishment (BRE) has estimated, conservatively, that the cost of cold and damp homes to the NHS is approximately £760 million per year[179]. Increasing resilience to rising temperatures is also a potentially significant climate change challenge and we are undertaking research into whether further measures on overheating are necessary for new homes.

Figure 19: Average annual cost of energy in homes by energy efficiency rating, 2014[180]



Source: DCLG

[177] DCLG (2017) English Housing Survey 2015 to 2016

[178] BEIS analysis based on English Housing Survey data

[179] Building Research Establishment (2011) The cost of poor housing to the NHS BEIS analysis based on English Housing Survey data

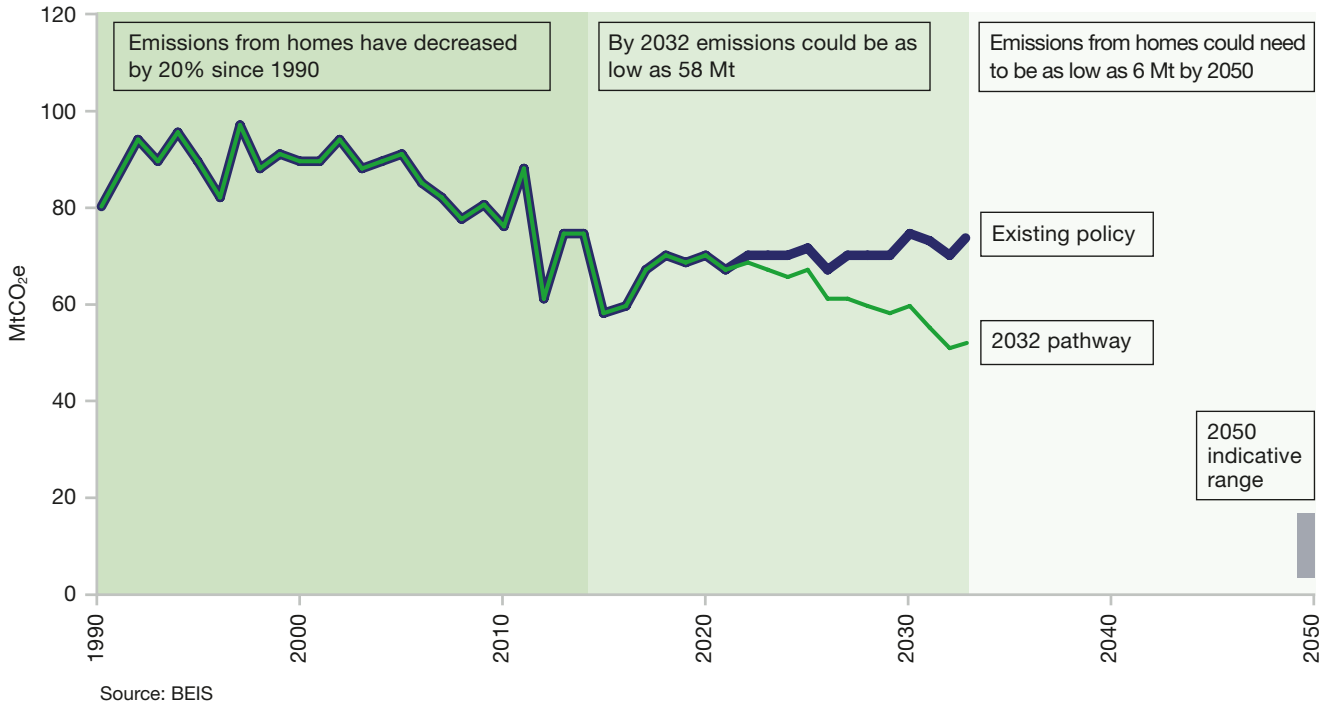
[180] BEIS analysis based on English Housing Survey data

Obligations on energy suppliers such as the Energy Company Obligation (ECO) are estimated to have reduced dual fuel customers' bills by over £800 million across the UK in 2016[181]. Since 2013, ECO has driven the installation of 2.1 million energy efficiency measures in 1.7 million properties[182]. Separately, the Domestic Renewable Heat Incentive has enabled householders to install over 55,000 low carbon heating technologies such as heat pumps, biomass boilers and solar water heating[183].

In particular, progress has been made to upgrade the homes of those living in fuel poverty: the number of fuel poor households in England living in homes at energy efficiency rating E or below reduced from 1.8 million in 2010 to 920,000 in 2015[184].

In parallel, the roll-out of smart meters is helping to give households more control over their energy use, based on near real-time information. As of June 2017, 7.7 million smart and advanced meters were operating in homes and small business sites across the country[185].

Figure 20: Actual and projected emissions in homes, taking into account the clean growth pathway, 1990-2050



Source: BEIS

[181] BEIS analysis

[182] BEIS (August 2017) Household Energy Efficiency National Statistics https://www.gov.uk/government/collections/household-energy-efficiency-national-statistics

[183] BEIS (July 2017) Renewable Heat Incentive Statistics https://www.gov.uk/government/collections/renewable-heat-incentive-statistics

[184] BEIS (2017) Fuel Poverty Trends https://www.gov.uk/government/statistics/fuel-poverty-trends-2017

[185] BEIS (Quarter 2 2017) Smart Metering Statistics https://www.gov.uk/government/statistics/statistical-release-and-data-smart-meters-great-britain-quarter-2-2017

Ambition

We want to further reduce emissions from homes while ensuring that everyone has a home that is comfortable, heathy and affordable to run. Our objective is to ensure our policies will encourage people to improve their homes where it is cost effective and affordable for them to do so. One possible pathway to 2032 could involve emissions from homes falling by almost one fifth compared to today, to around 58 Mt by 2032.

To achieve this 2032 pathway, we will need to ensure existing buildings waste even less energy. This pathway could see a further six to nine million properties insulated, especially focusing on those in fuel poverty where we are aiming to have the 2.5 million fuel poor homes in England improved to energy efficiency rating C or better by 2030[186]. More broadly, our aspiration is that as many homes as possible are improved to EPC Band C by 2035, where practical, cost-effective and affordable.

Reducing demand for energy will not be enough on its own to meet our ambitions for homes. By 2050, we will also likely need to fully decarbonise how we heat our homes. There are a number of low carbon heating technologies with the potential to support the scale of change needed, including heat pumps, using low carbon gases (such as hydrogen) in our existing gas grid and district heat networks. However, at present it is not certain which approaches or combination of them will work best at scale and offers the most cost-effective long-term answer. Decarbonising heat is our most difficult policy and technology challenge to meet our carbon targets.

We will therefore need to lay the groundwork this Parliament so we are ready to make decisions in the first half of the next decade about the long term future of how we heat our homes, including the future of the gas grid (please see box below on the Future of Heat Decarbonisation). This includes support for innovation to test and bring down the cost of low carbon heating technologies, many of which are currently too expensive.

Ahead of these decisions, we can take further action to reduce emissions from heating the 850,000 homes[187] currently not connected to the gas grid in England and that use oil for heating. We also need to avoid new homes needing to be retrofitted later and ensure that they can all accommodate low carbon heating. This could involve all new homes off the gas grid from the mid-2020s being heated by a low carbon system, such as a heat pump.

[186] Conservatives (2017) https://www.conservatives.com/manifesto

[187] BEIS analysis based on English Housing Survey data

Opportunities

The energy efficiency industry already contributes substantially to the low carbon economy, supporting 144,000 direct employees[187]. In 2016, investment in energy efficiency globally grew by nine per cent with substantial levels of global investment in energy efficiency predicted to deliver on the Paris Agreement. This is coupled with a potentially substantial domestic market of 27 million homes. The UK, therefore, has the opportunity to become a trusted leader in the quality, service and installation of low carbon and energy efficiency products and an exporter of knowledge, skills and products to other countries. These markets can build on the success of the UK gas boiler market – the biggest boiler market in the world, in terms of value and volume (the annual market value for boilers in the UK is around £2.5-£3 billion[188]) with some of the most experienced manufacturers and installers.

Exeter Road Project

Enfield's award-winning Exeter Road Project combined energy efficiency measures with the installation of a ground source heat pump system to provide a new heating and hot water system to 185 flats. The new heating system is estimated to reduce fuel costs by 80 per cent per flat, saving residents as much as £500 a year. Exeter Road resident **Ms Adeleke** says: "I am very happy with the heating, it keeps my home warm all of the time. My old heating didn't work properly all day and wasn't in every room. It is cheaper to run than the other heating so far this winter."

[187] ONS (2017) Low Carbon and Renewable Energy Economy Survey, final estimates: 2015 https://www.ons.gov.uk/economy/environmentalaccounts/bulletins/finalestimates/2015results

[188] Delta Energy & Environment (2016) Heat Insight Service, August 2016 Briefing note

Policies and Proposals

Improving People's Homes and Reducing Bills

1. ECO will upgrade around a million homes, supporting £3.6 billion of investment. We have changed the scheme so it is more focused on households with low incomes. We will extend support for home energy efficiency out to 2028 at least at the current level of ECO funding. We will review the best form of support beyond 2022 recognising the need to both save carbon and meet the Government's commitment to upgrade all fuel poor homes to EPC Band C by 2030.

2. For privately rented homes, we have legislated so that from April 2018, landlords of the worst performing properties will need to improve those properties to a minimum of EPC Band E before they can be let, lowering bills for some of the most vulnerable private tenants while ensuring costs of improvements are reasonable and affordable. We will consult shortly on steps to make these regulations more effective.

3. The Government will look at a long term trajectory for energy performance standards across the private rented sector, with the aim of as many private rented homes as possible being upgraded to EPC Band C by 2030, where practical, cost-effective and affordable. We will consider options with a view to consulting in 2018. In addition, the Government will also look at how social housing can meet similar standards on the same timetable. When looking at this we will need to take account of the findings of the independent public inquiry into the fire at Grenfell Tower[189] and the Government's separate work looking at wider social housing policy issues[190].

4. We want all fuel poor homes to be upgraded to EPC Band C by 2030, and our aspiration is that, across the whole housing stock, as many homes as possible reach a similar standard by 2035, where practical, cost-effective and affordable.

5. To build the market for energy efficiency, we need to make it as easy as possible for people to pay for and make home energy efficiency improvements. We are publishing a call for evidence on additional measures to encourage energy performance improvements, including a focus on:

   - Working with mortgage lenders to incorporate energy efficiency into their lending decisions, alongside developing innovative "green mortgage" products. The Government is now exploring ways that it could support the launch of more products, and further details are included in our call for evidence.

   - Looking at incentives and other levers that could encourage homeowners to invest in energy efficiency improvements.

[189] Grenfell Tower Inquiry (2017) Terms of Reference https://www.grenfelltowerinquiry.org.uk/news/prime-minister-announces-inquiry-terms-reference/

[190] Prime Minister's response of 15th August 2017 https://www.grenfelltowerinquiry.org.uk/key-documents/

6. We will work with industry to implement the independent, industry-led *Each Home Counts*[191] review to improve quality and standards for all retrofit energy efficiency and renewable energy installations.

7. We will replace the existing, telephone-only Energy Saving Advice Service with a digitally-led service by spring 2018, working closely with the *Each Home Counts* implementation, offering tailored advice on improving the energy performance of people's homes.

8. Homeowners expect building work that improves the energy efficiency of a property to be high quality, helping them reduce energy bills and making their homes more comfortable. The Government has commissioned an independent review of Building Regulations and fire safety, being led by Dame Judith Hackitt. The review will report in spring 2018. Subject to the conclusions of that review, the Government intends to consult on making improvements to Building Regulations requirements, so that any new work (i.e. extensions to a property and other building work) to existing properties meets a high standard of energy efficiency, where the evidence shows there are cost-effective and affordable opportunities and that it is safe and practical to do so. Any improvements would focus on the standards of the work carried out on properties itself, and would not include any wider "consequential" improvements to other parts of the property.

9. Following the sale of the Green Deal Finance Company, the Government is publishing a call for evidence on how to reform and streamline the Green Deal framework to make the "Pay as You Save" system more accessible to businesses, while ensuring adequate protection for consumers.

10. It could be possible to extend EPCs to other trigger points and we will issue a Call for Evidence by spring 2018 seeking views in this area, as well as wider views on how EPCs could be further improved, in light of new sources of data and capabilities. As the EPC requirements derive from the Energy Performance of Buildings Directive, any future changes will need to be considered in the context of leaving the European Union.

11. Energy performance improvements installed in both new build and existing properties can fall short of expectations. The Government has commissioned an independent review of Building Regulations and fire safety, being led by Dame Judith Hackitt[192]. The review will report in spring 2018. Following the outcome of this review and subject to its conclusions we will look at the potential for any further action on compliance and enforcement related to energy performance. We will also continue to explore innovative solutions to this problem, such as measuring actual building performance using data from smart meters, and working with the industry to develop a 'quality mark' to drive up standards.

[191] DCLG (2016) Each Home Counts: Review of Consumer Advice, Protection, Standards, and Enforcement for Energy Efficiency and Renewable Energy https://www.gov.uk/government/publications/each-home-counts-review-of-consumer-advice-protection-standards-and-enforcement-for-energy-efficiency-and-renewable-energy

[192] Grenfell Tower Inquiry (2017) Terms of Reference https://www.gov.uk/government/news/independent-review-of-building-regulations-and-fire-safety-publication-of-terms-of-reference

12. We will ensure every home is offered a smart meter by the end of 2020 and we expect energy suppliers to make every effort to provide smart meters to all their customers. We will:

    - Continue to work with suppliers to ensure that people are provided with tailored advice when a smart meter is installed;
    - Trial the provision of regular information about their energy use to encourage long-term energy savings; and
    - Explore how the data available through the national smart metering platform can, with customers' consent, support personalised recommendations for saving energy, more targeted policy interventions and help businesses develop energy saving offers.

13. Alongside this Strategy, the Government has published *Boiler Plus*, improving standards for the 1.2 million new boilers[193] installed in England every year and ensuring control devices are included with every installation so people can more easily control comfort in their own homes for less fuel from April 2018.

Encouraging the Take-up of Cleaner Heating Systems

14. Through the Renewable Heat Incentive (RHI), we are spending £4.5 billion between 2016 and 2021 to support innovative low carbon heat technologies in homes and businesses, such as heat pumps, biomass boilers and solar water heaters. We are also reforming the RHI to focus the scheme towards long-term decarbonisation through greater uptake of technologies such as heat pumps and bio methane (biogas to grid)[194].

15. Beyond the RHI, our ambition is to phase out the installation of high carbon fossil fuel heating in new and existing off gas grid residential buildings (which are mostly in rural areas) during the 2020s, starting with new homes as these lend themselves more readily to other forms of low carbon heating. In line with broader Government priorities on delivering clean air, we are considering a range of policy options to support this, and are investing £10 million in an innovation challenge fund to support low carbon heating systems. We will involve consumers and industry in developing our new policy so that it is straightforward for people to get new technologies installed. The Government will also explore the use of the £200 million package of Growth Programme and Countryside Productivity offers to support renewable energy projects in rural areas[195].

16. In the Spending Review 2015, we allocated funding out to 2021 to grow the UK heat networks market so it is self-sustaining in the longer term. This could support significant investment of private and other capital by 2021. This will enable the construction of heat networks in areas of high heat demand density such as urban centres, campuses and business parks, including in rural locations. Following recommendations from an industry taskforce, we will also examine the measures necessary to create an effective long-term market framework for the sector beyond 2020.

[193] BEIS (2017) Boiler Standards IA https://www.gov.uk/government/consultations/heat-in-buildings-the-future-of-heat

[194] BEIS (2016) The Renewable Heat Incentive: A reformed and refocused scheme https://www.gov.uk/government/consultations/the-renewable-heat-incentive-a-reformed-and-refocused-scheme

[195] Defra (2017) £200 million boost for rural England https://www.gov.uk/government/news/200-million-boost-for-rural-england

17. The Government has commissioned an independent review of Building Regulations and fire safety, being led by Dame Judith Hackitt. The review will report in Spring 2018. Following the outcome of the independent review, and subject to its conclusions, the Government intends to consult on improving requirements for new homes where the evidence suggests that there are cost-effective and affordable opportunities, and it is safe and practical to do so. This will look to ensure that new homes are future-proofed for the installation of lower carbon heating systems where this is cost-effective and affordable. This will help to phase out high carbon fossil fuels in the future, starting with homes off the gas grid.

Government Innovation Investment

The Government expects to invest £184 million[196] out to 2021 in research, development and deployment of innovative energy efficiency and heating technologies, and the gas network. These will address the key innovation challenges to meet our long-term goals, including:

- Developing better energy efficiency and heating technologies. We need innovation in products, supply chain capacity and skills, and new business models to reduce the expense and challenge of retrofit solutions. To deliver this the Research Councils are investing over £70 million in energy efficiency, including £22 million in buildings research. In addition, we will run:
  - A new £10 million grant fund for the innovation of new insulation materials, installation methods and business models for existing buildings.
  - A further £10 million grant fund will focus on making low carbon heating technologies more affordable, better performing, and attractive to the consumer.
  - We also need to ensure that existing regulation does not impede the development of new low cost energy efficiency technologies. This will be considered as part of our call for evidence on additional measures to encourage energy improvements alongside this Strategy.
- Building lower cost, low carbon homes. New methods in construction including factory production and off-site manufacturing may help us build new energy efficient homes more quickly and more cheaply. The Government is currently tendering a £1.4 million three-year research project to address the drivers, barriers, and challenges of new low carbon homes.

[196] All figures are indicative and are subject to competitive bidding processes across sectors and value for money tests.

Econovate

Econovate, based in Hemel Hempstead produce construction 'blocks' made from recycled waste which might otherwise end up in landfill. They received an Energy Entrepreneurs Fund grant of £800,000, and their product is now fully certified for use. Econovate have subsequently raised over £645,000 capital funding to grow the manufacturing of their award winning product which has a high level of performance, saving more than 300kg of CO_2 per cubic metre compared to standard concrete, and which is four times stronger than current blocks.

- Behaviour change. Innovation can help overcome non-financial barriers, in particular behavioural barriers, to energy efficiency. Research Councils are planning to invest around £19 million to research how people's energy choices can help them stop wasting as much energy. Government is investing in smart ways of developing heating services, with work led by the Energy Systems Catapult.
- Network solutions. To inform the decisions that will be needed on our long term approach to decarbonising heat (please see box below on the Future of Heat Decarbonisation), we will run a £25 million project on using hydrogen as an alternative to natural gas[197], including looking at regulatory standards and the development of appliances.
- Supporting innovation through policy instruments. We recognise that the way in which Government policies are designed can have an impact on the rate of deployment of new, innovative low carbon and energy efficient technologies. As such, we will explore ways in which we could make it easier for innovative approaches or products to be installed under our consumer-facing schemes such as ECO – potentially reducing costs, improving the overall performance of the technologies, and building a stronger evidence base on the savings they deliver.
- Ofgem is making available up to £195 million for gas network companies in Great Britain to develop and demonstrate new technologies as well as new operating and commercial arrangements.

[197] BEIS (July 2017) Funding for innovative approaches to a low carbon built environment https://www.gov.uk/government/publications/funding-for-innovative-approaches-to-using-hydrogen-gas-for-heating

The Future of Heat Decarbonisation

Heating our homes, businesses and industry accounts for nearly half of all energy use in the UK and a third of our carbon emissions. Nearly 70 per cent of our heat is produced from natural gas. Meeting our target of reducing emissions by at least 80 per cent by 2050 implies decarbonising nearly all heat in buildings and most industrial processes. Reducing the demand for heat through improved energy efficiency will have an important role to play but will not by itself suffice to meet our 2050 target.

We need to lay the groundwork in this Parliament to set up decisions in the first half of the next decade about the long term future of heat. The demands on our energy infrastructure will change as low carbon heating technologies take over from fossil fuels, with a greater dependence on electricity and potentially new infrastructure needed for system balancing and the generation of low carbon gases. Supply chains will need time to grow to provide products and services consumers across the country will need.

There is a range of low carbon heating technologies with the potential to support the scale of change needed. These include the electrification of heating with households moving away from gas or oil boilers, to electric heat pumps; decarbonising the gas grid by substituting natural gas with low carbon gases like biogas and hydrogen; and heat networks (which are likely to be particularly effective in dense urban areas). At present, it is not clear which approach will work best at scale and offer the most cost-effective, long term answer. We will work with industry, network operators, manufacturers, and consumers to achieve a clear and shared understanding of the potential as well as the costs and benefits and implications of different pathways for the long term decarbonisation of heat. This includes modelling the costs and benefits of different approaches, establishing the likely level of change for households and demands on the electricity grid building on the work of others in this field.

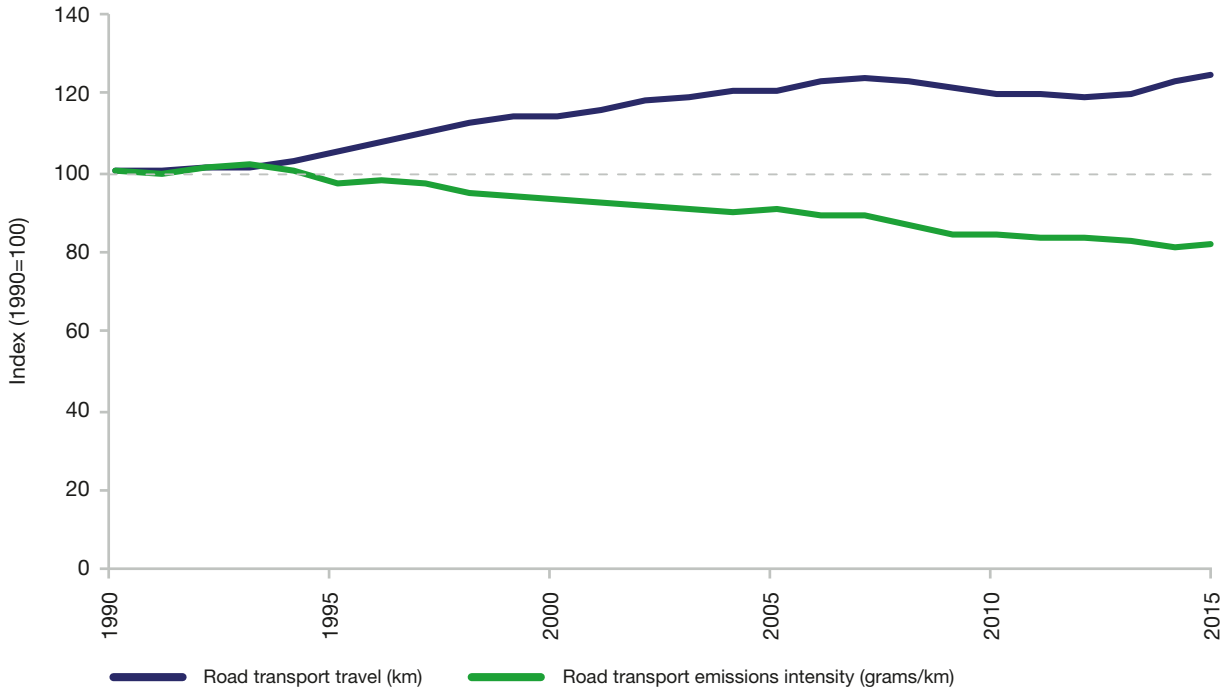
Government has commissioned research into different heat demand scenarios, the use of hydrogen, what changes might be needed to the electricity grid in response to large scale uptake of heat pumps, the role that bioenergy might play in decarbonising heat and international activity. We plan to publish initial findings from a number of studies later this year, and a full report on our review of the evidence by summer 2018.

Accelerating the Shift to Low Carbon Transport

Progress

Transport emissions in 2015 were down two per cent compared to 1990[198,199]. While new cars in the UK are up to 16 per cent more efficient than they were in 2000[200], this improvement has been largely offset by a nine per cent increase in road traffic to 2015[201], with the number of registered vehicles increasing over the same period from 28.9 million to 36.5 million[202]. The transport sector now accounts for 24 per cent of the UK's emissions[203].

Figure 21: Emissions intensity of road transport (cars, vans and HGVs) 1990-2015



Source: DfT, BEIS

[198] BEIS (2017) Final UK greenhouse gas emissions statistics 1990-2015 https://www.gov.uk/government/statistics/final-uk-greenhouse-gas-emissions-national-statistics-1990-2015

[199] Provisional statistics suggest that GHG emissions from transport may show an increase 1990-2016. BEIS (2017) Provisional UK greenhouse gas emissions statistics 2016 https://www.gov.uk/government/statistics/provisional-uk-greenhouse-gas-emissions-national-statistics-2016

[200] Fuel efficiencies are from DfT modelling using DfT (2017) Vehicle statistics; ICCT (2015) From Laboratory to Road: A 2015 update http://www.theicct.org/laboratory-road-2015-update

[201] DfT (2016) Road traffic estimates in Great Britain: 2015 https://www.gov.uk/government/statistics/road-traffic-estimates-in-great-britain-2015. Measured in 'vehicle miles' which combines the number of vehicles on the road and how far they drive.

[202] DfT (2017) Licensed vehicles and new registration tables https://www.gov.uk/government/statistical-data-sets/all-vehicles-veh01 VEH0102

[203] BEIS (2017) Final UK greenhouse gas emissions statistics 1990-2015 https://www.gov.uk/government/statistics/final-uk-greenhouse-gas-emissions-national-statistics-1990-2015

Improvements by manufacturers in the fuel efficiency of vehicles have largely been driven by tighter regulation, mainly set at EU level[204]. Driving a new car bought in 2015 would have saved car owners up to £200 on their annual fuel bill, compared to a car bought new in the year 2000[205].

The fuel we use in our cars is also lower carbon, with the Renewable Transport Fuel Obligation (RTFO) driving the greater use of biofuels. Biofuels now account for around three per cent of fuel sales, with around half of that derived from wastes[206]. Average greenhouse gas savings from biofuels are around 70 per cent compared to petrol and diesel[207]. The RTFO has stimulated around £1 billion of investment in UK production facilities[208] including, for instance, Argent Energy's £75 million production plant in Cheshire which is using innovative technology to turn sewage waste into biodiesel[209].

We are now seeing greater innovation from carmakers, beyond the internal combustion engine, as the world accelerates towards mass adoption of zero emission vehicles. The UK now has over 115,000 ULEVs on the road[210]. ULEV uptake has been driven through a combination of grants, which reduce the upfront costs of ultra low emission cars by up to £4,500[211], together with improved charging infrastructure[212] and new approaches like the £40 million Go Ultra Low Cities scheme, through which eight local authority areas are trialling local initiatives including city centre charge point hubs, free parking and access to bus lanes for ULEVs[213].

On public transport, Government has invested £37 billion in the public transport system between 2011 and 2016[214]. Rail passenger journeys are now at their highest level since the 1920s[215].

[204] With a target of 95g/km for cars in 2021 (down from 146g/km in 2009) - Reducing CO_2 Emissions from passenger cars, https://ec.europa.eu/clima/policies/transport/vehicles/cars_en

[205] Annual average household saving from driving a car purchased new in 2015 (the latest year for which data is available) compared to driving a car purchased new in 2000. Fuel savings valued using 2015 prices. DfT (2017) National Travel Survey; DfT (2017) Vehicles Statistics; ICCT (2015) From Laboratory to Road; BEIS (2016) Green Book supplementary appraisal guidance

[206] DfT (2017) Renewable Transport Fuel Obligation statistics: https://www.gov.uk/government/collections/biofuels-statistics Period 9 2016/17, report 2

[207] DfT (2017) Renewable Transport Fuel Obligation statistics: https://www.gov.uk/government/collections/biofuels-statistics Period 8 2015/16, report 6

[208] DfT (2014) Renewable Transport Fuel Obligation: Post Implementation Review https://www.gov.uk/government/consultations/renewable-transport-fuel-obligation-a-draft-post-implementation-review

[209] DfT press release (2016) Transport Minister views plans to boost Port of Liverpool https://www.gov.uk/government/news/transport-minister-views-plans-to-boost-port-of-liverpool

[210] DfT (2017) Vehicles registered for the first time by body type, monthly: Great Britain and United Kingdom https://www.gov.uk/government/statistical-data-sets/allvehicles-veh01 Table VEH0150

[211] Currently up to £4,500 for cars, £1,500 for motorcycles, £8,000 for vans, £7,500 for taxis, and through competitive funding support for low emission buses and taxis.

[212] Currently up to £500 for home charge-points, up to £300 per socket for workplace charging and up to £7,500 per charge points for local authorities putting charging in residential areas.

[213] £40 million to drive green car revolution across UK cities https://www.gov.uk/government/news/40-million-to-drive-green-car-revolution-across-uk-cities

[214] HM Treasury (2016) Country and regional analysis: 2016 https://www.gov.uk/government/statistics/country-and-regional-analysis-2016

[215] DfT (2017) Rail Trends Factsheet 2016 https://www.gov.uk/government/statistics/rail-factsheets-2016

Ambition

We want a more modern transport system – one that is clean, affordable and easy to use. That means cutting our carbon dioxide emissions, and improving our air quality – clean air is one of the most basic requirements of a healthy environment for us all to live, work and bring up families.

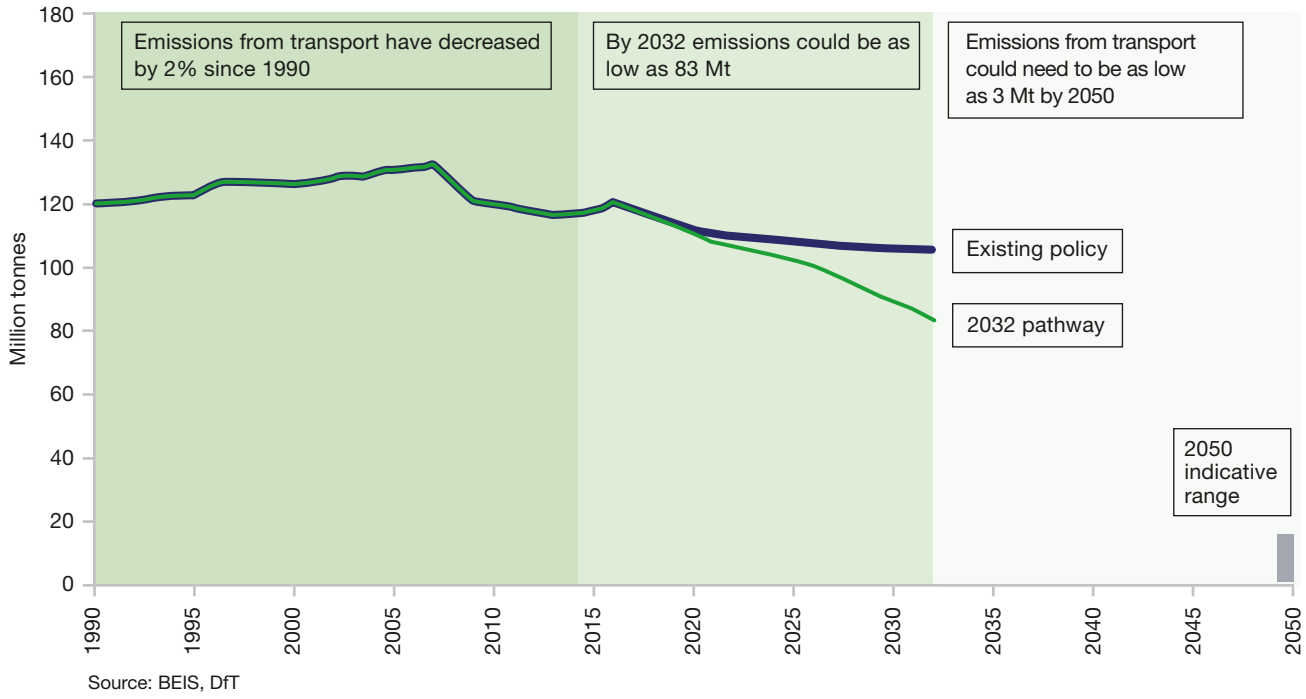
To meet our 2050 target, almost every car and van will need to be zero emission by 2050. The Government has announced an end to the sale of all new conventional petrol and diesel cars and vans by 2040.

Emissions from heavy goods vehicles (HGVs) will also need to reduce significantly to make a meaningful contribution towards meeting the UK's overall 2050 target. Walking and cycling will be made easier for many shorter journeys. By 2040, we want cycling and walking to be the natural choices for shorter journeys, or as part of a longer journey.

We will continue to modernise our aviation and shipping sectors, both through international action, such as standards and offsetting schemes, and domestically, for example through support for sustainable alternative fuels, improved efficiency and new technologies[216].

One possible pathway to 2032 could involve emissions from transport falling by almost 30 per cent compared to today (to around 83 Mt by 2032).

Figure 22: Actual and projected emissions in transport, taking into account the clean growth pathway,1990-2050



Source: BEIS, DfT

[216] Although emissions from international aviation and shipping are not currently included in the UK's targets under the Climate Change Act, our carbon budgets put the UK on a trajectory consistent with a 2050 target that includes these emissions. The Government has not reached a final view on the appropriate level of aviation emissions in 2050. For details on modelling assumptions, please see the technical annex.

To achieve this 2032 pathway, we need to further upgrade our transport system:

- ULEVs on the market today are already an attractive proposition for a significant proportion of motorists given the significantly lower running costs, but we can do more to accelerate ULEV development and uptake. ULEVs should become progressively more affordable as economies of scale are realised and they could provide savings for consumers compared to equivalent internal combustion engine cars by the mid-2020s or sooner[217]. As a result, at least 30 per cent of new car sales are expected to be ULEVs by 2030, and possibly as many as 70 per cent. For new vans, up to 40 per cent of sales could be ULEVs by 2030.
- There needs to be significant improvement in the efficiency of HGVs, with new HGVs needing to be up to 15 per cent more efficient by 2030. We also need to take steps to encourage the industry in moving towards low emission technologies.
- We need a cleaner public transport system. Low emission buses now represent 13 per cent of all buses in the UK[218,219], but we want to go well beyond this to achieve significant uptake of ultra low and zero emission buses. We will seek more use of electric, bi-mode (electric and diesel hybrid) and alternative fuel traction on the railway, and will continue to invest in route electrification where it benefits passengers[220].
- It will be important to reduce the number of shorter journeys made by car, by supporting people to use alternative forms of transport for these trips such as cycling and walking.
- We want to see a near doubling of sustainable bioenergy used in the transport sector.

Opportunities

The UK already has a thriving automotive sector, producing 1.7 million cars annually, employing over 160,000 people and generating £40 billion in exports[221]. The sector's skilled workforce, established manufacturing bases and high productivity ideally place it to be a world leader in the low emission vehicle market. In 2015, low emission vehicle exports were already estimated to be worth £2.5 billion to the UK economy[222]. With 80 per cent of UK produced vehicles already exported across the world[223] and increasing global demand for low emission vehicles the UK industry has real opportunity to further expand.

[217] This is based on the whole-life cost of electric vehicles. The up-front cost of these vehicles is expected to fall below that of conventional vehicles in the second half of the 2020s. Bloomberg New Energy Finance (2015) Are the economics of EVs competitive with conventional cars?; Element Energy (2016) Low carbon cars in the 2020s; International Council on Clean Transportation (2016) Evolution of incentives to sustain the transition to a global electric vehicle fleet.

[218] Low Carbon Vehicle Partnership (retrieved August 2017): http://www.lowcvp.org.uk/Hubs/leb/Home.htm

[219] DfT (2016) Vehicle stocks technology and equipment https://www.gov.uk/government/statistical-data-sets/bus06-vehicle-stocks-technology-and-equipment BUS0601

[220] DfT (2017) Written Statement to Parliament: Rail update: bi-mode train technology https://www.gov.uk/government/speeches/rail-update-bi-mode-train-technology

[221] Automotive Council (2017) The UK Automotive Sector: core briefing, http://www.automotivecouncil.co.uk/wp-content/uploads/sites/13/2017/03/UK-Automotive-Sector-Core-Briefing-March-2017.pdf

[222] ONS (2017) Low Carbon and Renewable Energy Economy Survey, final estimates: 2015 https://www.ons.gov.uk/economy/environmentalaccounts/bulletins/finalestimates/2015results

[223] Automotive Council UK (2017) The UK Automotive Sector: core briefing, http://www.automotivecouncil.co.uk/wp-content/uploads/sites/13/2017/03/UK-Automotive-Sector-Core-Briefing-March-2017.pdf

Health Benefits

The Government has pledged to be the first generation to leave the environment in a better state than it inherited. As well as significantly reducing greenhouse gas emissions, wide-scale adoption of ULEVs will improve our health and quality of life by making the air cleaner in our towns and cities.

While air quality in the UK has been improving in recent decades and will continue to do so due to Government action and investment of over £3 billion in air quality and cleaner transport, there are some parts of the country where there are unacceptable levels of air pollution. Poor air quality remains the largest environmental risk to public health in the UK.

The most immediate challenge is the problem of nitrogen dioxide concentrations around some roads, due mainly to conventional road vehicles, and the Government has published a plan to address this[224]. As part of this plan, the Government announced a £255 million Implementation Fund to help local authorities develop and deliver targeted action to improve air quality, and committed to establishing a new Clean Air Fund.

In 2018, the Government will also publish a wider Clean Air Strategy, setting out how it will significantly reduce the emissions of five damaging air pollutants by 2020 and 2030.

Policies and Proposals

Accelerating Take up of Ultra Low Emission Vehicles

1. The Government has announced an end to the sale of all new conventional petrol and diesel cars and vans by 2040.
2. We are spending £1 billion to drive the uptake of ULEVs. If battery prices continue to fall there will be less need for Government subsidies for new vehicles in the future. We will provide support for ULEVs to help the development of a mature and self-sufficient market.
3. We will encourage ULEV uptake through schemes that build on our experience in delivering initiatives - for example the £40 million 'Go Ultra Low Cities' scheme.
4. We want to have one of the best electric vehicle (EV) charging networks in the world. We will set out our strategy to achieve this using regulation, funding and private investment. To support this:
   - In addition to workplace and residential charging support, the Government has also allocated an additional £80 million to support charging infrastructure deployment, alongside £15 million from Highways England to ensure rapid charge points every 20 miles across 95 per cent of England's Strategic Road Network[225].
   - New powers under the Automated and Electric Vehicles Bill[226] will allow the Government to set specific requirements for the provision of EV charge points or hydrogen refuelling infrastructure at motorway service stations and large fuel retailers, as well as ensuring that charge points are convenient to access and work seamlessly right across the UK.

[224] DEFRA (2017) UK plan for tackling roadside nitrogen dioxide concentration: Detailed plan. See: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/633270/air-quality-plan-detail.pdf

[225] UK Parliament (2017) Electric Vehicles: Written question – 59924 http://www.parliament.uk/business/publications/written-questions-answers-statements/written-question/Commons/2017-01-13/59924/

[226] Cabinet Office (2017) Queen's Speech Background Briefing Notes 2017 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/620838/Queens_speech_2017_background_notes.pdf

Electric Cars

Sue Bentley from Runcorn, Cheshire: "When I purchased an electric car I was the only one in my neighbourhood at that time. I believe electric vehicles are the way forward, they're easy to run, reliable and good for the planet. Now seven people in my neighbourhood have one and they love them!".

- The Bill will also allow the Government to require all new charge points sold or installed in the UK to be 'smart' enabled. This will help shift charging away from peak times of the day, reducing demand on the electricity system and keeping costs lower for everyone.
- We will consider the role of regulation to accelerate the UK's transition to widespread provision of ULEV infrastructure.

5. The Government has provided £4.8 million through the Hydrogen for Transport Advancement Programme to create a network of 12 hydrogen refuelling stations, and £2 million through the Fuel Cell Electric Vehicle Fleet Support Scheme to increase uptake of hydrogen fuel cell cars and vans in the public and private sector. A new £23 million fund was recently announced to boost the creation of hydrogen fuel infrastructure and encourage roll-out of hydrogen vehicles[227].
6. We will announce plans for the public sector to lead the way in transitioning to zero emission vehicles, with an ambitious uptake requirement for central government and new Buying Standards to encourage procurers to choose the cleanest, low emission vehicle.
7. We will support the uptake of low emission taxis:
   - The Government will provide £50 million for the Plug-in Taxi programme, which gives taxi drivers up to £7,500 off the purchase price of a new ULEV taxi, alongside £14 million to support ten local areas to deliver dedicated charge points for taxis[228].
   - We will consider whether our revised best practice guidance to local taxi and private hire vehicle (PHV) licensing authorities in England should recommend zero emission capability in urban areas by 2032. In considering the Law Commission's recommendation for national taxi and PHV standards in England, we will examine the potential for Government to make this target mandatory.

[227] DfT (2017) £23 million boost for hydrogen-powered vehicles and infrastructure https://www.gov.uk/government/news/23-million-boost-for-hydrogen-powered-vehicles-and-infrastructure

[228] BEIS, DfT (2017) 1,000 jobs created at new £325 million factory for electric taxis https://www.gov.uk/government/news/1000-jobs-created-at-new-300-million-factory-for-electric-taxis

8. 'Go Ultra Low'[229] brings the Government and leading vehicle manufacturers together to explain the benefits of ULEVs to motorists and businesses, and its success has been internationally recognised. We will continue to work with industry on consumer communications on ULEVs until at least 2020.

9. The Government will set out further detail on a long term strategy for the UK's transition to zero road vehicle emissions by March 2018.

Enabling our Automotive Industry to Become a World Leader in Zero Emission Technologies

10. The Automotive Council is now developing an Industrial Strategy Sector Deal, building on the £1 billion Advanced Propulsion Centre, which is seeking to establish the UK as a world leader in zero emission vehicle technologies[230]. The Sector Deal will aim to accelerate the transition to zero emission vehicles, complemented by Automotive Council research to determine UK priorities for the EV supply chain.

Developing a More Efficient and Low Carbon Freight System

11. Low emission vans and HGVs between 3.5 and 44 tonnes have been eligible since late 2016 for plug-in grants worth up to £20,000 for the first 200 vehicles bought using the grant[231].

12. We are consulting on proposals to allow category B (car) licence holders to drive slightly heavier vans if they are powered by a low emission technology, effectively offsetting the additional weight of the powertrain[232]. This will encourage further uptake of cleaner goods vehicles.

13. The Government's Freight Carbon Review[233], published in February 2017, identified a range of measures to help fleet operators reduce their emissions, including through improved fuel efficiency. The Energy Saving Trust is piloting a scheme to advise HGV fleet operators on reducing fuel consumption. The Government will set out further measures to support the pathway to low emission freight by March 2018, as part of a long term strategy for the UK's transition to zero vehicle emissions.

14. Our 2016 Rail Freight Strategy[234] highlighted the potential to reduce emissions by growing rail freight and reducing HGV journeys. We will accelerate our activity to enable cost-effective options for shifting more freight from road to rail, including using low emission rail freight for deliveries into urban areas, with zero emission last mile deliveries.

[229] Go Ultra Low https://www.goultralow.com/

[230] Advanced Propulsion Centre: Background http://www.apcuk.co.uk/about-apc/background/

[231] DfT, BEIS (2016) £4 million boost to help businesses switch vans and trucks to electric https://www.gov.uk/government/news/4-million-boost-to-help-businesses-switch-vans-and-trucks-to-electric

[232] DfT (2017) Consultation: Regulatory changes to support the take-up of alternatively-fuelled light commercial vehicles https://www.gov.uk/government/consultations/category-b-driving-licence-derogation-for-alternatively-fuelled-commercial-vehicles

[233] DfT (2017) Freight Carbon Review 2017: Moving Britain Ahead https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/590922/freight-carbon-review-2017.pdf

[234] DfT (2016) Rail Freight Strategy: Moving Britain Ahead https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/552492/rail-freight-strategy.pdf

University of Cambridge – Centre for Sustainable Road Freight

The Centre for Sustainable Road Freight at the University of Cambridge has developed a new trailer design for articulated vehicles that makes the vehicle more aerodynamic. They were awarded £4.4 million in funding from the Engineering and Physical Sciences Research Council and £1.4 million in joint funding from an industrial consortium comprising freight operators such as DHL, John Lewis Partnership, Tesco and Wincanton, as well as vehicle industry partners including Firestone, Goodyear, Haldex and Volvo. Their innovation cuts fuel consumption and pollution by articulated vehicles by around seven per cent. Waitrose has already added 36 of the modified trucks to its fleet and Warburtons will use the new design for all future fleet purchases.

Encouraging Low Carbon Alternatives to Car Journeys

15. We will continue to invest in our public transport network, and help people to cycle, walk or travel by bus or train.

16. Our Cycling and Walking Investment Strategy[235] identifies £1.2 billion which may be invested in cycling and walking from 2016-21. Under this new strategic approach, Local Cycling and Walking Infrastructure Plans identify improvements required at the local level, and enable a long-term approach to developing local cycling and walking networks, ideally over a ten year period.

17. As announced in the 2016 Autumn Statement, the Government will provide £100 million for a national programme of support for retrofitting and new low emission buses in England and Wales, including hundreds of new low emission buses and retrofitting of thousands of older buses.

18. The Government will seek more use of electric, bi-mode (electric and diesel hybrid) and alternative fuel traction on the railway. We will continue to invest in route electrification where it provides benefits to passengers. The industry is also developing trains powered by alternative fuels, for example using battery and hydrogen power.

More Efficient Vehicles and Driving Behaviour

19. As we leave the EU, we want the UK to continue to be a world leader in low carbon transport, and we will look for opportunities to strengthen further the controls on vehicle CO_2 emissions. We will pursue an approach which offers certainty to industry, and is at least as ambitious as current arrangements.

[235] DfT (2017) Cycling and Walking Investment Strategy https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/603527/cycling-walking-investment-strategy.pdf

20. We will continue to help promote and support efficient driving behaviours amongst fleets and private drivers, seeking to maximise the potential of new technologies including early adoption in public sector fleets and close working with other programmes to improve driver standards.

Lower Carbon Fuels

21. We will promote sustainable alternative fuels, which reduce the carbon emissions from petrol and diesel vehicles, and we will set targets to support development of advanced fuels suitable for HGVs and aviation.

22. We have recently relaunched the Future Fuels for Flight and Freight Competition – a £22 million industry competition to encourage development and deployment of low carbon HGV and aviation fuels.

Modernising the Domestic Aviation and Shipping Sectors

23. We will set out our strategic approach to the aviation sector in a series of consultations over the next 18 months[236], including a paper on how to support growth while tackling the environmental impacts of aviation. This will culminate in the publication of a new Aviation Strategy for the UK by the end of 2018.

24. Industry and the Government have made a joint £3.9 billion commitment between 2013 and 2026 to the development of new aircraft technology with the Aerospace Technology Institute[237]. We have announced that we will extend the RTFO to include incentives to use biofuels in aviation.

25. On domestic shipping, the Government will continue to work with industry to develop improved fuel efficiency technologies, including new propulsion systems, hull design and aerodynamic structures.

26. We will work with ship owners and ports to identify the barriers faced in supplying and using sustainable alternative fuels and cleaner emissions technologies, to explore possible solutions. In addition, we expect operational improvements to play a role, including better use of ship capacity.

Government Innovation Investment

The Government expects to invest around £841 million out to 2021 in innovation in low carbon transport technology and fuels, primarily through programmes run by DfT, OLEV, the Research Councils, Innovate UK, and BEIS[238].

The Government will build on this investment to make the UK one of the world's leading innovators in new low carbon technologies. Investments include:

- Electric vehicle and battery technology. Government investment will help bring down the cost of EVs and increase their range. Through the Industrial Strategy Challenge Fund (ISCF), we will invest £246 million over four years in the design, development and manufacture of batteries for the electrification of vehicles, as part of the 'Faraday Challenge'[239]. The Government has also awarded £10 million to build UK capability in the development and commercialisation of automotive battery packs.

[236] HM Government (2017) Beyond the Horizon: The future of UK aviation – a call for evidence on a new strategy https://www.gov.uk/government/consultations/a-new-aviation-strategy-for-the-uk-call-for-evidence

[237] Aerospace Technology Institute http://www.ati.org.uk/

[238] All figures are indicative and are subject to competitive bidding processes across sectors and value for money tests.

[239] BEIS (2017) Business Secretary announces Industrial Strategy Challenge Fund investments https://www.gov.uk/government/news/business-secretary-announces-industrial-strategy-challenge-fund-investments

- Charging and grid support. We will provide at least £70 million over the next five years to support innovation in energy storage, demand side response and other smart energy technologies, including up to £20 million for vehicle-to-grid products and services[240]. This is focused on how an expanded fleet of EVs could provide network flexibility and system balancing while potentially offering benefits to bill payers.
- Advanced fuels. There are fewer options for reducing emissions in the freight and aviation sectors, and here innovation in fuel technology can play an important role. We are providing £40 million out to 2021, to fund the development of advanced low carbon fuels derived from wastes or industrial and agricultural by-products. In August 2017 we relaunched the Future Fuels for Flight and Freight Competition - a £22 million industry competition to encourage development and deployment of low carbon HGV and aviation fuels.
- Zero emission HGVs. In January 2017, we announced the winners of over £20 million for the Low Emission Freight and Logistics Trial[241]. Twenty different projects are receiving funding to demonstrate and trial low and zero emission vehicles in UK fleets, for example using hydrogen, electric and biogas technologies. In the longer term, there is an opportunity to take forward projects to support innovative technologies such as 'dynamic charging' as a potential solution to decarbonising freight.
- HGV platoons. HGV platooning, using advanced vehicle technologies, enables lorries to move in a group and could deliver significant fuel and emissions savings. We will be delivering trials of HGV platoons, with joint funding from Highways England, to assess the feasibility and potential costs and benefits of this technology on UK roads. In August 2017, we announced a trial of HGV platoons, jointly funded with Highways England, which will see up to three HGVs travelling in convoy, with acceleration and braking controlled by the lead vehicle, and with a driver ready to take control at any time in all the HGVs. Platooning trials have been conducted across Europe and the USA, and these trials will assess whether the technology is appropriate and beneficial on UK roads.

Government has also established the Centre for Connected and Autonomous Vehicles (CCAV) and invested over £250 million, matched by industry, to position the UK at the forefront of research, development, and demonstration. These technologies have the potential to smooth traffic flows and increase efficiency of road transport. CCAV is also coordinating engagement with the wider research base and industry, identifying and reducing barriers to innovation or business expansion.

[240] BEIS (2017) Funding for innovative smart energy systems https://www.gov.uk/guidance/funding-for-innovative-smart-energy-systems

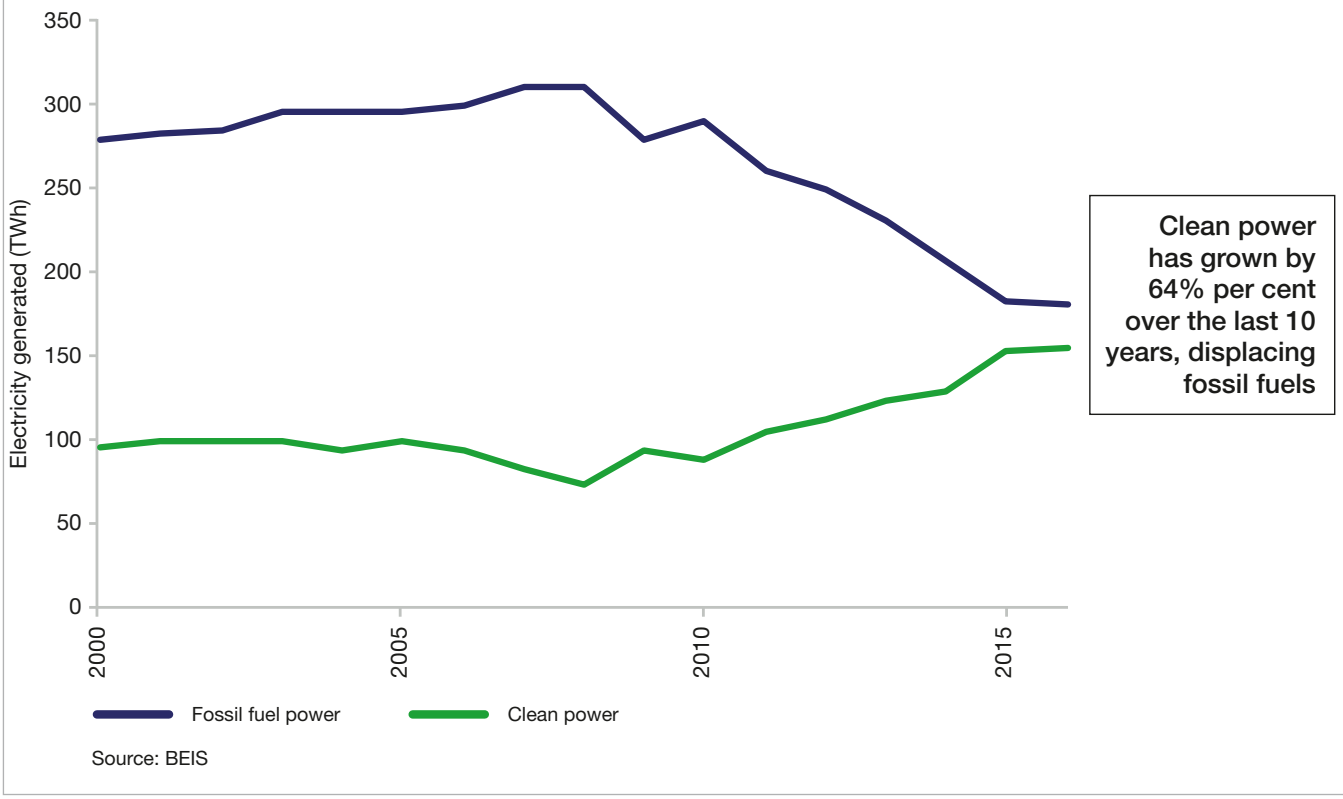
[241] DfT (2017) Low emission freight and logistics trial competition winners announced https://www.gov.uk/government/news/low-emmission-freight-and-logistics-trial-competition-winners-announced

Delivering Clean, Smart, Flexible Power

Progress

Power sector emissions have fallen 49 per cent since 1990 as we have switched from coal to gas and renewable power such as wind and solar, with biomass conversions also playing an important transitional role, alongside improvements in the efficiency of our economy[242]. Last year, 47 per cent of our electricity came from low carbon sources, with the rest mainly coming from coal and gas[243]. Coal use fell to record low levels last year, and on 21 April 2017, for the first time since 1882, we did not use any coal for a 24-hour period[244]. At the same time, we have ensured a secure supply of electricity.

Figure 23: UK electricity generation by fuel type, 2000-2016[245]



[242] BEIS (2017) Final UK greenhouse gas emissions national statistics: 1990-2015 https://www.gov.uk/government/statistics/final-uk-greenhouse-gas-emissions-national-statistics-1990-2015

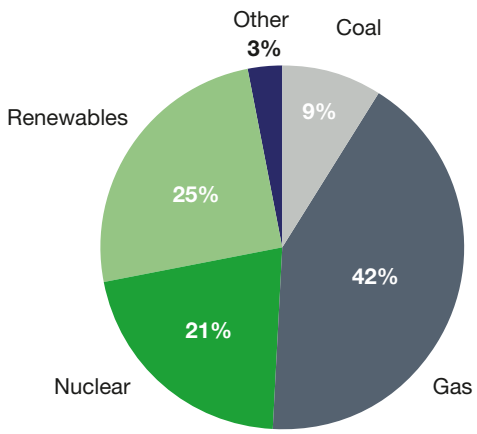
[243] BEIS (2017): Digest of UK Energy Statistics 2017 https://www.gov.uk/government/statistics/energy-chapter-1-digest-of-united-kingdom-energy-statistics-dukes

[244] Financial Times (2017) Britain passes historic milestone with first days of coal-free power https://www.ft.com/content/fc2c8d12-191d-11e6-bb7d-ee563a5a1cc1

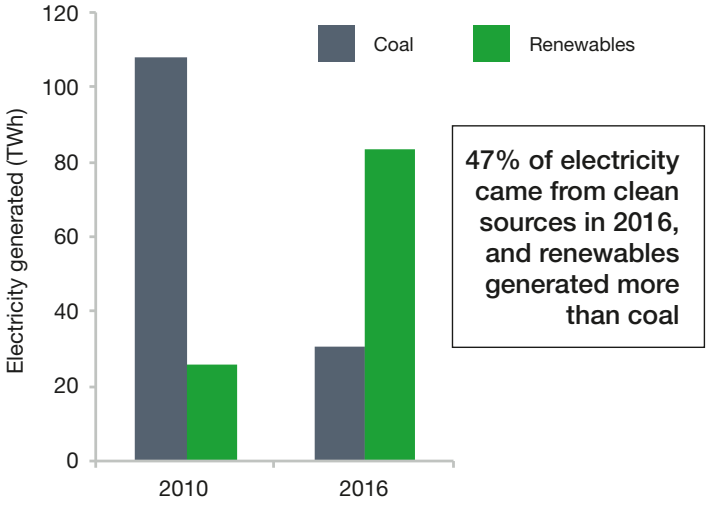
[245] BEIS (2017) Energy Trends June 2017 https://www.gov.uk/government/collections/energy-trends

The costs of low carbon and more efficient technologies have fallen significantly since 2010 through a series of innovations and growth in deployment. Solar photovoltaic modules are now almost 80 per cent cheaper[246], LED lightbulbs over 80 per cent cheaper[247], and batteries for electric vehicles (EVs) over 70 per cent cheaper[248]. Average household electricity bills in 2016 were around 10 per cent lower than in 2008, when the Climate Change Act was introduced[249]. While policy costs on bills have increased over this period, this has been more than offset by reduced electricity use, thanks in part to tightening standards on electrical products.

Figure 24: UK electricity generation mix, 2016 (left) and UK electricity generation from coal and renewables 2010-16 (right)[250]



Source: BEIS



Source: BEIS

[246] IRENA & IEA (2017) Perspectives for the energy transition: Investment needs for a low carbon energy system http://www.irena.org/DocumentDownloads/Publications/Perspectives_for_the_Energy_Transition_2017.pdf

[247] International Energy Agency (2016) Energy Efficiency Market Report https://www.iea.org/eemr16/files/medium-term-energy-efficiency-2016_WEB.PDF

[248] Bloomberg New Energy Finance (2016) 2016 lithium-ion battery price survey https://www.bnef.com/core/insights/15597

[249] CCC (2017) Energy prices and bills report https://www.theccc.org.uk/publication/energy-prices-and-bills-report-2017/

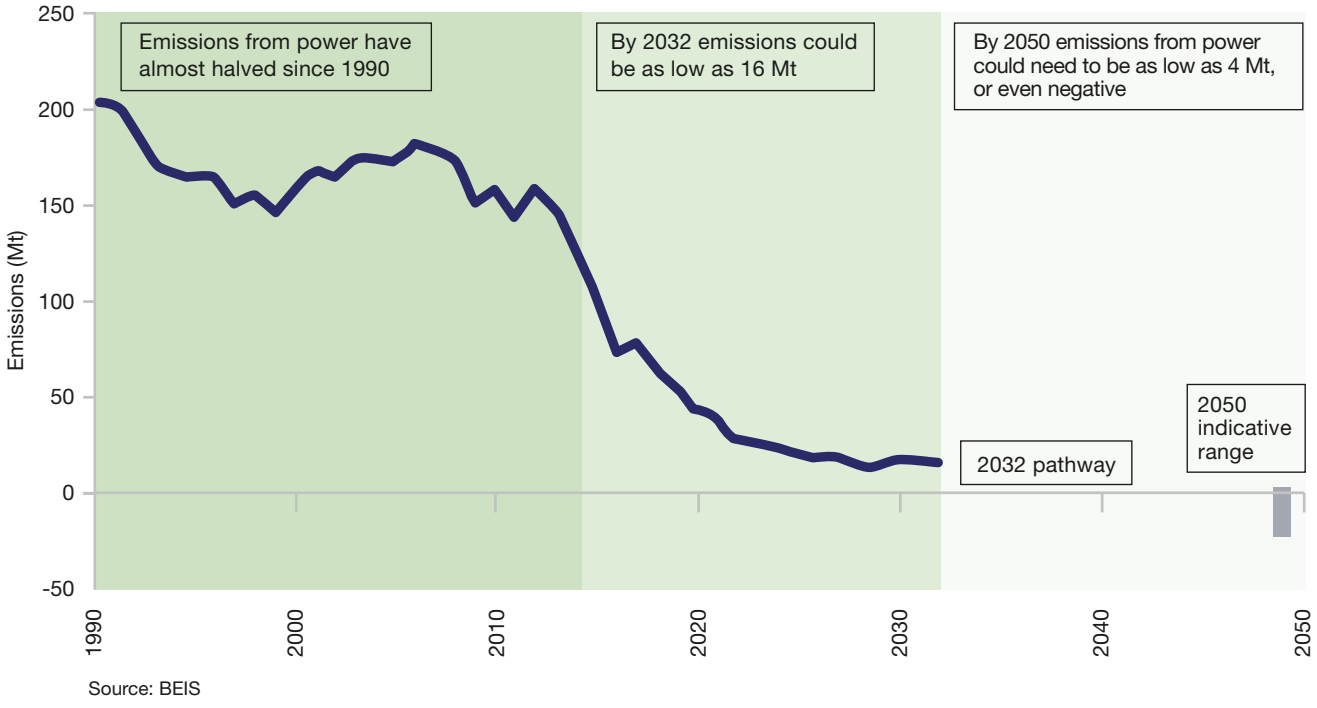
[250] BEIS (2017) Energy Trends https://www.gov.uk/government/collections/energy-trends

Ambition

We want a diverse electricity system that supplies our homes and businesses with secure, affordable and clean power. That means developing low carbon sources of electricity that are both cheap and clean, taking into account wider system impacts for all sources of generation. It also means upgrading our electricity system so it is smarter (using data to provide greater control), more flexible (providing energy when it is needed) and takes advantage of rapidly developing technologies such as energy storage.

By 2050, we anticipate that emissions from the power sector could need to be close to zero[251]. Indeed, we may even see negative emissions – that is, greenhouse gases being removed from the atmosphere – from the sector if sustainable bio-energy and carbon capture and storage are used together. At the same time, many more people are expected to drive EVs, many homes and offices may have efficient electric heating and cooling, and more industrial sites could be powered by clean electricity. There are however alternatives to electrification, such as hydrogen, which could mean that electricity demand is more similar to today.

Figure 25: Actual and projected power sector emissions, taking into account the clean growth pathway, 1990-2050



Source: BEIS

[251] BEIS internal analysis of 2050 pathways

One possible pathway to 2032 could see power emissions fall by 80 per cent compared to today, to around 16 Mt[252]. This could be achieved by:

- Growing low carbon sources such as renewables and nuclear to over 80 per cent of electricity generation, and phasing out unabated coal power.
- Enabling a smarter, more flexible system, unlocking significant expansion of interconnection, electricity storage, and demand side response, the first steps of which are set out in the Smart Systems and Flexibility Plan[253]. For consumers, this could mean smart appliances and smart tariffs which help balance the grid in return for lower bills.
- Keeping costs down for consumers by reducing any wasted energy, including more efficient electrical products.

To achieve this we need to continue bringing down the costs of low carbon generation from renewables and nuclear power, and ensure that the UK can deploy CCUS at scale during the 2030s, subject to costs coming down sufficiently. We also need to remove barriers and improve price signals for smart energy innovations which improve the efficiency and flexibility of the system.

Oxis Energy

OXIS energy, based in Oxfordshire has developed a high performing rechargeable battery which is lighter, more efficient and cheaper than competitor products. The company has received £2.7m in funding from Innovate UK and has grown to employ 60 staff. Their most recent grant is supporting them to produce a revolutionary electric vehicle battery.

[252] BEIS internal analysis of 2032 pathway

[253] BEIS and Ofgem (2017) Upgrading our energy system: smart systems and flexibility plan https://www.gov.uk/government/publications/upgrading-our-energy-system-smart-systems-and-flexibility-plan

Powering Electric Vehicles and Heating

Electric vehicles, electric heating and energy efficiency are key options for reducing emissions in transport and buildings. The impacts of these measures on the power sector are taken into account in our 2032 pathway and summarised below. It shows a net increase of around 3 per cent in the electricity demand and around 4 per cent in peak demand in 2032, and how this can be met through a mix of technologies. In practice, we do not yet know exactly how quickly costs will fall and take-up will increase for electric vehicles, or the role that electrification could play in the long-term decarbonisation of heat.

	Generation (2032)	Capacity (2032)
Impact of the 2032 pathway (compared to BEIS reference case)	Extra demand: 10 TWh (+3%)	Extra peak demand: 2.8 GW (+4%)
	Extra supply: Clean generators 3 TWh Interconnection 4 TWh Fossil fuels 4 TWh	Extra capacity and flexibility: Demand-side response 4.9 GW Storage 0.3 GW Clean generators 0.5 GW Fossil fuels 1.2 GW

Source: BEIS internal analysis of GB power system

Note: The impact of the 2032 pathway is assessed against an updated version of the published BEIS 2016 reference case[254]. Not all extra capacity and flexibility is available to help meet peak demand. Numbers may not sum due to rounding.

For this analysis, we took into account the potential for smart charging of electric vehicles and smart use of heat pumps. For example, we assumed potential to shift charging of most electric vehicles to overnight, which could reduce bills for consumers on a smart tariff[255]. This 'demand-side response' – adjusting energy consumption to when it is plentiful and cheap – would help to balance the grid and reduce peak demand. Our Smart Systems and Flexibility Plan is about unlocking this potential[256].

[254] BEIS (2017) Energy and Emissions Projections 2016 https://www.gov.uk/government/publications/updated-energy-and-emissions-projections-2016 A number of model updates and improvements have been made regarding the electricity demand profiles of key technologies and how this demand might be shifted, the availability of electricity storage technologies, and assumed system operability requirements.

[255] Fisher, J., Gammon, R. and Irvine, K.N. (2015) My Electric Avenue https://www.dora.dmu.ac.uk/xmlui/handle/2086/12180 There is considerable uncertainty on the extent to which customers will change their behaviours and we will be monitoring the evidence here.

[256] BEIS and Ofgem (2017) Upgrading our energy system: smart systems and flexibility plan https://www.gov.uk/government/publications/upgrading-our-energy-system-smart-systems-and-flexibility-plan

Opportunities

The UK is well placed to benefit from the transition to a cleaner, smarter power sector and we already see jobs, regional investment and export sales flowing from UK supply chains for clean power technologies. In 2015, the low carbon electricity sector generated over £12 billion in turnover and directly supported 47,000 jobs, with more in supply chains[257].

There is an opportunity for the UK to become one of the most advanced economies for smart energy and technologies, which is a core component of our Industrial Strategy, while upgrading our power infrastructure will improve energy security and air quality. Consumers will benefit from a smarter, more flexible power system to keep down costs, and will have more control of their energy through smart meters, with near real-time information on energy use and cost.

Clayhill solar farm

Clayhill solar farm and energy storage facility is the first in the UK to be built without subsidy. Consisting of over 30,000 solar panels, it can generate enough power for 2,500 homes. Five onsite batteries allow electricity to be stored and utilised when needed, providing services for the electricity grid, such as frequency response. Co-locating storage at new renewable sites, combined with significant reductions in generation and storage technology costs, may allow more subsidy free sites to be built – providing services that help to maintain the reliability of the grid and clean electricity at low cost.

[257] ONS (2016) Low Carbon Economy and Renewable Energy Economy Survey https://www.ons.gov.uk/economy/environmentalaccounts/bulletins/finalestimates/2015results

Policies and Proposals

Growing Low Carbon Sources of Electricity

1. We confirm the Government's intention to phase out unabated coal generation by 2025, and we will shortly publish the Government's detailed response to the consultation.

2. We are delivering new nuclear capacity through the final investment decision on Hinkley Point C, and will progress discussions with developers to secure a competitive price for future projects in the pipeline.

3. We will work with industry as they develop an ambitious Sector Deal for offshore wind. Provided costs continue to fall, this could result in 10 gigawatts of new capacity built in the 2020s, with the potential to support high value jobs and a sustainable UK industry exporting goods and services around the world. We will also consider whether there could be opportunities for additional offshore wind deployment in the 2020s, if this is cost-effective and deliverable. This would mean up to £557 million for further Pot 2 Contract for Difference auctions, with the next one planned for spring 2019. We will work with the Crown Estate and the Crown Estate (Scotland) to understand the potential for deployment of offshore wind in the late 2020s and beyond and it is our current intention that wind projects on the remote islands of Scotland that directly benefit local communities will be eligible for the next Pot 2 auction, subject to obtaining State aid approval.

4. We want to see more people investing in solar without government support and are currently considering options for our approach to small scale low carbon generation beyond 2019, and will provide an update later this year. More nascent technologies such as wave, tidal stream and tidal range, could also have a role in the long-term decarbonisation of the UK, but they will need to demonstrate how they can compete with other forms of generation.

5. We remain committed to carbon pricing to help reduce emissions in the power sector. Further details on carbon prices for the 2020s will be set out in the autumn 2017 Budget.

Delivering Smarter, More Efficient Energy

6. The Government will ensure that every household is offered a smart meter by their energy supplier by the end of 2020, and we expect energy suppliers to make every effort to provide smart meters to all their customers.

7. The Government, Ofgem and industry will implement the 29 actions set out in the Smart Systems and Flexibility Plan published on 24 July. These will enable technologies such as energy storage and demand side response to compete effectively within the energy market, help integrate more low carbon generation such as solar into our energy system, and deliver secure, smart appliances and smart tariffs to allow consumers to benefit from using energy at times when it is cheaper. Innovations and other steps to increase flexibility could unlock up to £40 billion in energy cost savings up to 2050[258].

[258] BEIS and Ofgem (2017) Upgrading our energy system: smart systems and flexibility plan https://www.gov.uk/government/publications/upgrading-our-energy-system-smart-systems-and-flexibility-plan

8. We will continue to work with Ofgem and the National Grid to create a more independent system operator which will help to keep household bills low through greater competition, coordination and innovation across the system.

9. We will work with Ofgem to ensure the necessary regulatory and market arrangements evolve to support the development of a clean, smart and flexible energy system as outlined in their strategy for regulating the future energy system[259].

10. We will work to ensure significant private investment in new electricity interconnectors, which will help keep prices low for consumers, ensure a more secure grid and help integrate clean generation. Project assessments indicate the potential for at least 9.5 gigawatts more interconnection by the early-to-mid 2020s, in addition to the 4 gigawatts today and the 4.4 gigawatts under construction[260,261].

11. Ofgem's price control regime will enable up to £26 billion of investment in upgrading and operating our electricity distribution networks from 2015-23[262] and we will work closely with industry to capitalise on the opportunities for smart integration of electric vehicles into the electricity system.

12. We confirm that when an installer installs solar panels with a battery in residential accommodation, this can attract a reduced VAT rate of 5 per cent if the installation conditions are met[263]. We will keep the tax treatment of technologies such as solar, storage and heat networks under review.

Keeping Energy Costs Down for Businesses and Households

13. The Government has commissioned an independent review into the cost of energy led by Professor Dieter Helm CBE which will recommend ways to deliver the Government's carbon targets and ensure security of supply at minimum cost to both industry and domestic consumers. Once Ministers have had the opportunity to consider the Helm review's proposals, the Clean Growth Strategy will incorporate its recommendations into our further policy development as appropriate.

14. We are publishing a draft bill to require Ofgem to impose a cap on standard variable and default tariffs across the whole market.

15. The existing Levy Control Framework will be replaced by a new set of controls beyond 2020/21. These will be set out later this year.

16. We are evaluating the results of the Electricity Demand Reduction Pilot, which has offered organisations £5.4 million of funding for projects that could reduce bills and improve security of supply through making energy savings at peak times.

Government Innovation Investment

The Government expects to invest around £900 million[264] of public funds between 2015 and 2021 in research and innovation in the power sector.

- Power and smart systems: Ensuring that the power system is smart and resilient to new demands and new sources of supply

[259] Ofgem (2017) Our strategy for regulating the future energy system https://www.ofgem.gov.uk/publications-and-updates/our-strategy-regulating-future-energy-system

[260] Ofgem https://www.ofgem.gov.uk/electricity/transmission-networks/electricity-interconnectors

[261] Ofgem (2017) Cap and floor regime: Initial Project Assessment of the GridLink, NeuConnect and NorthConnect Interconnectors https://www.ofgem.gov.uk/publications-and-updates/cap-and-floor-regime-initial-project-assessment-gridlink-neuconnect-and-northconnect-interconnectors

[262] Ofgem (2017) RIIO ED1 Annual Report 2015-16 https://www.ofgem.gov.uk/publications-and-updates/riio-electricity-distribution-annual-report-2015-16

[263] Each case will be considered on the specific facts. If batteries are sold separately and retrofitted to existing solar systems, VAT will be charged at the standard rate of 20%.

[264] All figures are indicative and are subject to competitive bidding processes across sectors and value for money tests. Numbers may not sum due to rounding.

will be important for energy security, cost and industrial opportunities. The Government, in partnership with the Research Councils and Innovate UK, expects to invest around £265 million in research, development and deployment in this area which will help to reduce the cost of electricity storage, advance innovative demand response technologies and develop new ways of balancing the grid, for example using EVs.

- Nuclear: We need to bring down the costs of nuclear power while maintaining safety by investing in innovation that will help plants to be built to time and budget. The Government, in partnership with the Research Councils and Innovate UK, expects to invest around £460 million to support work in areas including future nuclear fuels, new nuclear manufacturing techniques, recycling and reprocessing, and advanced reactor design. The Government has asked the Nuclear Innovation and Research Office (NIRO) to convene a new advisory Board, building on the success of the Nuclear Innovation and Research Advisory Board (NIRAB). The Board will provide independent expertise and advice to support and inform the Government's Nuclear Innovation Programme. The Government is also announcing that it will invest £7 million to further develop the capability and capacity of the nuclear regulators to support the development of advanced technologies. Industry is developing a potential nuclear sector deal as part of the Government's Industrial Strategy, co-ordinated around the objective of achieving cost reductions.

- Renewables: The UK already has a world leading offshore wind sector and is well placed to benefit from further investment in renewables innovation to accelerate cost reduction. The Government, in partnership with the Research Councils and Innovate UK, expects to invest around £177 million to further reduce the cost of renewables, including innovation in offshore wind turbine blade technology and foundations. New innovation opportunities are likely to arise in a number of areas, including floating offshore wind platforms, and advanced solar PV technologies.

- Carbon capture, usage and storage: CCUS could reduce the cost of meeting our 2050 target by supporting emissions reductions in industry, power, heating and transport[265]. Our new approach to CCUS is set out in the Business chapter.

- Ofgem is making available to GB electricity network companies up to £525 million of regulated expenditure between 2016 and 2021[266]. The goal is to support smarter, flexible networks, from enabling the integration of clean generation through to customer-focussed energy efficiency measures. This builds on previous network company innovation which delivered 4.5 – 6.5 times more benefits for consumers than it cost[267].

[265] BEIS internal analysis of 2050 pathways

[266] Ofgem internal analysis

[267] Poyry and Ricardo Energy & Environment (2016) An independent evaluation of the LCNF https://www.ofgem.gov.uk/system/files/docs/2016/11/evaluation_of_the_lcnf_0.pdf

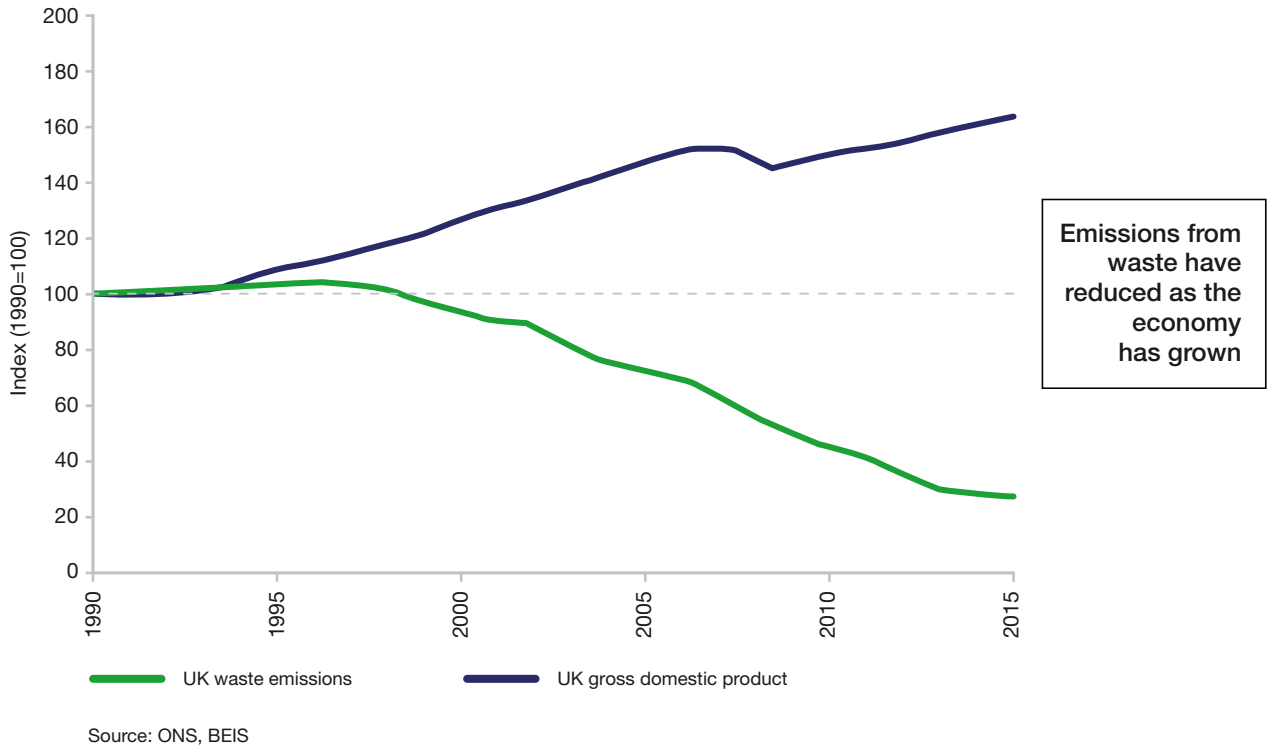
Enhancing the Benefits and Value of Our Natural Resources

Progress

The UK is generating more value from the use of our natural resources (covering livestock, crops, trees, land use and waste) while also cutting emissions. We have halved our emissions from these sectors since 1990 and they now only account for 15 per cent of total UK emissions[268].

During this time emissions from the waste sector have decreased by 73 per cent. This has been driven by taxing waste to landfill, increased recycling and more and better waste infrastructure. We have seen household recycling rates increase from 11 per cent to 44 per cent between 2000/1 and 2015/16[269]. At the same time, the UK waste sector has become an important contributor to electricity generation. Waste helped to generate 14 per cent of UK renewable electricity in 2015, enough to power 2.3 million homes[270].

Figure 26: Changes in emissions from waste and economic growth, 1990-2015



Source: ONS, BEIS

[268] BEIS (2017) Final UK greenhouse gas emissions national statistics: 1990-2015 https://www.gov.uk/government/collections/final-uk-greenhouse-gas-emissions-national-statistics

[269] Defra (2016) ENV18 - Local authority collected waste: annual results tables https://www.gov.uk/government/statistical-data-sets/env18-local-authority-collected-waste-annual-results-tables

[270] BEIS (2017) Energy Trends: Renewables https://www.gov.uk/government/statistics/energy-trends-section-6-renewables

This shift in resource efficiency has also been seen in agriculture – since 1990 emissions from producing a kilogram of pork have decreased by 30 per cent and by 16 per cent for a litre of milk. Many of our farms are using more efficient agricultural practices, for example improving crop nutrient and crop health management.

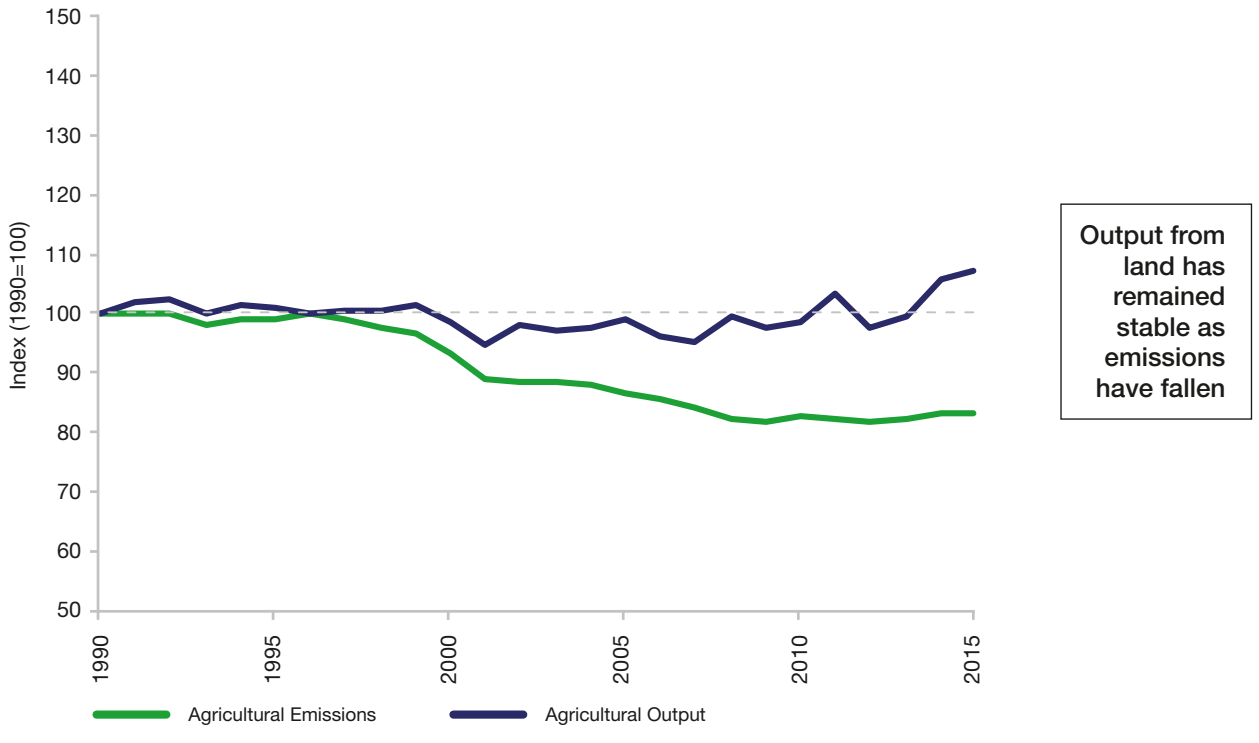
Ambition

We want low emission, highly productive land while ensuring we hand our environment on to the next generation in a better state than we found it. As part of this, we want the UK to become a world leader in terms of competitiveness, resource productivity and resource efficiency: maximising the value we extract from our resources, and minimising the negative environmental and carbon impacts associated with their extraction, use and disposal. We will work toward achieving zero avoidable waste by 2050.

Reducing emissions from natural resources will be important for meeting the 2050 target cost-effectively. Emissions from natural resources could fall by 30 per cent, with tree cover in England increasing by 180,000 hectares from 9.8 per cent to 11 per cent, as they are nurtured from saplings into maturity, providing essential spaces for our communities and enhancing our carbon sink.

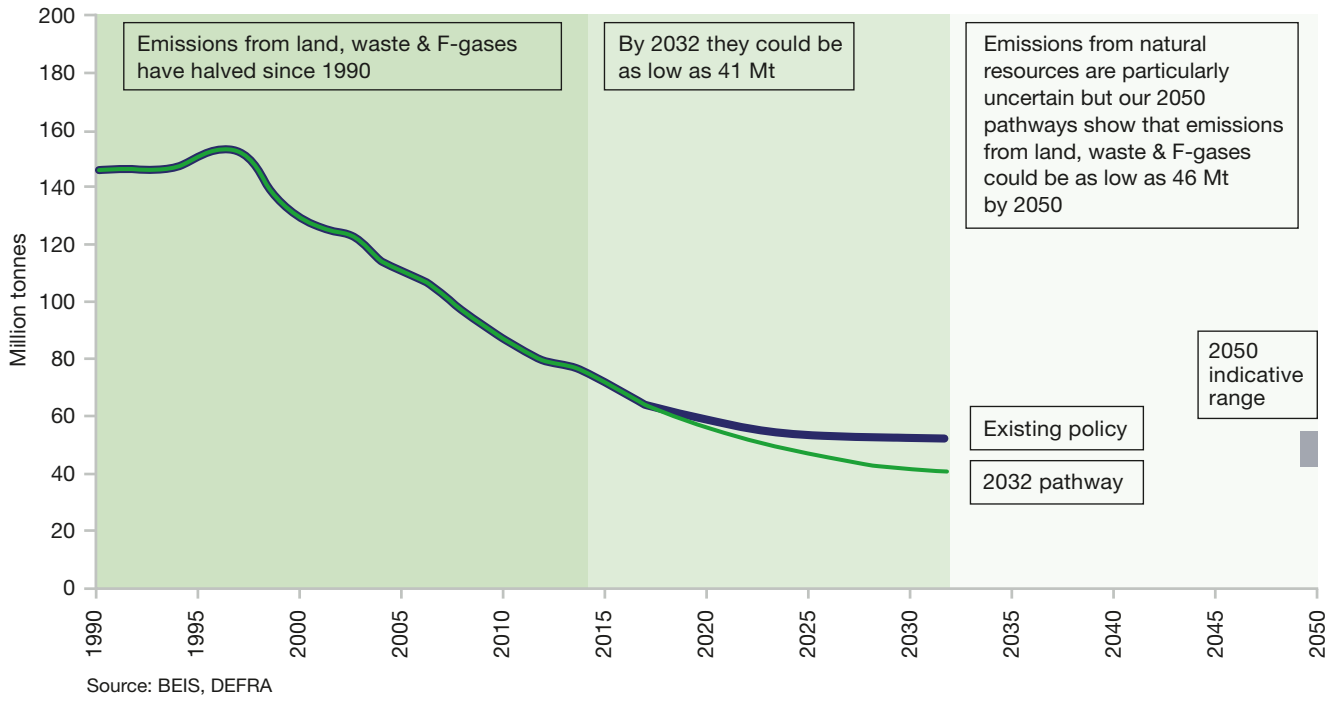
One possible pathway to 2032 could involve emissions from our natural resources falling by almost two fifths compared to today, and is consistent with meeting the Government's 2060 aspiration, to increase England's woodland cover from 10 per cent to 12 per cent. The pathway ramps-up planting in the 2020s recognising the significant contribution trees make to later carbon budget periods.

Figure 27: Changes in emissions from agriculture and agricultural outputs, 1990-2015[271]



[271] ONS (2016) Annual and quarterly low level aggregates of UK output gross value added (GVA), https://www.ons.gov.uk/economy/grossdomesticproductgdp/datasets/ukgdpolowlevelaggregates/current

Figure 28: Actual and projected emissions in natural resources, taking into account the clean growth pathway, 1990-2050



Source: BEIS, DEFRA

To achieve this 2032 pathway, we need to ensure that our farmers and land managers have the right incentives to promote environmental improvement while encouraging consumers, businesses and industry to further reduce waste and improve their resource efficiency, resulting in reduced bills. This means:

- Leaving the Common Agricultural Policy and designing a new system of future agricultural support will give us the opportunity to address climate change more directly. We will design a new system to support the future of farming and the countryside, with a strong focus on delivering better environmental outcomes, including tackling climate change. An Agriculture Bill was announced in the Queen's Speech following the 2017 general election, the details of which will be announced shortly.

- Our indicative pathway could involve planting up to 130,000 hectares of new woodland and implement plans for farmers to plant more trees across England, providing not just carbon reduction but recreational space for our growing communities and timber for our bioeconomy.
- We will develop new ambitious plans for the sustainable management of our natural environment including capturing more carbon by our plants and soil.
- Action to divert more food waste than ever before from landfill, to support resource productivity and avoid further emissions by preventing food waste in the first place.

Opportunities

The UK has some of the most dynamic and innovative businesses working on using our natural resources more efficiently. Government will work with them to deliver smart and ambitious regulation and targets to help us meet new environmental demands while also driving growth from these sectors.

There are clear economic benefits to be gained from driving resource productivity, a more efficient farming sector and developing the UK's land use sector. Forestry is a growth sector, with forestry and wood processing providing 43,000 jobs in the UK and contributing £2 billion to the economy[272]. This, in turn, provides an important carbon sink – the doubling of woodland cover over the past century means UK forests currently absorb 20 million tonnes of carbon dioxide a year.

Analysis from the Waste and Resources Action Programme (WRAP) suggests progress to a more resource efficient economy has the potential to create up to 205,000 jobs[273]. Some 54,000 of these jobs could be created in regions and at pay grades where there is spare capacity, making a net contribution to UK employment.

Manchester City of Trees

Manchester City of Trees is an urban community partnership focussed on tree planting, woodland management and re-connecting communities to green spaces. The goals of the project are 3 million trees planted, one for every man, woman and child across Greater Manchester, 2,000 hectares of unmanaged woodland brought back into a productive state, and to connect people to the trees and woods around them.

[272] Forestry Commission (2016) Forestry Statistics 2016 https://www.forestry.gov.uk/pdf/Ch8_Finance_FS2016.pdf/$FILE/Ch8_Finance_FS2016.pdf; https://www.forestry.gov.uk/pdf/Ch7_Employment_FS2016.pdf/$FILE/Ch7_Employment_FS2016.pdf Estimate of economic value and jobs relates to forestry and primary wood processing; National Atmospheric Emissions Inventory (2017) Projections of emissions and removals from the LULUCF sector to 2050 http://naei.beis.gov.uk/reports/reports?report_id=927

[273] Waste and Resources Action Programme (2015) Employment and the Circular Economy http://www.wrap.org.uk/content/employment-and-circular-economy

Policies and Proposals

The Government's 25 Year Environment Plan will set out the Government's approach to improving our natural environment, including reducing both carbon emissions and other dangerous pollutants. In meeting carbon budgets we are committed to policy development that enhances our natural assets, helps prepare for the impacts of climate change and supports our commitments on clean air.

Farmers and Rural Businesses Benefit from Clean Growth Opportunities

We want our land and agriculture sectors to play a significant role in low carbon growth, supported through a system of incentives to improve efficiency and improve our natural environment:

1. The Government will introduce a new agri-environment system to support the future of farming and the countryside, with a strong focus on delivering better environmental outcomes, including mitigation of and adaptation to climate change.
2. We aim to support industry in strengthening farm biosecurity to improve productivity, reduce reliance on veterinary medicines and reduce emissions. To begin this, we are developing a scheme to directly tackle endemic diseases in beef and dairy herds.
3. We will work with industry to encourage the use of low-emissions fertiliser. We will review the levels of take up over the next five years using data from the British Fertiliser Practice Survey. This will provide evidence to shape our future policies.
4. We will work with industry to produce a UK Bioeconomy Strategy that will bring together biological industries, academia and innovators, linking up farmers and land managers with high tech industries. Through a thriving innovation-based bioeconomy, we will develop less carbon intensive products such as bio-based chemicals, plastics and other materials.
5. We will develop a new incentive structure to harness the potential for growth in forestry and renewables being supplied from within the UK, including on bioenergy, as part of our ambitions for strengthening the rural economy and encouraging diversification of farm businesses.
6. Funding from the £200 million package of Rural Development Plan for England (RDPE)[274] Growth Programme and Countryside Productivity Offers, announced in July 2017, could be used to support renewable energy projects, such as solar panels or small wind turbines linked to battery storage.

[274] Rural Development Programme for England (RDPE), which works to make England's agriculture and forestry sectors more competitive, to improve the quality of life in rural areas and to diversify rural economies.

Natural Capital

What is natural capital? Natural capital enables us to think about our natural environment and the countryside as a set of valuable assets (for example, forests, clean air, soils, species, freshwaters, oceans and minerals). Like any asset, natural capital, if maintained and invested in, provides flows of services to the economy and society. These include food, energy, carbon sequestration, pollutant removal, flood risk reduction, recreational and educational opportunities, health benefits and many others. Many of these benefits do not have a direct market value.

Why is natural capital relevant for reducing carbon emissions? The Climate Change Act requires that our plan for reducing emissions contribute to sustainability. As part of this work we have looked at how measures and policies could have impacts on our natural assets, including the impact of reducing carbon emissions. Natural capital can also contribute significantly to reducing levels of greenhouse gases through land use and land use change. This is described in the Technical Annex. The Government's wider work on natural capital will be set out in the 25 Year Environment Plan.

Making Sure Our Land Plays a Central Role in Capturing Carbon and Enhancing Natural Capital

7. During the 2020s we need to accelerate the rate of tree planting, working towards our 12 per cent tree cover aspiration by 2060. To do this will require investment by the private and charitable sectors, not just government. A number of our policy proposals will create the conditions for that investment to come forward. We will need new skills in forest design, a reliable supply of resilient planting stock, new opportunities for domestic timber, and a new generation of skilled people helping to enhance our towns, cities and countryside. Recently published natural capital accounts by the Office for National Statistics show that Britain's woodlands provide services of £2.3 billion per year to the economy in terms of recreation, carbon sequestration, timber and air pollutant removal[275].
8. We will develop a new network of English forests with the right incentives and rules to establish and support new regional and national community woodlands to help reach 12 per cent woodland cover in England by 2060. We have allocated funding to woodland planting to support our commitment to plant 11 million trees[276].
9. We will set up a stronger and more attractive domestic carbon offset market that will encourage more businesses to support cost-effective emissions reductions, such as through planting trees. We will also explore how we could extend this market to include other land activities.
10. We will unlock private finance to invest in forestry by establishing forestry investment zones to offer investors streamlined decision making and more certainty, within shorter timelines.
11. We will fund larger-scale woodland and

[275] ONS (2017) UK natural capital: ecosystem accounts for freshwater, farmland and woodland https://www.ons.gov.uk/economy/environmentalaccounts/bulletins/uknaturalcapital/landandhabitatecosystemaccounts

[276] Forestry Commission and Natural England (2017) Countryside Stewardship opens for 2017 https://www.gov.uk/government/news/countryside-stewardship-opens-for-2017

forest creation, and we will design woodland creation incentives that attract more landowners and farmers to plant on marginal land, including through agroforestry and bioenergy production, to help diversify land-based businesses and enhance the farmed environment.

12. Peatland, like woodland, forms a key part of the UK's natural capital, but is widely degraded. We launched a £10 million capital grant scheme for peat restoration in July 2017 to target peatlands in England. Funds are available from April 2018 for three years[277].

13. We will work with industry to increase the amount of UK timber used in construction, creating a conveyor belt of locked-in carbon in our homes and buildings.

The UK will work towards being a Zero Avoidable Waste economy by 2050

14. Zero avoidable waste equates to eliminating all waste where it is technologically, environmentally and economically practicable to do so and working to support innovation in new materials, products and processes that extend the range of materials covered by this categorisation.

15. Working in partnership with business and civil society toward our shared zero avoidable waste ambition, we will support the transition to a highly productive and competitive economy where we unlock the environmental and economic benefits associated with greater resource productivity without imposing negative costs on business or society.

16. By working in partnership with industry, we will be able to seek out opportunities to achieve even greater levels of recycling, improve the utilisation of our food and bio-waste and incentivise activities such as reuse, repair and remanufacturing – protecting our environment and strengthening our economy in the long-term.

17. We will work towards no food waste entering landfill by 2030. Many local authorities have introduced separate collection of food waste and we will work to support more so that the amount of food waste sent to landfill continues to decline.

18. We will set out a new Resources and Waste strategy which seeks to maximise resource productivity, reduce waste in our energy and resource systems, promote well-functioning markets for secondary materials and incentivise producers to design better products. The strategy will focus on three key areas:

    - Maximising resource productivity - through more efficient manufacturing processes
    - Maximising the value we get from resources throughout their lifetimes - by designing products more smartly to increase longevity and enable recyclability
    - Managing materials at end of life – by targeting environmental impacts

[277] Defra press release (2017) New £10 million fund to restore peatland https://www.gov.uk/government/news/new-10-million-fund-to-restore-peatland

19. We will explore how data can support the development of a network of resource efficiency clusters led by Local Enterprise Partnerships (LEPs), whereby LEPs would develop local level strategies to drive greater resource efficiency, supporting processes such as industrial symbiosis and the development of new disruptive business models that challenge inefficient practice.

20. We will explore how we can better incentivise producers to manage resources more efficiently through producer responsibility schemes.

21. We will take action through the Courtauld 2025 Agreement to reduce the amount of food that is wasted in the UK. This could deliver up to £20 billion worth of savings to the UK economy between 2015 and 2025[278]. We will also divert more food from landfill to support resource productivity and avoid further emissions.

22. We will explore new and innovative ways to manage emissions from landfill, undertaking research and analysis to support new approaches such as optimising surface methane oxidation. We will also investigate accelerating the breakdown of waste in landfill to improve the quantity and quality of landfill gas captured. This research should identify innovation to bring down the costs of low carbon technologies and lay the groundwork for future decisions.

Government Innovation Investment

The Government expects to invest £99 million out to 2021 on innovation in natural resources. The Government wants the UK to be at the forefront of land-based innovation – ensuring our industry remains at the cutting edge of agricultural and bio-based technology development through the forthcoming bioeconomy strategy and through the existing £160 million Agri-Tech Strategy[279]:

Recycling Technologies

Recycling Technologies, based in Swindon, has developed a new process that can recycle mixed plastic waste, which normally goes to landfill or is incinerated, into a clean fuel. With the support of an Energy Entrepreneurs Fund grant of around £700,000, testing has shown that this product can be used in industrial burners or marine engines. As an alternative, the product could be distilled and used as feedstock to make more new plastics, paints, polishes or lubricants. Recycling Technologies recently raised £5 million in private investment and are now actively on the lookout for further manufacturing sites.

[278] WRAP (2016) The Courtauld Commitment 2025 to transform UK food and drink http://www.wrap.org.uk/content/courtauld-commitment-2025-transform-uk-food-and-drink

[279] Defra (2015) Agricultural technologies (agri-tech) strategy https://www.gov.uk/government/collections/agricultural-technologies-agri-tech-strategy

- Innovative technology: The Government has supported research on innovative technologies in agriculture via the Agri-Tech Catalyst, to accelerate the translation of research into practical solutions to improve agricultural productivity, whilst reducing the environmental impact of agricultural production, some of which has additional low carbon benefits.
- Centres for Agri-tech Innovation: Four centres have been funded in partnership with industry, academia and Government:
    - Agrimetrics - £11.8 million for a 'big-data' centre of excellence for Agri-metrics to utilise data science and modelling to build a more productive, sustainable and efficient food system.
    - Agricultural Engineering Precision Innovation Centre (Agri-EPI) - £17.7 million on precision agriculture to help the UK's agri-food sector develop more productive and sustainable UK agriculture and export markets.
    - Centre for Crop Health and Protection (CHAP) - £21.3 million to revolutionise how farmers manage crop threats including pests and disease, both in the UK and overseas.
    - Centre for Innovation Excellence in Livestock (CIEL) - £29.1 million to create new livestock technology and products to boost the profitability and productivity of livestock farming.

To complement this early action on innovation, the Government believes there are further opportunities for innovation linked to natural resources. In determining these we have focused where the Government can add the most value and develop UK opportunities. The main innovation challenges that could be unlocked are below, with detail on opportunities for UK investment.

Land

Improving productivity and management skills on farms, coupled with technological innovation, will provide the tools for achieving a step change in the level of carbon savings.

- Fertiliser: We will develop affordable low carbon fertiliser products to reduce and replace fertilisers; explore the potential for bio-stimulants to improve nutrient use efficiency; and explore the viability of fertiliser production by recovering nutrients from wastes and other organic materials.
- Soil health: We will aim to target new sustainable land management techniques to overcome the decline in soil quality in the UK and the impact on productivity. We are already funding UK research into soils to deliver greenhouse gas removals (GGR) and abatement technologies as part of the £8.6 million research on GGRs[280].
- Crops and livestock genetics: We will explore the mitigation potential of new breeding technologies and any barriers to their deployment to improve agricultural and forestry productivity and resilience.

[280] The National Environment Research Council (2017) £8.6 million UK research programme on greenhouse gas removal http://www.nerc.ac.uk/press/releases/2017/09-greenhousegas/

- Low emission farming techniques: We will reduce the costs of resource use in crop and livestock production by: improving our understanding of crop soil interactions; explore the potential of robotics and the latest sensor technologies; precision farming technologies more viable on smaller scale farms, investigate the potential of improving soil health and carbon stocks.
- Forestry innovation: We need to improve the resilience and productivity of our forests such as through greater understanding of how tree genetics can contribute to GGRs, especially as we approach 2050.

Innovate UK will also ensure that future rounds of its health and life science calls encourage bids which directly or indirectly support practices that may have a positive impact on climate change.

Waste

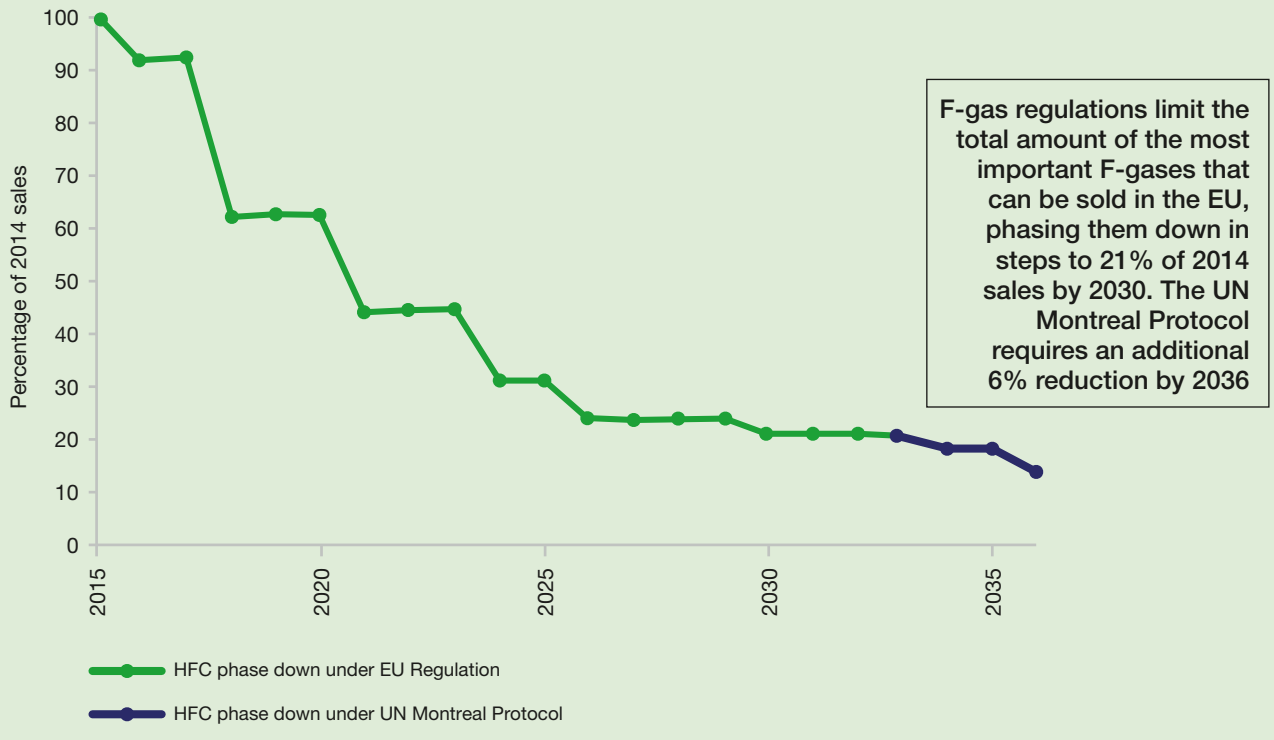
- Anaerobic Digestion. We need to ensure the sector continues to support our carbon and air quality goals, and that best practice is followed when digestate is spread to land to minimise ammonia release and air quality and pollutant impacts. This includes development of improved digestion and ammonia and phosphate extraction technologies while working with the sector to focus on reducing methane emissions.
- Resource efficiency. We will encourage the development of business models which encourage resource efficiency, extend product life, conserve resources, and prevent material from becoming waste. Innovate UK's £15 million Manufacturing and Materials Competition will support the development of more flexible and efficient processes and materials.
- Energy recovery processes. We will work with the waste sector to ensure that different waste materials going into energy recovery processes are treated in the best possible way, to minimise environmental impact and maximise their potential as a resource. The National Infrastructure Commission's work on different pathways for the treatment of waste will feed into this. We will also work with businesses to explore the use of bio-based materials and to promote recyclable packaging so that more is recycled.
- Landfill gas capture and management. There is an opportunity to undertake further research to accelerate methane production in the early life of a landfill site to reduce the length of aftercare required. This could help to reduce emissions from landfill further and in a sustainable way.

Fluorinated Gases

Fluorinated gases (F-gases) are powerful greenhouse gases with a climate change effect up to 23,000 times greater than carbon dioxide[281]. Often used as refrigerants, the reduction in F-gas emissions has been a major success story as we decarbonise the economy. UK emissions decreased by 20 per cent between 1995 and 2015. Our current policies will cut UK F-gas emissions from 17 $MtCO_2e$ in 2015 (about 3 per cent of total UK emissions) to 9.3 $MtCO_2e$ by 2023, 6.6 $MtCO_2e$ by 2027 and 3.2 $MtCO_2e$ by 2035, representing an 81 per cent cut from 2015 levels[282].

The UK led the way in pledging to phase down use of hydrofluorocarbons (HFCs) by 79 per cent by 2030. Following the UK lead, 197 countries agreed under the United Nations Montreal Protocol to a global phase down of HFCs which will see the UK and other developed countries go even further by delivering an 85 per cent phase down by 2036. It is estimated that this deal will reduce emissions equating to 0.5ºC of avoided temperature change[283] by 2100, making a major contribution to the Paris Agreement on climate change and the goal of keeping the global temperature increase well below 2 degrees.

Figure 29: F-gas reduction steps, 2015-2036[284]



[281] IPCC (2007) Climate Change 2007: Working Group I: The Physical Science Basis https://www.ipcc.ch/publications_and_data/publications_ipcc_fourth_assessment_report_wg1_report_the_physical_science_basis.htm

[282] BEIS (2017) Energy and Emissions Projections 2016 https://www.gov.uk/government/publications/updated-energy-and-emissions-projections-2016

[283] National Institute for Public Health and the Environment – Netherlands (2016) RIVM research basis for historic climate agreement on HFCs http://www.rivm.nl/en/Documents_and_publications/Common_and_Present/Newsmessages/2016/RIVM_research_basis_for_historic_climate_agreement_on_HFCs

[284] European Parliament and Council (2014) Annex V of Regulation (EU) no 517/2014 of the European Parliament and of the Council of 16 April 2014 on fluorinated greenhouse gases and repealing Regulation (EC) No 842/2006 http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32014R0517&from=EN

Leading in the Public Sector

Progress

Since 1990, the public sector – including central and local government, health, education and emergency services – has reduced its emissions by 40 per cent[285] as a result of energy efficiency and rationalisation of the central government estate.

Central government and its agencies have led by example through the Greening Government Commitments (GGC), which include a greenhouse gas reduction target. As of 2015/16, we have succeeded in meeting the target by delivering a 27 per cent emissions reduction and £127 million of savings against 2009/10 levels[286]. The original target was a 25 per cent reduction compared to the 2009/10 baseline so new targets were set in January 2017, with the aim of achieving a 32 per cent reduction by 2019/20.

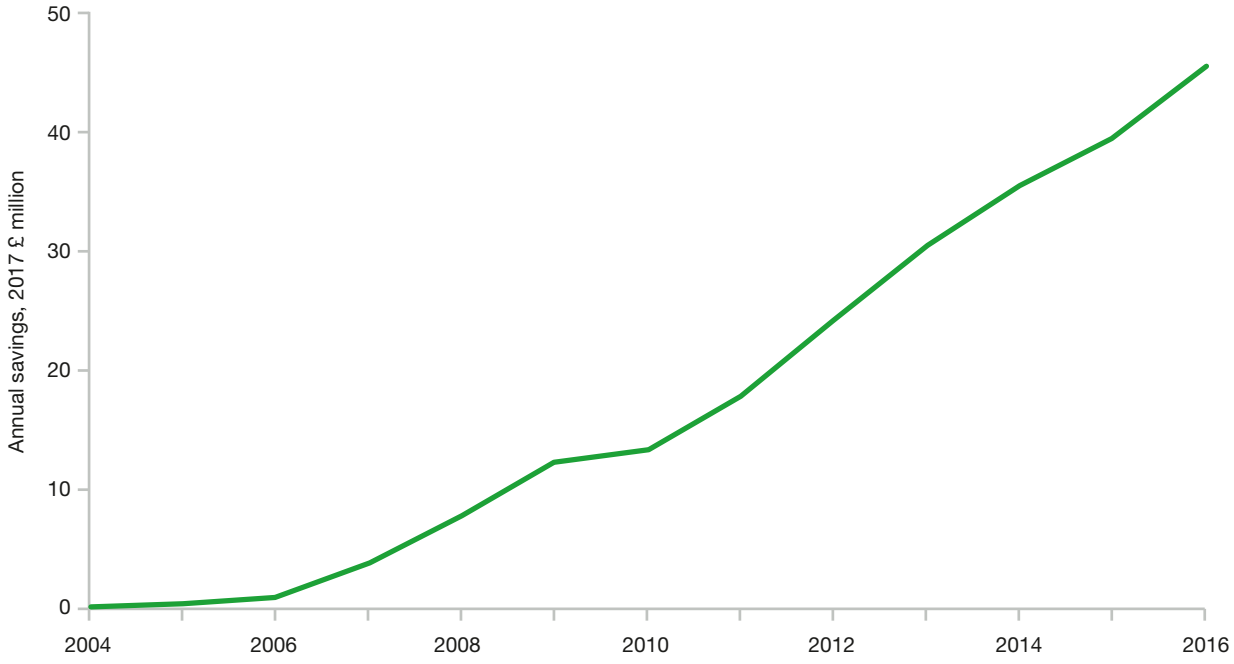
Outside central government, energy efficiency has been supported by an interest-free loan scheme, managed by Salix Finance. To date, the loan scheme has funded over 16,000 projects, improving public sector and higher education buildings for its users and is projected to save the sector around £55 million on energy bills this year[287]. In addition, the Re:Fit programme, managed by Local Partnerships, has helped public sector organisations invest in energy efficiency and energy generation projects by helping them to establish energy service contracts.

[285] Compared to 2015 levels. Sustainable Development Unit (2016) Sustainable Development in Health and Care Report – Health Check 2016 http://www.sduhealth.org.uk/policy-strategy/reporting/sustainable-development-in-health-and-care-report-2016.aspx

[286] Defra (2017) Greening Government Commitments 2015-2016 Annual Report https://www.gov.uk/government/publications/greening-government-commitments-2015-to-2016-annual-report This includes all end use emissions

[287] Salix Finance: Public Sector Loan Scheme https://www.salixfinance.co.uk/

Figure 30: Annual energy bill savings from public sector Energy Efficiency Loans



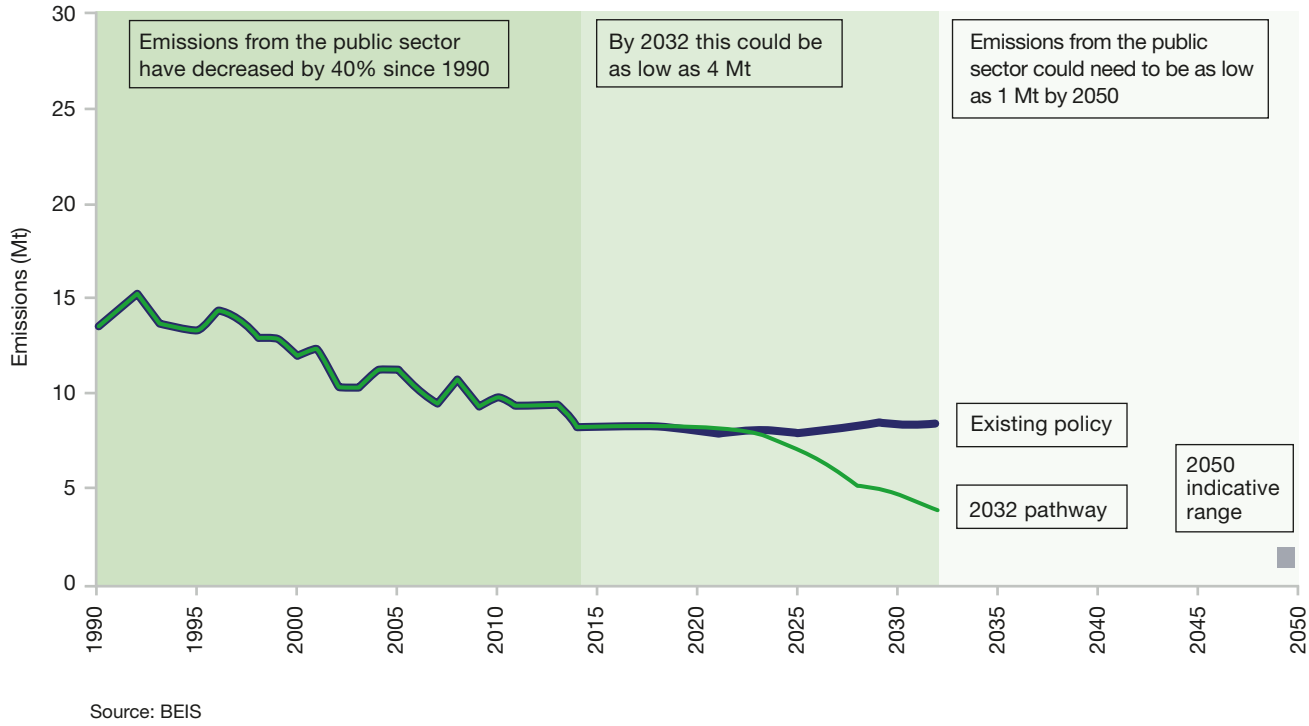
Source: Public Sector Energy Efficiency Loan Scheme BEIS model

Ambition

We want the public sector to be a leader in reducing carbon emissions; an approach that will also save organisations significant amounts of money. While central government has shown what is possible, we now want the wider public sector to reap the benefits of this approach. The annual energy bill across all public sector buildings in England and Wales is estimated to be around £2 billion[288] and this could be reduced significantly, releasing funds for front line services. The public sector also has a key role to play in demonstrating best practice, promoting transparency over emissions reporting and catalysing markets in energy efficiency by implementing measures at scale.

[288] BEIS (2016) Building Energy and Efficiency Survey https://www.gov.uk/government/publications/building-energy-efficiency-survey-bees

Figure 31: Actual and projected emissions in the public sector, taking into account the clean growth pathway, 1990-2050



Source: BEIS

To meet the UK's 2050 target, emissions from the buildings and activities of the public sector will need to be near zero. As with homes and commercial property, this means improving energy efficiency and energy management, and decarbonising the heating and cooling of buildings as far as possible.

Our pathway to 2032 sees emissions from the public sector falling by around 50 per cent compared to today. To achieve this, the Government will need to:

- Set longer term emissions reduction targets across the public sector, and encourage transparent reporting on these.
- Address barriers to energy efficiency and low carbon investment, such as supporting organisations to access finance, and make the case for action internally.

Opportunities

Ambitious action in the public sector will catalyse further innovation in low carbon products and services, generating new business and employment opportunities, and acting as a springboard for the wider low carbon market in the UK and internationally.

Spotlight: NHS

The NHS is responsible for around a third[289] of public sector carbon emissions and in 2015/16 around £570 million was spent by the NHS Trust on energy[290]. Emissions from energy and travel alone have an annual carbon footprint of 7.4 million tonnes[291] demonstrating the important role of the NHS and the health supply chain in reducing the UK's emissions. Despite the challenges in the sector, over the last ten years the health system has reduced its annual carbon emissions by 3.6 million tonnes and saved almost £2 billion in energy costs[292]. Health organisations have in place mandatory Sustainable Development Management Plans which include recommendations on reducing carbon emissions, improving energy efficiency, increasing local energy generation and understanding the health and financial impacts of travel[293]. NHS organisations are expected to report annually on carbon reduction with 69 per cent of providers and Clinical Commissioning Groups meeting minimum standards. Health organisations are also strongly encouraged to adopt and report on progress against a carbon reduction target of 34 per cent in line with the Climate Change Act with an NHS baseline of 2007/08[294]. Forty one per cent[295] of trusts already report they are on track to meet the 34 per cent target by 2020/21.

Dryden School

Dryden School is a secondary special school in Gateshead. They cut their energy bill using a 100 per cent interest free loan of almost £80,000, funded by the Government's Salix scheme. By installing LED lighting, pipework insulation and improving the Building Energy Management System and hydrotherapy pool ventilation system they cut their bill by £17,000 a year – saving over £342 per pupil, and meaning their loan pays back in just over four years.

[289] BEIS (2016) Building Energy Efficiency Survey (BEES) https://www.gov.uk/government/publications/building-energy-efficiency-survey-bees

[290] NHS Digital (2017) Hospital Estates and Facilities Statistics http://hefs.hscic.gov.uk/DataFiles.asp

[291] Sustainable Development Unit (2016) Carbon Footprint update for NHS in England http://www.sduhealth.org.uk/policy-strategy/reporting/nhs-carbon-footprint.aspx

[292] Sustainable Development Unit (2016) Securing Healthy Returns http://www.sduhealth.org.uk/policy-strategy/engagement-resources/financial-value-of-sustainable-development.aspx

[293] Sustainable Development Unit (2017) Health Outcomes Travel Tool http://www.sduhealth.org.uk/delivery/measure/health-outcomes-travel-tool.aspx

[294] Sustainable Development Unit (2014) Sustainable Development Strategy http://www.sduhealth.org.uk/policy-strategy/engagement-resources.aspx

[295] Hospital Estates and Facilities Statistics http://hefs.hscic.gov.uk/ReportFilterConfirm.asp?FilterOpen=&Year=2015%2F2016+01&Level=T&Section=S&SHA=&Org_Type=&Foundation=&Site_Type=&PFI=&getReport=Get+Report

Policies and Proposals

Setting Targets and Reporting Against Them

1. Outside central government, some parts of the wider public and higher education sectors have already set emission reduction targets to encourage organisations to focus on cutting carbon and energy bills. However there is no common target that covers the whole sector. Therefore, the Government will introduce a voluntary wider public and higher education sector target of a 30 per cent reduction in greenhouse gases by 2020/21, against a 2009/10 baseline, and will publish a Call for Evidence alongside this document to gain views from the sector on the target and a proportionate reporting framework to underpin this, as well as further policies to realise carbon and cost saving potential. We will review progress against this voluntary target by 2020, with a view to moving to a more ambitious target during the 2020s (such as a 50 per cent reduction by 2030). Once a reporting framework is in place, and there is clear evidence of the impact of voluntary action, a mandatory target could also be considered.

2. For central government, the Greening Government Commitments (GGCs) have already produced significant emissions savings across departments and agencies. We are currently working with departments to agree higher targets for 2020 and actions to further reduce greenhouse gas emissions beyond this date. We will publish the new targets in due course.

Supporting Access To Finance

3. In the 2015 Spending Review, the Government announced £295 million of new funding for public sector energy efficiency across the UK. In England, this increased funding is invested in the existing public sector energy efficiency loan scheme, which is available to the wider public and higher education sectors. The loan scheme administrator currently manages £210 million, and this will rise to some £385 million by 2020. This revolving loan scheme will continue to be recycled to at least 2025. Similar schemes run in Scotland and Wales received £40 million of the 2015 spending review award.

4. An Energy Performance Contract provides finance to organisations so that they can invest in cost-effective energy conservation measures, without incurring any upfront capital costs. The Government will continue to support their expansion in the public sector, as they offer a new route to improve energy efficiency, while producing guaranteed savings. To underpin this approach we are continuing support to the RE: FIT programme in 2017/18, alongside Local Partnerships.

Local Leadership

Moving to a productive low carbon economy cannot be achieved by central government alone; it is a shared responsibility across the country. Local areas are best placed to drive emission reductions through their unique position of managing policy on land, buildings, water, waste and transport. They can embed low carbon measures in strategic plans across areas such as health and social care, transport, and housing.

The Government recognises the importance of anchoring economic growth in the strengths of local areas. Indeed, each local area will be responsible for coordinating its own local industrial strategy in alignment with the national Industrial Strategy[296].

Local leaders are already rising to the challenge and putting local carbon targets and strategies in place. Nearly 70 local authorities are signed up to using 100 per cent clean energy by 2050 as part of the UK100 network[297], reflecting the leadership shown by mayors globally on climate change and clean energy. Partnerships across public, private and community sector organisations can unlock powerful integrated local energy solutions.

The Government is committed to supporting local leadership and has already given additional powers and responsibilities through the Cities and Local Government Devolution Act 2016; many of the Local Devolution deals agreed to date include energy commitments. We work with local areas to support delivery, develop partnerships, and enable access to low carbon procurement frameworks.

In 2017, in England we funded 13 Local Enterprise Partnerships (LEPs) to develop local energy strategies and will support the remaining 25 LEPs to produce their own later this year. We will also launch a new Local Energy programme to support local areas in England to play a greater role in decarbonisation. This will increase local capacity and capability across England and provide on the ground practical support and expertise to unlock local energy opportunities.

The programme will start to support delivery of the Industrial Strategy and Smart Systems Plan, working with local areas to demonstrate that deep decarbonisation can be achieved through local system change in a way that keeps costs down and maximises economic benefit.

Innovation at the local level is also vital. The Energy Innovation Board will ensure that all relevant clean technology innovation funds are accessible to local actors including local authorities, Local Enterprise Partnerships, community sector organisations and others, as appropriate.

Government will continue to work with and support local leaders. We will establish a Local Energy Contact Group, building on the valuable work of the previous Community Energy Contact Group, to continue the crucial dialogue between local stakeholders and Ministers.

Local Leadership: Cornwall

Cornwall hosts a wealth of renewable energy resources including wind, solar, geothermal and marine energy. Cornwall now contributes more than 768 MW of sustainable energy generation to the UK energy mix[296], with approximately 25 per cent in local ownership, including 8 MW of Council-owned solar PV and more than 1MW owned by community groups supported by England's first community energy revolving fund with £2.5 million council funds[297].

[296] Regen (2016) Renewable Energy: a local progress report for England https://www.regensw.co.uk/renewable-energy-progress-reports

[297] Cornwall Council press release (2017) https://www.cornwall.gov.uk/council-and-democracy/council-news-room/media-releases/news-from-2017/news-from-march-2017/community-energy-remains-at-the-heart-of-cornwall-council-s-energy-agenda/

Chapter 5:
Next Steps

This Strategy sets out our plan to meet our future carbon budgets. Chapter 4 sets out the potential to reduce emissions across each sector and our policies and proposals to unlock the further savings needed. The timeframes for these actions are set out in full in annexes A and B.

In addition to the Emissions Intensity Ratio, we have also developed a set of metrics which will help us assess and understand progress. These metrics are summarised below and set out in Annex D.

This Strategy is not the end of the process. Our policies and proposals will evolve as we respond to costs coming down, to lessons about what does and does not work, to improved evidence, and to wider trends in the economy, society, technology and innovation. To keep track of this moving picture and our progress towards carbon budgets, we will be monitoring and reporting against each element of this Strategy.

From 2018, we will use the Government's response to the Committee on Climate Change's annual progress report to bring together reporting against this strategy on the emission intensity ratio, metrics and actions. We will publish our performance against the Emissions Intensity Ratio on an annual basis. We will also update key elements of the Strategy in line with our annual statutory responses to the Committee on Climate Change's reports on progress, ahead of setting the sixth carbon budget by 30 June 2021.

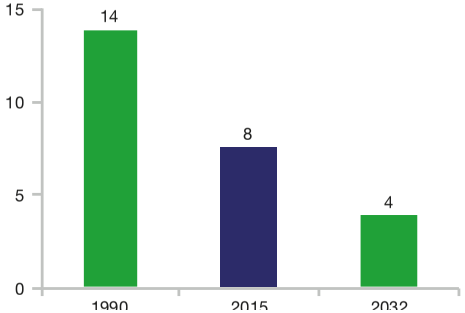
We welcome views on this Strategy. Comments and suggestions should be sent to CleanGrowthStrategy@beis.gov.uk by the end of December 2017. Government intends that the individual departmental policies and proposals contained within the plan will be consulted on separately, where such consultation has not already taken place. Views received in response to both this Strategy and the detailed policy proposals which will follow it will be considered as we update key elements of our strategy before setting the sixth carbon budget by 30 June 2021.

The Government will also launch an annual week focusing on climate issues across the UK, to showcase our progress and successes on climate action, share the latest climate science, and highlight and promote economic opportunities arising from clean growth around the country.

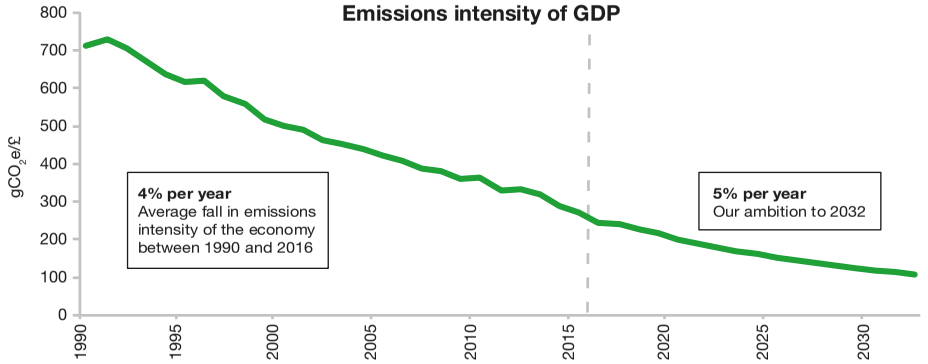
Whole economy

We will report progress against this framework of economy-wide and sector-level metrics annually. Details of each metric are set out in Annex D

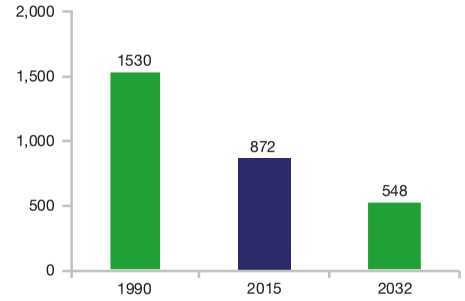
Emissions per capita (tCO_2e/person)



Emissions intensity of GDP

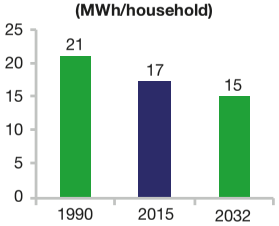


Final energy consumption intensity of GDP (MWh/£ million)

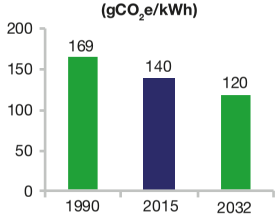


Homes

Home energy use per household (MWh/household)

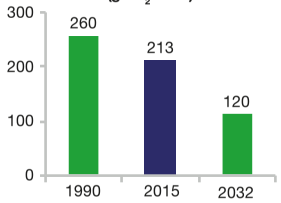


Emissions intensity of home energy use (gCO_2e/kWh)

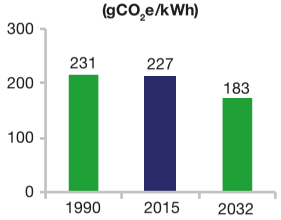


Transport

Road transport emissions per vehicle kilometre (gCO_2e/km)

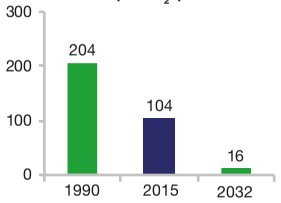


Road transport emissions per energy use (gCO_2e/kWh)

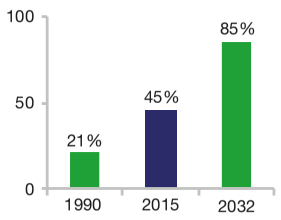


Power

Emissions from generation ($MtCO_2e$)

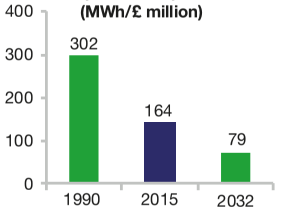


Share of electricity supply from clean sources (%)

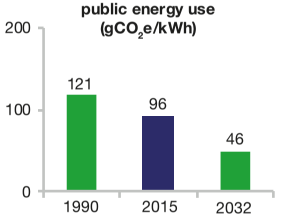


Non-industrial business & public sector

Non-industrial business and public energy use per £m output (MWh/£ million)

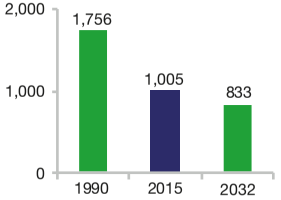


Emissions intensity of non-industrial business and public energy use (gCO_2e/kWh)

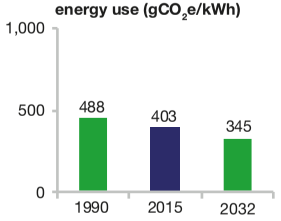


Industrial business

Industrial business energy use per £ million output (MWh/£ million)

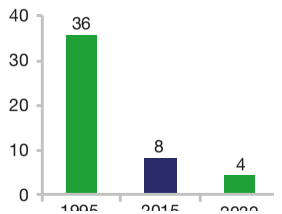


Emissions intensity of industrial business energy use (gCO_2e/kWh)

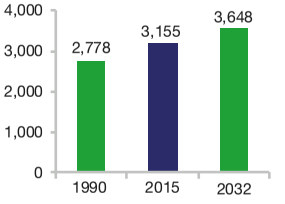


Land & environment

Biodegradable waste sent to landfill (Million tonnes)



Total UK conventional woodland area (thousand hectares)



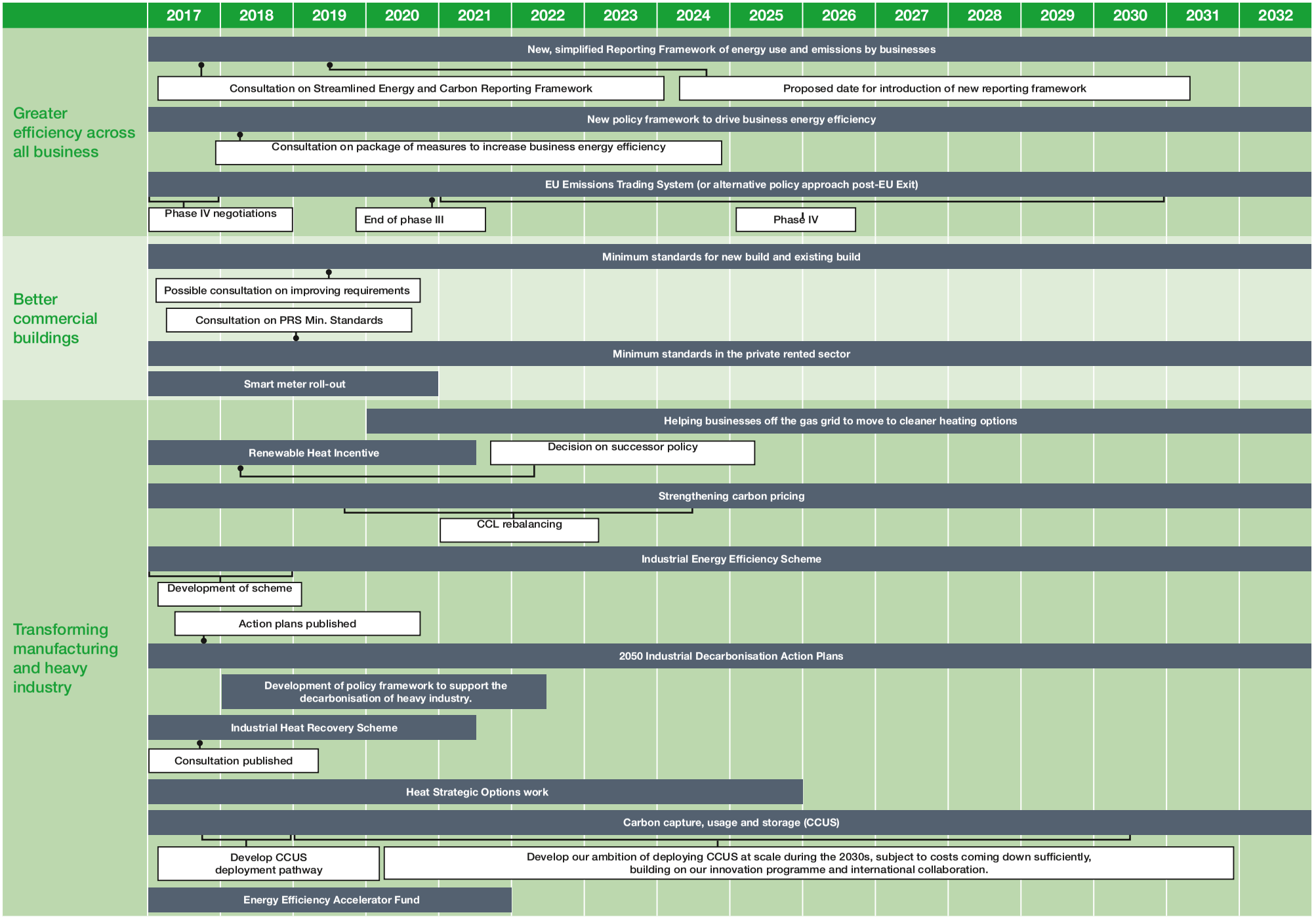
Annexes

Building our
Industrial Strategy

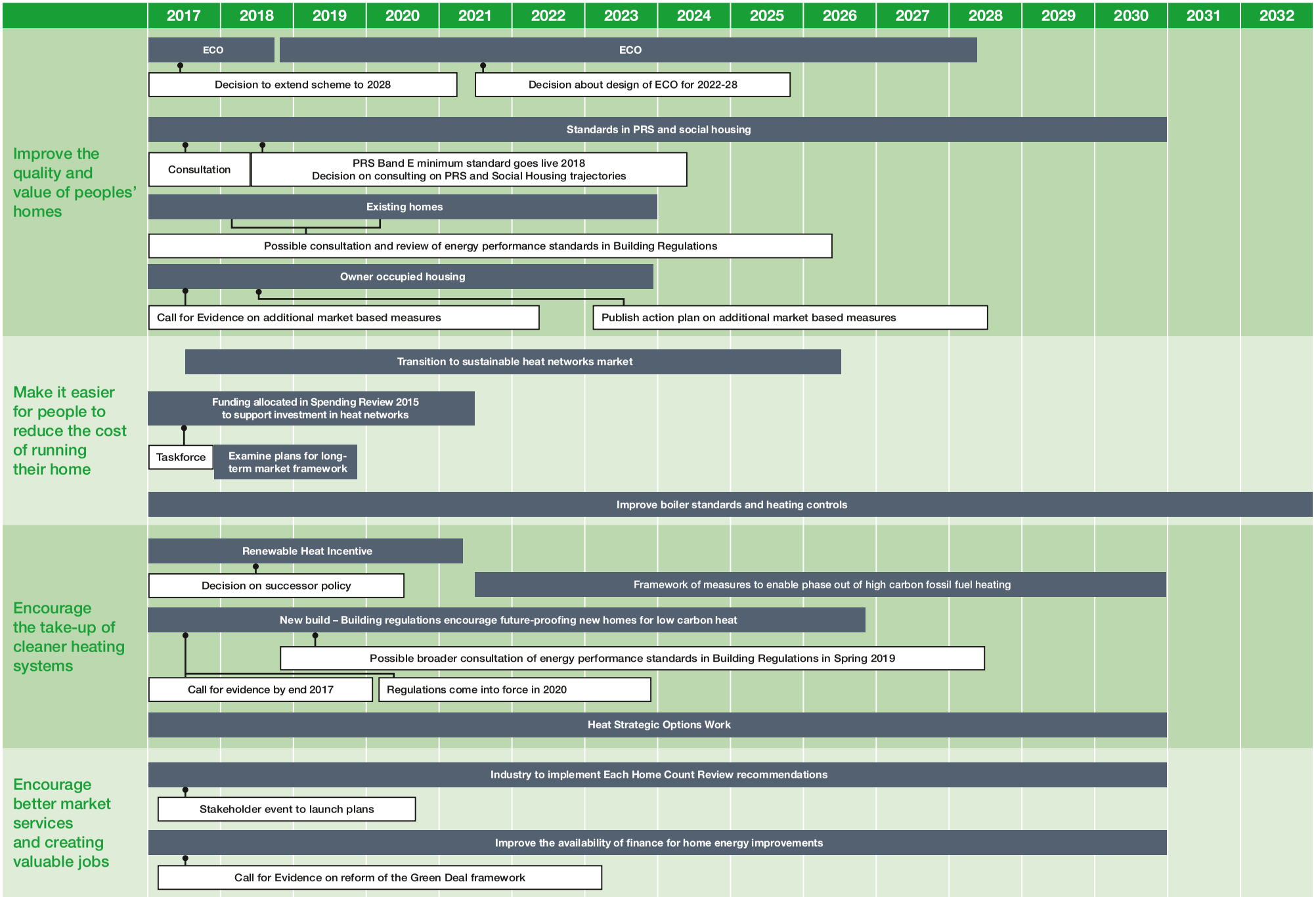
Annex A:
Decision pathways

These following decision pathways give an overview of how the policies and proposals set out in this Strategy map over time. They include future policy development such as publications, key decisions, reviews and consultations, which aim to unlock further carbon savings. Some Government programmes, such as the Industrial Strategy, cut across several sectors and so are not reflected below.

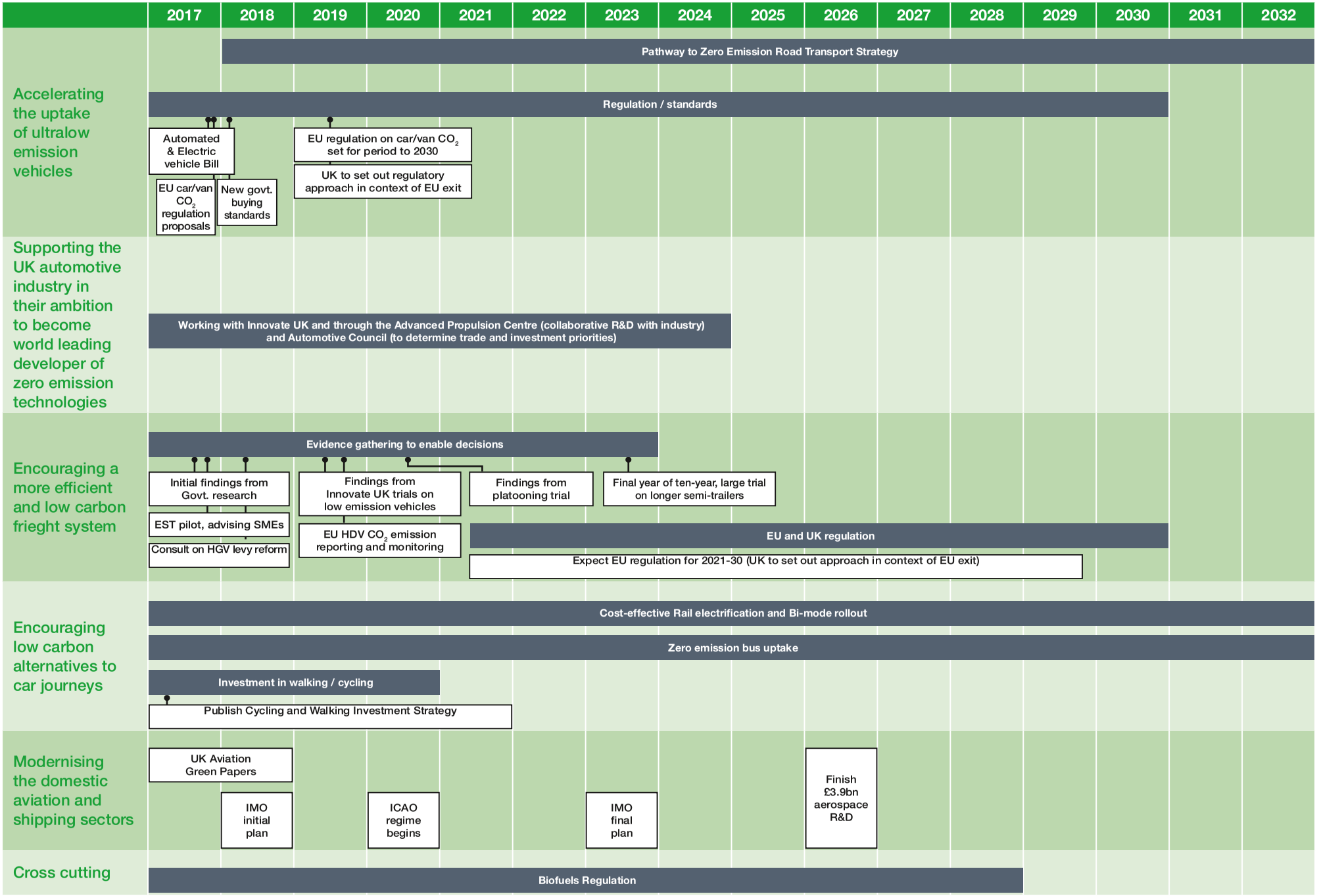
Business and Industry



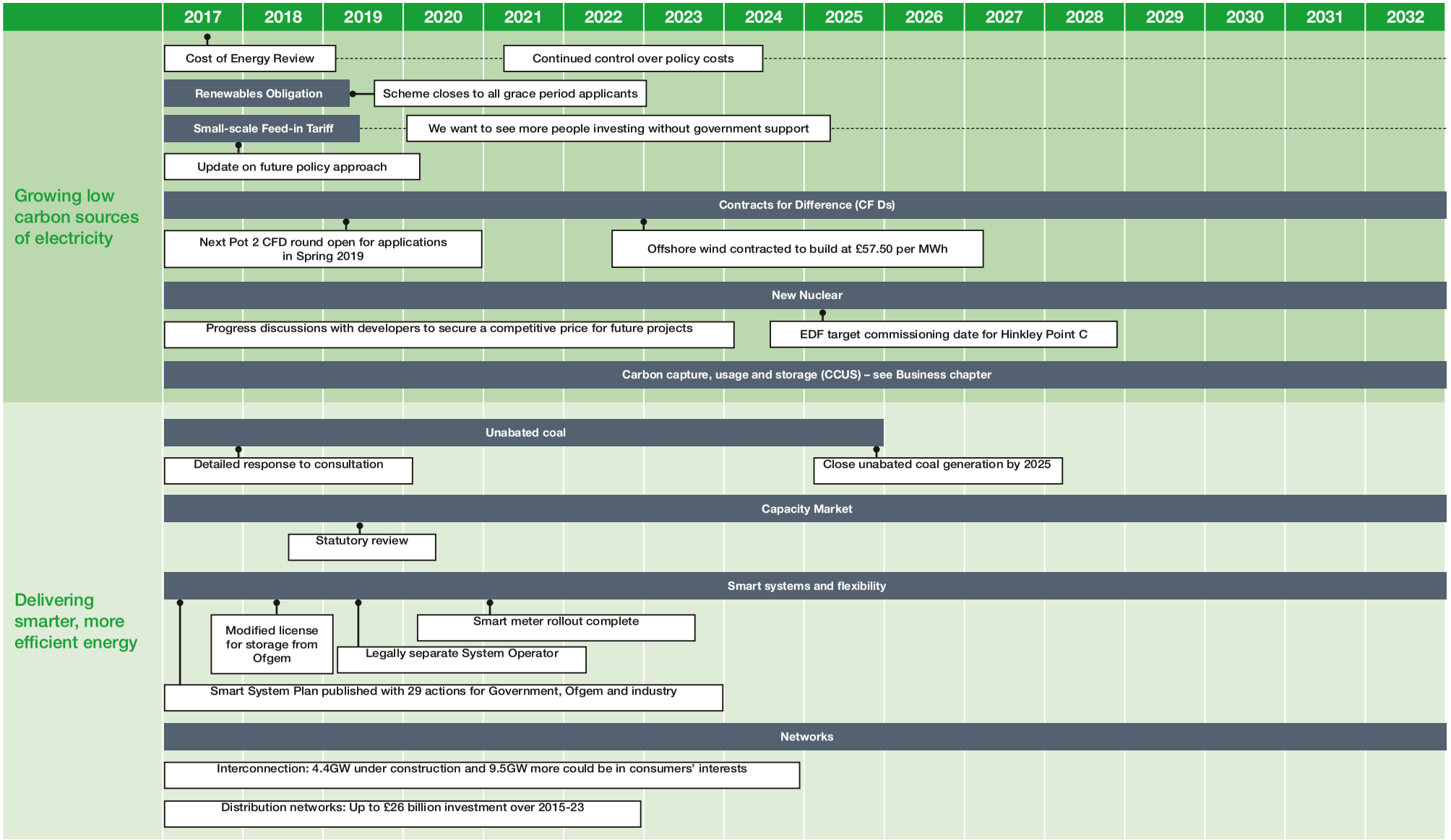
Homes

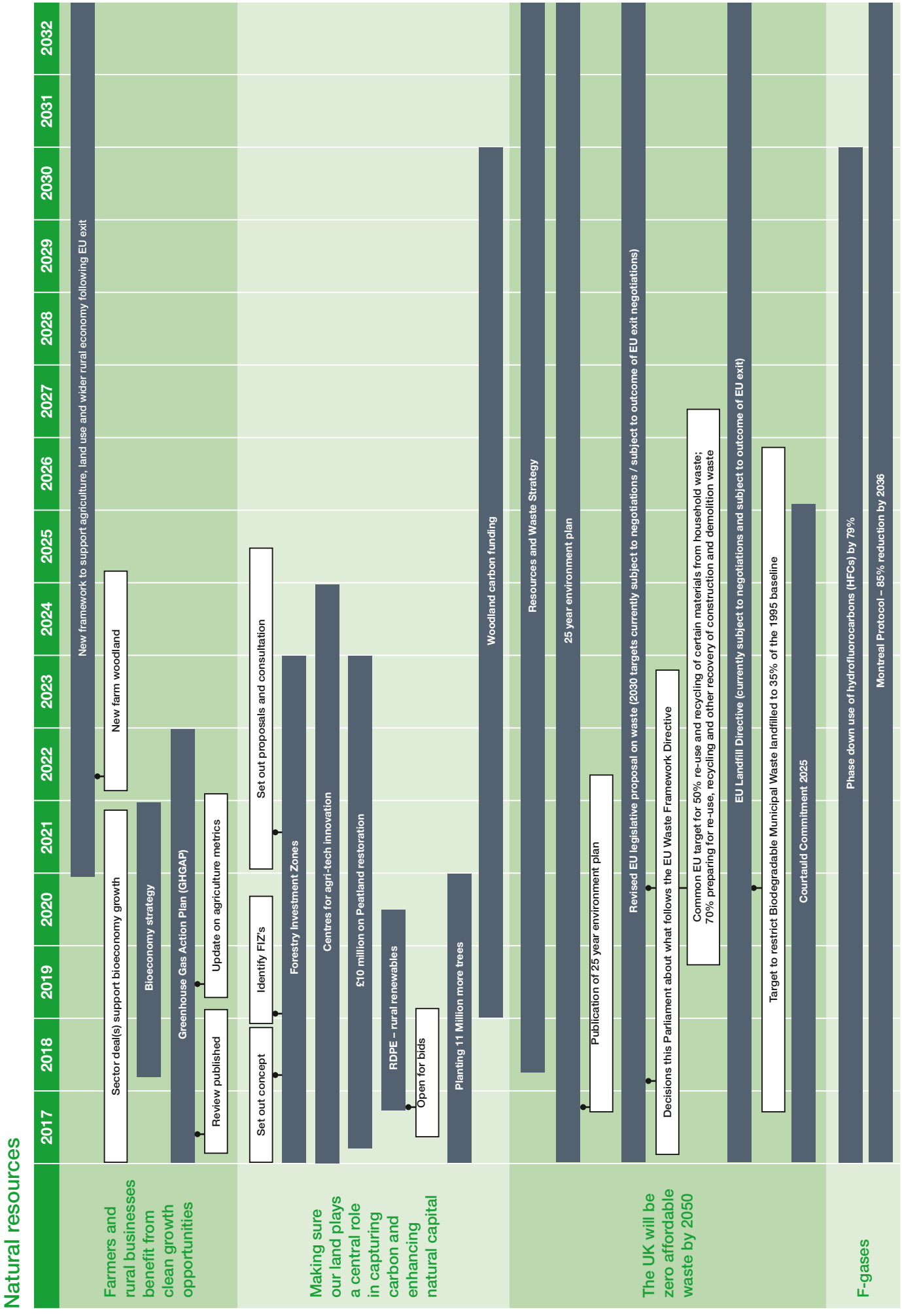

2017
2018
2019
2020
2021
2022
2023
2024
2025
2026
2027
2028
2029
2030
2031
2032
Improve the quality and value of peoples' homes
ECO
ECO
Decision to extend scheme to 2028
Decision about design of ECO for 2022-28
Standards in PRS and social housing
Consultation
PRS Band E minimum standard goes live 2018
Decision on consulting on PRS and Social Housing trajectories
Existing homes
Possible consultation and review of energy performance standards in Building Regulations
Owner occupied housing
Call for Evidence on additional market based measures
Publish action plan on additional market based measures
Make it easier for people to reduce the cost of running their home
Transition to sustainable heat networks market
Funding allocated in Spending Review 2015 to support investment in heat networks
Taskforce
Examine plans for long-term market framework
Improve boiler standards and heating controls
Encourage the take-up of cleaner heating systems
Renewable Heat Incentive
Decision on successor policy
Framework of measures to enable phase out of high carbon fossil fuel heating
New build – Building regulations encourage future-proofing new homes for low carbon heat
Possible broader consultation of energy performance standards in Building Regulations in Spring 2019
Call for evidence by end 2017
Regulations come into force in 2020
Heat Strategic Options Work
Encourage better market services and creating valuable jobs
Industry to implement Each Home Count Review recommendations
Stakeholder event to launch plans
Improve the availability of finance for home energy improvements
Call for Evidence on reform of the Green Deal framework

Transport

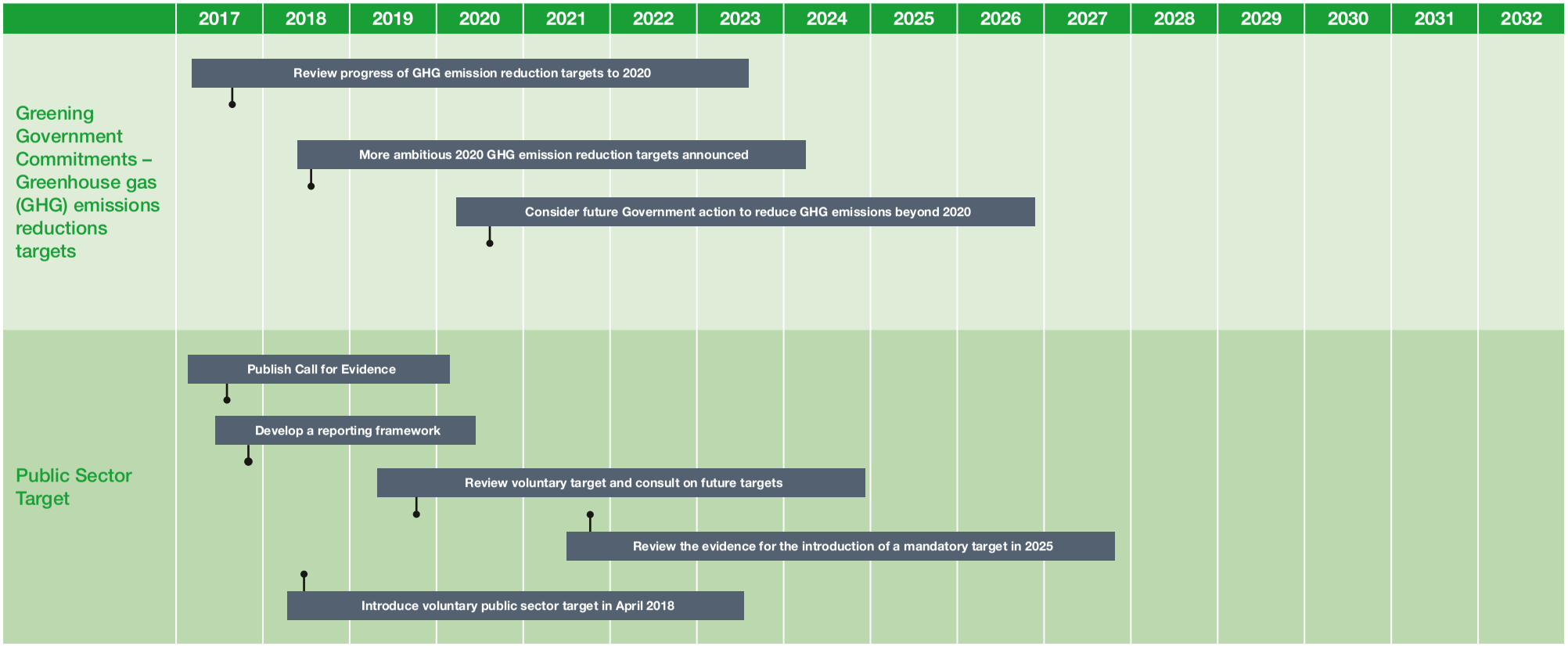

2017
2018
2019
2020
2021
2022
2023
2024
2025
2026
2027
2028
2029
2030
2031
2032
Accelerating the uptake of ultralow emission vehicles
Pathway to Zero Emission Road Transport Strategy
Regulation / standards
Automated & Electric vehicle Bill
EU car/van CO2 regulation proposals
New govt. buying standards
EU regulation on car/van CO2 set for period to 2030
UK to set out regulatory approach in context of EU exit
Supporting the UK automotive industry in their ambition to become world leading developer of zero emission technologies
Working with Innovate UK and through the Advanced Propulsion Centre (collaborative R&D with industry) and Automotive Council (to determine trade and investment priorities)
Encouraging a more efficient and low carbon frieght system
Evidence gathering to enable decisions
Initial findings from Govt. research
EST pilot, advising SMEs
Consult on HGV levy reform
Findings from Innovate UK trials on low emission vehicles
EU HDV CO2 emission reporting and monitoring
Findings from platooning trial
Final year of ten-year, large trial on longer semi-trailers
EU and UK regulation
Expect EU regulation for 2021-30 (UK to set out approach in context of EU exit)
Encouraging low carbon alternatives to car journeys
Cost-effective Rail electrification and Bi-mode rollout
Zero emission bus uptake
Investment in walking / cycling
Publish Cycling and Walking Investment Strategy
Modernising the domestic aviation and shipping sectors
UK Aviation Green Papers
IMO initial plan
ICAO regime begins
IMO final plan
Finish £3.9bn aerospace R&D
Cross cutting
Biofuels Regulation

Power


2017
2018
2019
2020
2021
2022
2023
2024
2025
2026
2027
2028
2029
2030
2031
2032
Growing low carbon sources of electricity
Cost of Energy Review
Continued control over policy costs
Renewables Obligation
Scheme closes to all grace period applicants
Small-scale Feed-in Tariff
We want to see more people investing without government support
Update on future policy approach
Contracts for Difference (CF Ds)
Next Pot 2 CFD round open for applications in Spring 2019
Offshore wind contracted to build at £57.50 per MWh
New Nuclear
Progress discussions with developers to secure a competitive price for future projects
EDF target commissioning date for Hinkley Point C
Carbon capture, usage and storage (CCUS) – see Business chapter
Delivering smarter, more efficient energy
Unabated coal
Detailed response to consultation
Close unabated coal generation by 2025
Capacity Market
Statutory review
Smart systems and flexibility
Modified license for storage from Ofgem
Smart meter rollout complete
Legally separate System Operator
Smart System Plan published with 29 actions for Government, Ofgem and industry
Networks
Interconnection: 4.4GW under construction and 9.5GW more could be in consumers' interests
Distribution networks: Up to £26 billion investment over 2015-23


Natural resources
2017
2018
2019
2020
2021
2022
2023
2024
2025
2026
2027
2028
2029
2030
2031
2032
Farmers and rural businesses benefit from clean growth opportunities
Making sure our land plays a central role in capturing carbon and enhancing natural capital
The UK will be zero affordable waste by 2050
F-gases
New framework to support agriculture, land use and wider rural economy following EU exit
Sector deal(s) support bioeconomy growth
New farm woodland
Bioeconomy strategy
Greenhouse Gas Action Plan (GHGAP)
Review published
Update on agriculture metrics
Set out concept
Identify FIZ's
Set out proposals and consultation
Forestry Investment Zones
Centres for agri-tech innovation
£10 million on Peatland restoration
RDPE – rural renewables
Open for bids
Planting 11 Million more trees
Woodland carbon funding
Resources and Waste Strategy
25 year environment plan
Publication of 25 year environment plan
Revised EU legislative proposal on waste (2030 targets currently subject to negotiations / subject to outcome of EU exit negotiations)
Decisions this Parliament about what follows the EU Waste Framework Directive
Common EU target for 50% re-use and recycling of certain materials from household waste; 70% preparing for re-use, recycling and other recovery of construction and demolition waste
EU Landfill Directive (currently subject to negotiations and subject to outcome of EU exit)
Target to restrict Biodegradable Municipal Waste landfilled to 35% of the 1995 baseline
Courtauld Commitment 2025
Phase down use of hydrofluorocarbons (HFCs) by 79%
Montreal Protocol – 85% reduction by 2036

Public sector



Annex B:
Actions and milestones

This annex sets out actions and milestones that the Government is committing to in this plan, and related publications. Actions will be updated and progress reported through the Government's response to the Committee on Climate Change's annual progress report. Details of the Government's Innovation Investment are set out in Chapter 4.

Lead department	Description	Timing
Improving Business and Industry Efficiency and Supporting Clean Growth		
BEIS	Consult on new and streamlined energy and carbon reporting framework. This will replace some existing schemes, such as the reporting element of the CRC Energy Efficiency Scheme, and align with mandatory annual greenhouse gas reporting by UK quoted companies.	Published alongside this Strategy, with proposed introduction of new framework by 2019
BEIS	Consult on the design of a new £18 million industrial heat recovery programme.	Published alongside this Strategy
BEIS	Publish joint industrial decarbonisation and energy efficiency action plans with seven of the most energy intensive industrial sectors, building on three years of joint industry-Government cooperation.	Published alongside this Strategy
BEIS	New Ministerial-led CCUS Council with industry established.	From 2017
BEIS	CCUS Cost Challenge Taskforce established to deliver a plan to reduce the cost of deploying CCUS.	From 2017
BEIS	Establish an Industrial Energy Efficiency scheme.	From 2017
BEIS/DCLG	Consult on how best to improve the performance of the commercial and private rented sector, through tighter minimum building standards in the Private Rented Sector.	2018
BEIS	Deployment pathway for CCUS produced.	2018
BEIS	Work with industrial clusters to identify the most appropriate way forward to test the potential for development of CCUS industrial decarbonisation clusters.	2018
BEIS	Organise an international CCUS event with international partners.	2018
BEIS	Commit to provide further details on CCUS innovation spend.	2018
BEIS	Develop and consult on a package of measures to support businesses to improve how productively they use energy.	From 2018
BEIS/HMT	Ensure incentives for investment in energy efficiency are regularly reviewed, for instance the list of products that qualify for enhanced capital allowances tax relief.	On-going
BEIS	Undertake an evaluation of the Climate Change Agreements to inform any successor scheme from 2023.	Expected to commence in 2018

Lead department	Description	Timing
DCLG	Following the outcome of the independent review of Building Regulations and fire safety, and subject to its conclusions, the Government intends to consult on improving the energy efficiency of new and existing commercial buildings.	2018
BEIS	Beyond support through the RHI, ambition to phase out high fossil fuel heating in businesses off the gas grid during the 2020s. Businesses and industry will be involved in developing the new policy.	During the 2020s
BEIS	Develop a clear policy framework to support decarbonisation in energy intensive industries.	By 2022

Improving our Homes		
BEIS	Publish a call for evidence on additional measures to encourage energy performance, particularly amongst owner occupiers.	Published alongside this Strategy
BEIS	Publish a call for evidence on how to reform and streamline the Green Deal framework to make the "Pay as You Save" system more accessible to businesses, while ensuring adequate protection for consumers.	Published alongside this Strategy
BEIS	Work with industry to implement the independent industry led *Each Home Counts review* to improve quality and standards for all retrofit energy efficiency and renewable energy installations.	2017
BEIS/HMT	Work with mortgage lenders to incorporate energy efficiency into their lending decisions, and look at incentives and other levers that could encourage home-owners to invest in energy efficiency improvements.	2017
BEIS	Explore ways in which we could make it easier for innovative approaches or products to be installed under our consumer-facing schemes such as the Energy Company Obligation.	2017
BEIS	For privately rented homes, from April 2018, landlords of the worst performing properties will need to improve those properties to a minimum of EPC E before they can be let; lowering bills for some of the most vulnerable private tenants. We will consult shortly on steps to make these regulations more effective.	2017
BEIS	Consult on ECO's operation through to 2022.	2018
BEIS	Reform the RHI to focus the scheme towards long-term decarbonisation through greater uptake of technologies such as heat pumps and bio methane (biogas to grid).	2017
BEIS	Continue to work with suppliers to ensure that people are provided with tailored advice when a smart meter is installed.	2017
BEIS	Alongside this Strategy, the Government has published *Boiler Plus*, improving standards for the 1.2 million new boilers installed in England every year and ensuring control devices are included with every installation so people can control comfort in their own homes for less from April 2018.	Spring 2018
BEIS	Replace the existing, telephone-only Energy Saving Advice Service with a digitally led-service working closely with the Each Home Counts implementation, offering tailored advice on improving the energy performance of people's homes.	Spring 2018
BEIS/DCLG	Issue a Call for Evidence seeking views on further triggers points for Energy Performance Certificates (EPCs) to be updated, as well as wider views on how EPCs could be further improved, in light of new sources of data and capabilities	Spring 2018

Lead department	Description	Timing
BEIS/DCLG	The Government will look at a long term trajectory for energy performance standards across the private rented sector, with the aim of as many private rented homes as possible being upgraded to EPC C by 2030 where practical, cost-effective and affordable.	2018
BEIS/DCLG	The Government will also look at introducing similar energy performance standards across the social housing sector, where practical, cost-effective and affordable. This will need to take account of the findings of the independent public inquiry into the fire at Grenfell Tower and the Government's separate work looking at wider social housing policy issues.	2018
BEIS/DCLG	Following recommendations from the review of Building Regulations and fire safety currently underway explore innovative solutions to energy performance improvements not performing as well as predicted, including potential actions on compliance and enforcement of energy performance.	By 2019
BEIS	Continue smart meter roll out.	Roll out complete by end of 2020
BEIS	Funding allocated in the Spending Review 2015 to grow the UK's heat networks market.	By 2021
BEIS	Beyond support through the RHI, ambition to phase out high fossil fuel heating in homes off the gas grid during the 2020s. Consumers and industry will be involved in developing the new policy.	During the 2020s

Accelerating the Shift to Low Carbon Transport		
DfT	Series of consultation papers setting out the Government's strategic approach to aviation, including how to support growth whilst tackling environmental impacts.	2017-2018
DfT	Regulation to improve EV charge point provision and consumer access under the Automated and Electric Vehicle Bill.	2017
DfT	Deployment of £80 million ULEV infrastructure funding announced in Autumn Statement 2016.	2017-2021
DfT	Consider outcome and next steps in light of SME HGV fleet review pilot.	2017
DfT	Pathway to Zero Emission Road Transport Strategy Document.	By early March 2018
DfT/Defra	Updating Government vehicle buying standards.	End 2018
DfT	EU HGV CO_2 emission reporting and monitoring starts.	January 2019
HMT	Decision(s) on future fiscal support/tax incentives for ULEVs.	Ongoing

Lead department	Description	Timing
DfT	Report from Low Emission Freight and Logistics Trial.	2019
DfT	Decision on domestic regulatory regime for car/van CO_2 regulations in context of EU exit.	2019
HMT	Decisions on support for cycling and walking following end of current funding period (to 2019/20).	2020
DfT	Decision on next steps in light of platooning and longer semi-trailer trials.	2020 onwards
DfT	Decision on domestic regulatory regime for freight CO_2 regulations in context of EU exit.	Mid 2020s
DfT	Active participation in the IMO to address GHG emissions from shipping.	Ongoing
Clean, Smart, Flexible Power		
BEIS	Publish a full response to the consultation on ending unabated coal generation in Great Britain.	Shortly
BEIS	Publish independent Cost of Energy Review, undertaken by Professor Dieter Helm CBE.	Autumn 2017
HMT	Set out further details on carbon prices beyond 2020/21.	Autumn 2017
BEIS	Work with industry to develop a nuclear Sector Deal as part of the Industrial Strategy, looking at boosting competitiveness and skills across the sector.	Autumn 2017
BEIS/HMT	Set out new controls to replace the Levy Control Framework beyond 2020/21.	End 2017
BEIS	Provide an update on our approach for small scale low carbon generation beyond 2019.	End 2017
Ofgem	Introduce a modified generation license for storage to improve regulatory clarity.	Summer 2018
BEIS	Continue to work with nuclear developers on their new build proposals, including on financing plans.	2018
Ofgem/National Grid	Create a legally separate system operator.	April 2019
BEIS	Planned Pot 2 Contract for Difference auction.	Spring 2019
BEIS	Continue to work with Ofgem and industry to implement the 29 actions in the Smart Systems and Flexibility Plan.	2020

Lead department	Description	Timing
Enhancing the Benefits and Value of our Natural Resources		
BEIS	Set out approach to bring together biological industries, academia and innovators, linking up farmers and land managers with high tech industries to make the most of existing resources and develop advance feed stocks that are essential for the future low carbon economy.	By end of 2017
BEIS	New Bioeconomy Strategy.	By end of 2017
Defra & BEIS	Set up a stronger and more attractive domestic carbon offset market that will encourage more businesses to support cost-effective emissions reductions such as through planting trees. We will also explore how we could extend this market to include other land activities.	2017 onwards
Defra	Establish forestry investment zones.	2017 onwards
Defra	Set out 25 Year Environment Plan.	2017 onwards
Defra	Government to publish a new Resources and Waste Strategy.	2018
Defra	Publish a Clean Air Strategy.	2018
Defra	£10 million capital grant scheme for peat restoration.	Funds available from April 2018 for 3 years
Defra	Continue working with the Organisation for Economic Co-operation and Development (OECD) on their project to improve the modelling of macroeconomic effects of the transition to a circular economy.	Project concludes end of 2018
Defra	Commit to make available up to £200 million to support rural communities over the next two years and set out agroforestry decisions.	By end of 2019
Defra	Allocated funding to woodland planting to plant 11 million trees.	2020
Defra	EU target of at least 50% of household waste being recycled by 2020.	2020
Defra	Woodland Carbon Fund: £19.2 million to fund larger-scale woodland and forest creation.	By 2021
Defra	Work with industry to encourage the use of low-emissions fertiliser, and review the levels of take up using data from the British Fertiliser Practice Survey.	Over next 5 years
Defra	Targets of a 20% reduction in food and drink waste arising in the UK, a 20% reduction in the greenhouse gas intensity of food and drink consumed in the UK, and a reduction in impact associated with water use in the supply chain through delivery of the Courtauld Commitment 2025.	Concludes in 2025, with an on-going review of progress
Defra	Work towards no food waste entering landfill by 2030.	2030
Defra	UK to phase down use of hydrofluorocarbons (HFCs) by 79% by 2030.	2030
Defra	UK to phase down use of HFCs by 85% by 2036 under the United Nations Montreal Protocol.	2036
Defra	Ambition for the UK to be zero avoidable waste economy by 2050.	2050

Lead department	Description	Timing
Leading in the Public Sector		
BEIS	Continue to fund further improvements in the wider public sector with £295 million of funding allocated to the public sector energy efficiency loan scheme, across the UK, in the 2015 Spending Review.	On going
BEIS	Introduce a voluntary wider public and higher education sector target of 30% reduction in greenhouse gases by 2020/21, against a 2009/10 baseline, and will publish a Call for Evidence. We will review progress against this voluntary target by 2020, with a view to moving to a more ambitious target during the 2020s (e.g. 50% reduction by 2030). Once a reporting framework is in place, and there is clear evidence of the impact of voluntary action, a mandatory target could be considered.	2018
BEIS	Review existing carbon saving policies impacting the public sector to assess whether changes or new policies are needed to realise the carbon and costs savings potential. We will explore this further through a Call for Evidence.	2017
BEIS	Currently assessing how much the current 2020 greenhouse gas emission reduction target under the GGCs could be stretched to be more ambitious yet achievable. We also aim to set an appropriate level of ambition beyond 2020.	2018
BEIS	Continue to support the expansion of Energy Performance Contracts in the public sector which can offer a new route for investment in energy efficiency alongside guaranteed savings.	We are providing continuing support in 2017/18

Annex C: Climate science

UK and international climate action is underpinned by a robust evidence base on the science of climate change. In this annex we summarise (i) the scientific evidence that reinforces the need for ambitious action to reduce emissions; (ii) the scientific rationale behind the internationally-agreed global temperature goals; (iii) UK climate action; and (iv) future scientific priorities from a UK government perspective.

1: Why we are committed to ambitious action on climate change

We are already seeing the impacts of climate change. The global average temperature of the Earth's surface has risen around 1°C since pre-industrial times[298]. All but one of the top sixteen warmest years on record have occurred since 2000[299], and each of the last three decades has been successively warmer at the Earth's surface than any preceding decades since 1850[300]. 2015 and 2016 were the warmest years on record by quite some margin[301] -albeit enhanced by the El Niño effect- and the impacts of climate change are already widespread and are affecting many sectors of society[302]. Arctic sea ice extent has declined by about 4 per cent every decade since records began in 1979 and sea level has risen by about 3 mm a year since the early 1990s[303]. In addition, increased uptake of carbon dioxide by the oceans has caused the pH of ocean surface water to decrease by 0.1 units since the beginning of the industrial era, corresponding to a 26 per cent increase in acidity[304]. Without action to reduce the level of greenhouse gases we emit globally, climate change is set to continue with increasing temperatures on the land and in our oceans. This will result in further increases in sea levels, more frequent and more severe heat waves and a changing rainfall pattern leading to more droughts and floods in some regions; and disruption to some ecosystems[305]. Without significant reductions in emissions, the world is likely to be on course for

[298] Met Office (2016) Indicators of change 2016 http://www.metoffice.gov.uk/news/in-depth/indicators

[299] Met Office press release (2016) http://www.metoffice.gov.uk/news/releases/2017/2016-record-breaking-year-for-global-temperature

[300] World Meteorological Organization press release (2017) https://public.wmo.int/en/media/press-release/climate-breaks-multiple-records-2016-global-impacts

[301] World Meteorological Organization press release (2017) https://public.wmo.int/en/media/press-release/climate-breaks-multiple-records-2016-global-impacts

[302] IPCC (2014) Climate: Summary for Policymakers. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability, Summary for Policymakers. http://www.ipcc.ch/report/ar5/wg2/. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change

[303] IPCC (2014) Climate Change 2014: Synthesis Report https://www.ipcc.ch/report/ar5/syr/ Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change

[304] IPCC (2014) Climate Change 2014: Synthesis Report https://www.ipcc.ch/report/ar5/syr/ Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change

[305] IPCC (2014) Climate Change 2014: Synthesis Report https://www.ipcc.ch/report/ar5/syr/ Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change

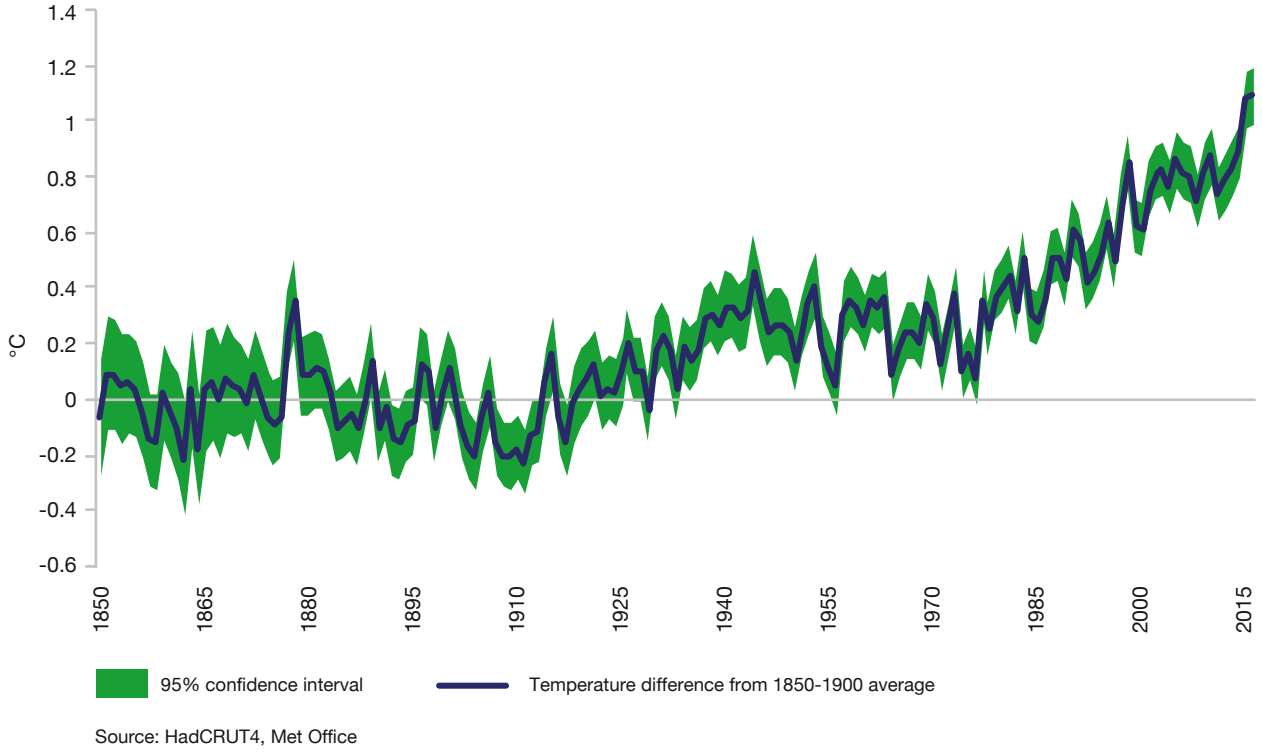
[306] IPCC (2014) Climate Change 2014: Synthesis Report https://www.ipcc.ch/report/ar5/syr/ Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change

average temperature rise in excess of 2°C above pre-industrial levels, and possibly as much as 5°C for the highest emissions scenarios, by the end of this century[306]. Additionally, continuing acidification of the oceans will pose substantial risks to marine ecosystems.

This growing level of global climate instability poses great risks to natural ecosystems, global food production, supply chains and economic development. It is likely to lead to the displacement of vulnerable people and migration, impact water availability globally, and result in greater human, animal and plant disease. Climate change can indirectly increase the risks of violent conflicts by amplifying drivers of conflicts such as poverty and economic shocks. For this reason the UN, Pentagon and UK's National Security and Strategic Defence Reviews cite climate change as a stress multiplier.

The UK is likely to feel the impact of climate change both directly and through impacts in other parts of the world which will affect our food and materials prices, trade, investments and security. In its recent UK Climate Change Risk Assessment[307] the Government endorsed the six key climate change risks for the UK identified in an independent review by the Adaptation Sub-Committee[308]: flooding and coastal change; shortages in public water supply; risks to health, wellbeing and productivity from high temperatures; risks to natural capital and our ecosystems; risks to food security and trade; and new pests and diseases.

Figure 32: Global near-surface annual average temperature relative to a pre-industrial baseline (1850-1900) from 1850 to 2016



Source: HadCRUT4, Met Office

[307] HM Government (2017) UK Climate Change Risk Assessment 2017 https://www.gov.uk/government/publications/uk-climate-change-risk-assessment-2017

[308] CCC (2017) UK Climate Change Risk Assessment 2017 Evidence Report https://www.theccc.org.uk/tackling-climate-change/preparing-for-climate-change/uk-climate-change-risk-assessment-2017/ccra-chapters/

2: Global temperature goals and our progress towards them

Scientific evidence shows that increasing magnitudes of warming increase the likelihood of severe, pervasive and irreversible impacts on people and ecosystems[309]. These climate change risks increase rapidly above 2°C but some risks are considerable below 2ºC. This is why, as part of the Paris Agreement in 2015, 195 countries committed to hold "the increase in the global average temperature to well below 2°C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5°C above pre-industrial levels, recognising that this would significantly reduce the risks and impacts of climate change". The Agreement recognised that in order to achieve this goal, global emissions of greenhouse gases would need to peak as soon as possible, reduce rapidly thereafter and reach a net zero level in the second half of this century.

As part of the Paris Agreement countries also committed to reduce or limit their greenhouse gas emissions. These are contained in their 'Nationally Determined Contributions' (NDCs). A number of studies[310] consider how close these commitments bring us to staying below 2°C, and estimate that if they were met we would be on a path to a global temperature rise of 2.7 to 3.7 °C above pre-industrial levels by 2100. It is worth noting that these assessments have different assumptions regarding both the extent to which countries meet their NDCs and, crucially, the actions that will be taken by countries to reduce their emissions after 2030, which will be a key determinant of whether the world will meet the long-term global temperature goal.

These assessments show that NDCs represent a significant deviation from the 4 to 5°C temperature rise projected if there were no further policies to reduce emissions beyond those in place or planned today. Action would also provide other co-benefits such as limiting the rate of ocean acidification and improving air quality. Nevertheless it is clear that greater action is needed from all countries if we are to limit global temperature increases to well below 2°C.

3: UK climate action

The UK's current target is to reduce its greenhouse gas emissions by at least 80 per cent by the year 2050, relative to 1990 levels. This 2050 target was set to be consistent with keeping the global average temperature to around 2°C above pre-industrial levels with a 50 per cent likelihood. In October 2016 the Committee on Climate Change (CCC) said[311] that the Paris Agreement target "is more ambitious than both the ambition underpinning the UK 2050 target and previous international agreements", but that the UK should not set new UK emissions targets now, as it already has stretching targets and achieving them will be a positive contribution to global climate action. The CCC advised that the UK's fair contribution to the Paris Agreement should include measures to maintain flexibility to go further on UK targets, the development of options to remove greenhouse gases from the air, and that its targets should be kept under review.

[309] IPCC (2014) Climate Change (2014) Impacts, Adaptation, and Vulnerability, Summary for policymakers http://www.ipcc.ch/report/ar5/wg2/ Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change

[310] For example: UNEP (2016) The Emissions Gap Report 2016 http://www.unep.org/emissionsgap/

[311] CCC press release (2016) https://www.theccc.org.uk/2016/10/13/concrete-action-needed-to-meet-uk-climate-commitments-following-paris-agreement-and-brexit-vote/

There will be an unavoidable level of climate change, regardless of future global emissions, because of the existing accumulation of greenhouse gases in the atmosphere. As a consequence, some level of adaptation will be necessary in the UK. To this end, the UK is already considering climate risks and what actions will be required through its five-yearly policy cycle of a Climate Change Risk Assessment followed by a National Adaptation Programme[312]. The scale of the potential investments, the risks associated with failure, and the long lifetimes and lead-times of the infrastructure, together mean that future investments are likely to be highly sensitive to how climate change evolves over the next two to three decades.

Actions to mitigate climate change can have wider positive impacts on the economy and the environment, beyond the direct benefits of avoided climate change[313]. There is strong evidence that well-designed climate mitigation action can provide substantial co-benefits while minimising any possible adverse side-effects[314]. For example, co-benefits can include substantial air quality improvements from avoided fuel combustion and health and wellbeing benefits of active travel.

4: Future scientific priorities and UK leadership

In recent years the debate and focus of scientific research has shifted from whether climate change is happening and/or is being caused by human activity, to the severity of the expected impacts and the level of action required to address climate change through a combination of adaptation and mitigation. Our knowledge has increased significantly but many key research priorities remain. As developed and agreed by the Government Chief Scientific Advisers (CSAs) our current science priorities are:

1. Present weather and climate risks globally and within the UK;
2. Future climate over this century under different emissions scenarios globally and within the UK, including extreme weather events[315];
3. Climate risks and impacts from future climate variability and change;
4. Emission pathways compatible with different levels of warming including timing and a consideration of technologies to achieve net zero emissions;
5. Impacts and opportunities of mitigation and adaptation; and
6. The case for early action: implications of delaying mitigation actions.

The UK is a global leader in climate science and will play a key role in addressing these research needs.

[312] The second UK Climate Change Risk Assessment was completed in 2017 and this is being used to inform the second National Adaptation Programme due for completion in 2018. The third Climate Change Risk Assessment will be delivered in 2022

[313] Royal Commission on Environmental Pollution (2007) The Urban Environment http://www.rcep.org.uk/reports/26-urban/26-urban.htm

[314] IPCC (2014) In: Climate Change 2014: Mitigation of Climate Change, Summary for Policymakers http://ipcc.ch/report/ar5/wg3/ Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change

[315] For example, this includes a better understanding of climate sensitivity and cloud processes, and improving the ability of global climate models to represent regional climate and extremes.

Annex D:
Changes that illustrate how our pathway could be delivered[316]

This table illustrates key changes in each sector that could lead to the emissions reductions set out in our 2032 pathway. It is possible that equivalent emissions savings could be achieved in different ways.

Table 4: Key historic and future changes by sector

		1990	2015	2032
Overall	Emissions per capita (tCO_2e/person)	14	8	4
	Emissions Intensity Ratio, EIR (tCO_2e/£ million of GDP)	717	271	107
	Final energy consumption intensity of GDP (MWh/£ million)	1,530	872	548
Business and public sector	Non-industrial business and public energy use per £ million output (MWh/£ million)	302	164	79
	Emissions intensity of non-industrial business and public energy use (gCO_2e/kWh)	121	96	46
	Industrial business energy use per £ million output (MWh/£ million)	1,756	1,005	833
	Emissions intensity of industrial business energy use (gCO_2e/kWh)	488	403	345
Homes	Home energy use per household (MWh/household)	21	17	15
	Emissions intensity of home energy use (gCO_2e/kWh)	169	140	120
Transport	Road transport energy use per 1,000 vehicle kilometres (kWh/km)	1,127	941	655
	Road transport emissions per vehicle kilometre (gCO_2e/km)	260	213	120
	Road transport emissions per energy use (gCO_2e/kWh)	231	227	183
Power	Emissions from generation ($MtCO_2e$)	204	104	16
	Share of electricity supply from clean sources (%)	21%	45%	85%
Natural Resources	Total UK conventional woodland area (thousand hectares)	2,778	3,155	3,648
	Emissions intensity per £m agricultural output (tCO_2e/£ million)	5,354	3,841	2,817
	Biodegradable waste sent to landfill (Million Tonnes)	36[317]	8	4
	Greenhouse gas emissions from landfill ($MtCO_2e$)	60	12	7

[316] Based upon BEIS, Defra, DfT and DCLG analysis. Further information on sources is made available in the technical annex.

[317] Covers the period 1995 as the earliest data available

Technical Annex

UK Carbon Budgets Explained

Framework

Parliament passed the Climate Change Act (the Act) in 2008, establishing the UK's 2050 target and the supporting framework of carbon budgets. Under the Act, the UK is legally required to reduce greenhouse gas emissions by at least 80 per cent by 2050 on 1990 levels[318]. In order to put the UK on a pathway to achieving the 2050 target, the Government is obliged to set legally binding five-year caps on emissions – 'carbon budgets' – twelve years in advance and then to publish a report setting out the policies and proposals to meet that budget and those budgets previously set.

The Committee on Climate Change

The Act also established the Committee on Climate Change (CCC), an independent statutory body, to advise the Government and the Devolved Administrations on setting and meeting carbon budgets. The CCC advises on the level of each budget, the respective contributions that different sectors could make and the extent to which carbon budgets could be met through the use of flexibilities.

Legislated carbon budgets

Five carbon budgets have been set to date, covering 2008 to 2032[319]. The fourth carbon budget (covering 2023 to 2027) was set in June 2011[320]. The fifth carbon budget (covering 2028 to 2032) was set in July 2016[321].

Accounting for emissions

The UK's performance against its 2050 target and carbon budgets is assessed through the UK's net carbon account, measured in tonnes of carbon dioxide equivalent (tCO_2e)[322].

The net carbon account[323] comprises greenhouse gas emissions from the UK, emissions which are captured and stored from land use, land-use change and forestry (LULUCF) and net purchases of international carbon units. Carbon units include allowances issued under cap and trade systems, such as the EU Emissions Trading System (EU ETS) and international carbon credits issued under international schemes, such as the Clean Development Mechanism[324].

[318] The target covers a selection of greenhouse gases in addition to carbon dioxide, namely methane, nitrous oxide, and a range of fluorinated gases (F-gases), specifically hydrofluorocarbons, perfluorocarbons, and sulphur hexafluoride. The 1990 baseline consists of emissions in 1990 for all greenhouse gases except for the F-gases, for which the baseline is 1995. The baseline is revised annually in line with updates made to the UK's greenhouse gas inventory (the official record of UK greenhouse gas emissions). BEIS (2017) Final greenhouse gas emissions inventory statistics 1990-2015 https://www.gov.uk/government/statistics/final-uk-greenhouse-gas-emissions-national-statistics-1990-2015

[319] UK Legislation (2009) The Carbon Budgets 2009 http://www.legislation.gov.uk/uksi/2009/1259/article/2/made Covering first three carbon budgets

[320] UK Legislation (2011) The Carbon Budget Order 2011 http://www.legislation.gov.uk/uksi/2011/1603/made

[321] UK Legislation (2016) The Carbon Budget Order 2016 http://www.legislation.gov.uk/uksi/2016/785/made

[322] Given the size of the UK economy, we typically describe targets in terms of millions of tonnes of carbon dioxide equivalent ($MtCO_2e$) – so the fifth carbon budget limits UK emissions to 1,725 $MtCO_2e$ or 1,725,000,000 tCO_2e

[323] The Annual Statement of Emissions sets out the net carbon account. BEIS (2017) https://www.gov.uk/government/collections/annual-statements-of-emissions

[324] Clean Development Mechanism: https://cdm.unfccc.int/

The net carbon account for each budget is calculated according to rules set out in Carbon Accounting Regulations[325]. Under current regulations, the net carbon account reflects the UK's share of the EU ETS for power, heavy industry and domestic aviation. The EU ETS sets a total cap on the amount of greenhouse gases that can be emitted by heavy industry and power plants in the participating countries. For the "non-traded" sectors which fall outside the EU ETS, the net carbon account reflects the UK's reported emissions under the United Nations Framework Convention.

The UK's 2050 target and carbon budgets currently exclude emissions from international aviation and international shipping, but the Act states that in setting carbon budgets, the Government must take these emissions into account[326]. The CCC advises that the UK should plan for international aviation and shipping emissions of around 41 $MtCO_2e$ in 2050 – this has been incorporated into our scenarios and will be kept under review. Further information is set out in the 2050 pathways section of this technical annex.

International actions

The 2015 Paris Agreement under the UN established the goal of keeping the global mean temperature rise to well below two degrees, whilst pursuing efforts to limit the rise to under 1.5°C. The UK is already playing its part, with the CCC confirming that there is presently no need for the UK to change its targets in light of the Paris Agreement (see Annex C on Climate Science).

As well as our obligations under Paris, as a current member of the EU, the UK has EU-level targets to 2020. In October 2014, the European Council agreed an EU level target of at least a 40 per cent reduction in EU domestic emissions from 1990 levels by 2030. This target will be split into an EU-wide target for the traded sector, governed by the EU ETS, and member state-level targets for the non-traded sector, set via the Effort Sharing Regulation (ESR). A separate Land Use, Land Use Change and Forestry Regulation will cover emissions from those activities. The EU ETS, ESR and the LULUCF Regulation for the period 2021-2030 are still under negotiation in Brussels, though we anticipate that the emissions reductions under the UK's domestic Climate Change Act will be more ambitious and challenging than those set by the EU. The EU legislation on greenhouse gas emissions is among the important current arrangements between the UK and EU that will be addressed as part of the UK's EU exit negotiations. However, whatever the form of the UK's partnership with the EU, working closely together to address the global challenge of climate change will remain important.

[325] For each carbon budget the Government proposes accounting rules for Parliament to agree. Carbon accounting rules for the first and second carbon budget can be found here: https://www.gov.uk/government/publications/2010-to-2015-government-policy-greenhouse-gas-emissions/2010-to-2015-government-policy-greenhouse-gas-emissions#appendix-4-carbon-budgets

[326] Climate Change Act: Section 30 http://www.legislation.gov.uk/ukpga/2008/27/section/30

The Role of Carbon Markets

Since establishing the first multi-industry carbon trading scheme in the world in 2002 - the voluntary UK ETS - the UK has had an influential role in establishing the EU Emissions Trading System (EU ETS), the first and largest carbon trading scheme. According to the Institute for Public Policy Research, 93.5 per cent of the global market in carbon exchanges is in London, making it the carbon trading capital of the world[327].

Putting a price on carbon is set to play an increasing role in moving to a global low carbon economy. Carbon markets can help reduce the cost of reducing emissions by enabling the reductions to occur where it is least cost to do so[328]. Already 40 national jurisdictions and over 20 cities, states and regions put a price on carbon amounting to 13 per cent of global greenhouse gas emissions[329].With China implementing a national emissions scheme this year, this will rise substantially.

The UK supports a number of initiatives to encourage development of carbon markets, such as the Carbon Initiative for Development and the Forest Carbon Partnership Facility Carbon Fund. These deliver development benefits while incentivising high quality, high volume supplies of carbon credits.

Looking beyond 2020, the Paris Agreement provides an opportunity to stimulate international co-operation. The agreement includes a framework for carbon trading, currently under development through international negotiations. It also provides incentives to engage the private sector to get more actively involved in the transition to a low carbon future. The opportunity to develop a trade in good quality carbon units is at the heart of the UK Government's vision for an efficient global carbon market.

Projections of UK energy and emissions

The Government projects what our energy demand, fuel mix and emissions might look like as a result of our existing policies. These Energy and Emissions Projections (EEP) give us a sense of whether we are on track to meet our carbon budgets. The latest projections were published on 15 March 2017. We are continually working to improve our projections. In 2018 we will share more details of the methodology, enabling further understanding.

Our latest projections show the trend of falling emissions while growing our economy is set to continue. They estimate that between 2015 and 2020 we will reduce emissions by 17 per cent, while the OBR forecasts the economy is set to grow by nine per cent (in real terms) over this period[330].

We have met our first carbon budget and current central projections show us exceeding requirements for both the second and third carbon budgets[331]. Emissions are projected to continue to fall through the 2020s, but there is an estimated shortfall against the fourth and fifth carbon budgets, based on estimates of emissions reductions from existing policies.

[327] IPPR (2017) https://www.ippr.org/public/index.php/news-and-media/press-releases/londons-status-as-carbon-trading-capital-of-the-world-at-risk

[328] World Bank Group (2016) State and Trends of Carbon Pricing 2016 https://www.openknowledge.worldbank.org/handle/10986/25160

[329] World Bank & Ecofys (2017) Carbon Pricing Watch 2017 http://www.ecofys.com/files/files/world-bank-ecofys-carbon-pricing-watch-2017.pdf

[330] OBR (2017) Economic and fiscal outlook – March 2017 http://budgetresponsibility.org.uk/efo/economic-fiscal-outlook-march-2017/

[331] BEIS (2017) Energy and Emissions Projections 2016 https://www.gov.uk/government/publications/updated-energy-and-emissions-projections-2016

Table 5: Performance against carbon budgets[332]

		Carbon Budget				
		1 2008-12	2 2013-17	3 2018-22	4 2023-27	5 2028-32
Budget, cumulative emissions, $MtCO_2e$		3,018	2,782	2,544	1,950	1,725
Average reduction vs 1990 emissions, %		-25%	-31%	-37%	-51%	-57%
Existing policies	Projected emissions, cumulative emissions, $MtCO_2e$	2,982 actual	2,650 E	2,453 E	2,096 E	1,972 E
	Result vs. Budget,%	-1.2%	-4.7%	-3.6%	+7.5%	+14.3%
Existing and new policies and proposals[333]	Projected emissions, cumulative emissions, $MtCO_2e$	2,982 actual	2,650 E	2,453 E	2,066 E	1,892 E
	Result vs. Budget, cumulative emissions, $MtCO_2e$	-36	-132	-91	+116	+167
	Result vs. Budget,%	-1.2%	-4.7%	-3.6%	+6.0%	+9.7%
	Cumulative surplus (+) or deficit (-), $MtCO_2e$		+132	+223	+107	-60

We expect our shortfall against the fifth carbon budget to reduce significantly based on the policies and proposals set out in this Strategy. Initial estimates of these new early stage policies and proposals show an additional potential reduction of up to 30 $MtCO_2e$ and 80 $MtCO_2e$ over the fourth and fifth carbon budget periods respectively[334]; these and other policies will be developed building on the proposals outlined in the Strategy.

The Climate Change Act permits the Secretary of State, at certain points in budgetary cycles, to decide to "carry forward" our over achievements from previous budgetary periods or credit carbon units to the net carbon account. These flexibilities may be utilised to meet any shortfalls that crystalised[335]. As is evident from the above table, there is currently sufficient projected surplus available to carry forward to meet the fourth carbon budget and some of the fifth carbon budget; any shortfall that persists following any carry forward may be met through the purchase of international credits, subject to the requirements of the Climate Change Act.

The current projections are subject to significant uncertainty. For example, we cannot predict exactly what type and scale of global technical innovation will develop over the next decade. Indeed as the past few years have shown we cannot predict our future energy mix since global action can transform the cost and installation of different technologies, driving very different outcomes to those expected.

Other uncertainties include:

Macroeconomic factors: such as population, public employment, and gas prices.

Policy impacts: How society will respond to incentives such as taxes or regulation.

Evidence base: Scientific knowledge evolves over time, as does our knowledge of technology performance.

Changing behaviours: Consumer and business behaviour will evolve over time as new priorities change and fashions develop.

This is why we have used "pathways" for each sector rather than specific estimates of emissions reductions from individual policies, to make sure we take an approach that is robust to these uncertainties.

[332] BEIS (2017) Energy and Emissions Projections 2016 https://www.gov.uk/government/publications/updated-energy-and-emissions-projections-2016

[333] BEIS initial estimates of a subset of new early stage policies and proposals show an additional potential reduction of up to 30 Mt and 80 Mt over the fourth and fifth carbon budget periods respectively; these and other policies will be developed building on the proposals outlined in the Strategy.

[334] BEIS initial estimates

[335] Chapter 2 sets out more detail on the Climate Change Act requirements Government will need to follow when taking any decisions on use of flexibilities to meet carbon budgets.

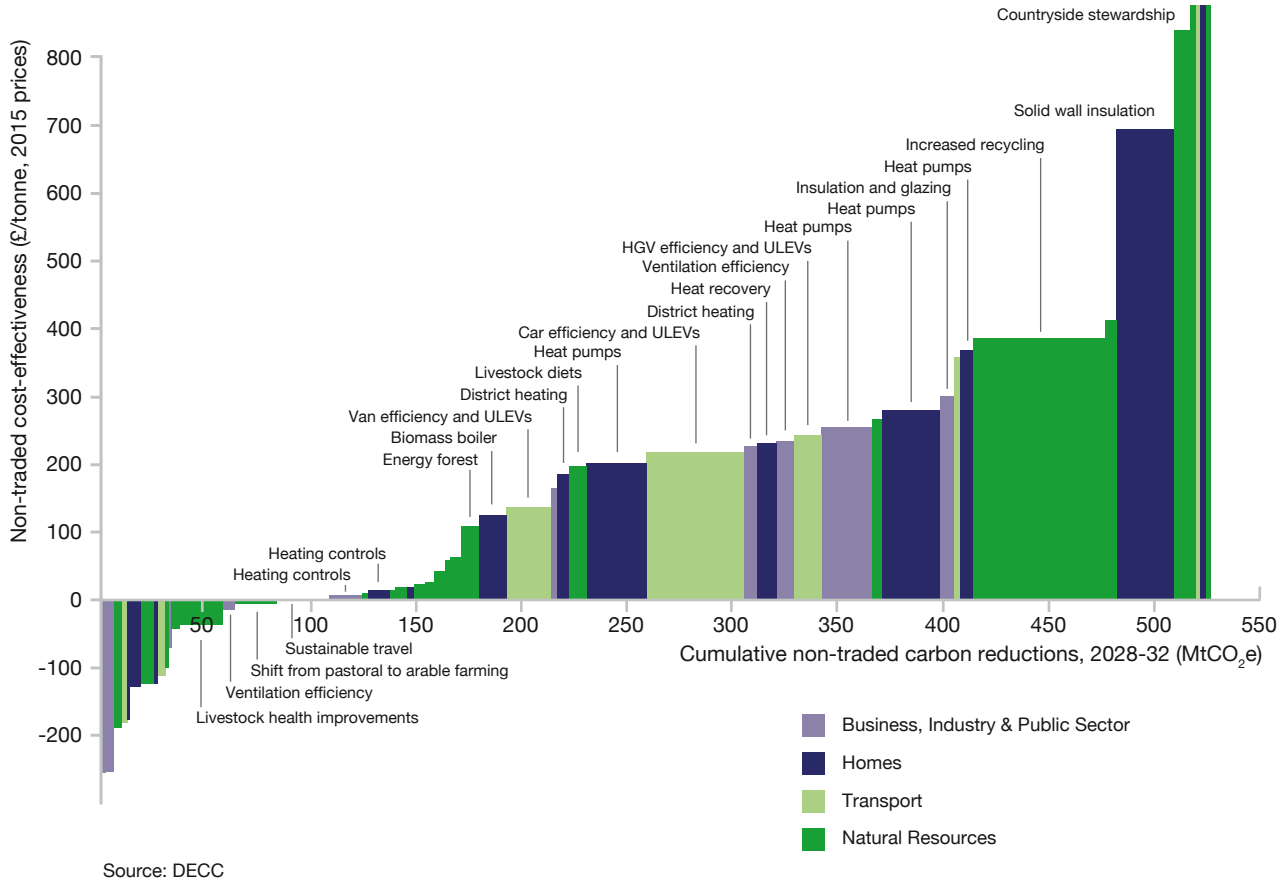
The 2032 pathway

This section provides further details on the impact of the economy-wide pathway presented in Chapter 4 on UK emissions over the period to 2032. Our latest energy and emissions projections provide the starting point for developing the 2032 pathway set out in Chapter 3, and are based on our existing policies.

Emissions reductions beyond our existing policies are then based on the maximum theoretical potential for further abatement identified in the Impact Assessment for the level of the fifth carbon budget[336]. In doing so, a marginal abatement cost curve (MACC) was estimated, indicating the extent, cost, and type of potential for available emissions reductions opportunities. This is shown in Figure 33.

Table 6 on the following page compares GHG emissions in 2017, 2032 and over the fifth carbon budget period based on a) projected emissions under existing (and past) policies, and b) the 2032 pathway for meeting the fifth carbon budget set out in Chapter 4.

Figure 33: Non-traded sector MACC showing maximum theoretical potential (central case, 2028-2032)



Source: DECC

[336] DECC (2016) Impact Assessment for the level of the fifth carbon budget http://www.legislation.gov.uk/uksi/2016/785/impacts Section 3.3.4

Table 6: Direct[337] greenhouse gas emissions by sector

$MtCO_2e$[338]		Current level	Current policies[339]		2032 pathway	
		2017	2032	Fifth Carbon Budget 2028-2032	2032	Fifth Carbon Budget 2028-2032
Business and Industry	Traded	70	63	317	54	283
	Non-Traded	46	37	192	30	158
	Total	116	100	509	83	441
Homes	Traded	0	0	0	0	1[340]
	Non-Traded	72	74	366	58	301
	Total	72	74	366	58	302
Transport	Traded	2	2	10	2	10
	Non-Traded	115	103	516	81	435
	Total	117	105	526	83	446
Power[341]	Traded	80	15	79	16	82
	Non-Traded	0	0	0	0	0
	Total	80	15	79	16	82
Natural resources	Traded	0	0	0	0	0
	Non-Traded	66	53	265	41	215
	Total	66	53	265	41	215
Public sector	Traded	0	0	1	0	1
	Non-Traded	8	8	41	4	22
	Total	8	9	42	4	23
Total	Traded	151	79	407	72	377
	Non-traded	308	276	1,380	213	1,132
	Total UK emissions	459	355	1,787	285	1,509
	Assumed UK share of EU ETS allowances[342]			590		590
	UK Net Carbon Account (non-traded emissions plus UK share of EU ETS allowances)			1,972[343]		1,722

Source: BEIS, DfT, Defra and DCLG analysis

[337] Direct emissions are those produced immediately within the housing sector, and exclude for example emissions from electricity generation.

[338] Figures may not sum due to rounding

[339] Beyond 2020, the emissions scenario for the power sector provides an illustration only.

[340] Increase due to large-scale heat networks

[341] Analysis of the power sector 2032 pathway is based on the BEIS (2017) Energy and Emissions Projections Reference scenario, 2016 https://www.gov.uk/government/publications/updated-energy-and-emissions-projections-2016. The analysis additionally takes into account changes in electricity demand resulting from actions outlined in the 2032 pathway in energy-consuming sectors (e.g. transport, homes, industry). Furthermore, a number of model updates and improvements have been made regarding the electricity demand profiles of key technologies and how this demand might be shifted, the availability of electricity storage technologies, and assumed system operability requirements.

[342] The UK Net Carbon Account is defined by UK Carbon Accounting Regulations. Current regulations require that emissions covered by the EU Emissions Trading System (Traded emissions) are included as being equal to the UK's allocation of permits under the System, rather than actual UK territorial emissions. When setting the fifth carbon budget, this allocation was estimated to be 590 $MtCO_2e$ during the fifth carbon budget period.

[343] Net carbon account as published in the BEIS (2016) Energy and Emissions Projections Reference Scenario prior to the additional analysis made on the power sector (see note above).

Table 7: Non-traded emissions reductions during 2028-2032: Maximum theoretical potential, and the 2032 pathway[344]

$MtCO_2e$	Maximum theoretical potential for reducing non-traded emissions during 2028-2032	Non-traded sector emissions reductions resulting from the 2032 pathway
Business, Industry and public buildings	82	53
Homes	145	65
Transport	107	80
Natural resources	193	50
Total	527	248

Source: DECC, BEIS

This evidence was combined with judgements about the barriers to delivering emissions reductions, the rate at which low carbon options could be adopted and the timescales of key decisions set out in the Decision Pathways annex. The pathway is based on our current expectations of the availability and performance of low carbon options, but there is considerable uncertainty about how these will develop, and this is only one of several plausible pathways.

The maximum theoretical potential for emissions abatement across the UK economy is compared with the emissions reductions in the 2032 pathway (relative to the central emissions projection) in Table 7.

Indicative annual range

Section 12 of the Climate Change Act 2008 requires the Government to publish an indicative annual range for the net UK carbon account for each year over which the levels of carbon budgets are set. An indicative annual range is a range within which the Secretary of State expects the amount of the net UK carbon account for the year to fall. Table 8 shows these ranges for the fifth carbon budget, taking account of the emissions savings implied by the 2032 pathway. The range reflects uncertainty in emissions projections under existing policies.

Table 8: Indicative annual range for the net UK carbon account, 2028-2032 ($MtCO_2e$)

Indicative net UK carbon account	Carbon Budget 5 2028-2032				
	2028	2029	2030	2031	2032
Upper Bound	382	381	372	363	358
Central	357	354	345	336	331
Lower Bound	343	341	331	324	319

Source: BEIS, DfT, Defra and DCLG analysis

[344] DECC (2016) Impact Assessment for the level of the fifth carbon budget http://www.legislation.gov.uk/uksi/2016/785/impacts Section 3.3.4

Table 9: Costs and benefits of the 2032 pathway

Capital and operating costs	The incremental costs of installing and running low carbon technologies
Finance costs	The real social cost of providing finance for capital investments, which varies between sectors
Energy savings	The value of lower energy use due to improved efficiency of energy consumption, or switching from fossil fuels to low carbon alternatives
Greenhouse Gas emissions impacts	The benefits associated with reduced emissions. Where emissions are covered by the EU ETS, this benefit will be the avoided financial cost of purchasing EU emissions allowances. Reductions in non-traded emissions are valued using the Government's non-traded carbon values
Impacts on air quality	The benefits associated with lower emissions of NO_x, $PM_{2.5}$ and other air pollutants detrimental to the health of individuals
Other cost and benefits	These include the hassle cost to households for installing measures, benefits of shorter journey times due to lower congestion, less noise pollution and warmer homes from energy efficiency improvements

Positive economic value

Delivering the 2032 pathway described in this Strategy would result in a wide range of costs and benefits as described in Table 9. These costs and benefits can vary significantly. In particular they will depend on a wide range of social and economic factors such as growth in population and gross domestic product; they will depend on how innovation results in new and lower cost low carbon technologies; and importantly the costs and benefits will also depend on the precise actions that are taken as a result of the Strategy.

The extent of these costs and benefits is not fully known at this point in time because they will depend on the final design of the policies and proposals to meet carbon budgets. When setting the fifth carbon budget an indicative set of costs and benefits were estimated and set out in the accompanying impact assessment[345]. Overall, it was estimated that meeting the fifth carbon budget through domestic action alone could be achieved with a net benefit to the UK of up to £5.5 billion over the fifth carbon budget period.

The impact assessment also set out the sensitivity of these estimates to a range of underlying social and economic factors. These factors in particular included uncertainty around technology costs, energy prices, underlying drivers of UK emissions, and non-cost barriers to delivery.

As noted, these estimates only provide an illustration of the potential scale of impacts. The 2032 pathway shows what is considered possible through domestic action, although this is only one of several plausible pathways. As Government delivers its Clean Growth Strategy and finalises policies, these will be accompanied with their own impact assessments where appropriate, which will set out the specific costs and benefits of the proposals.

[345] DECC (2016) Impact Assessment for the level of the fifth carbon budget http://www.legislation.gov.uk/uksi/2016/785/impacts Section 4.1

2050 pathways

Developing our illustrative 2050 pathways

To explore the range of opportunities for the UK out to 2050 we have used UK TIMES, a model of the whole UK energy and greenhouse gas system (see further detail below). The model allows us to explore different possible outcomes by considering the availability, performance, feasible build rates, and costs of existing and new technologies, as well as how the future economy might differ from today. This model has been developed by the Government in partnership with University College London (UCL) over a number of years, in consultation with many partners.

There are many ways the 2050 target could be met. To illustrate key potential technologies and uncertainties we investigated three pathways in depth. These three have all been deliberately selected to illustrate a wide range of possible pathways; for example, from 100 per cent battery electric cars to 100 per cent hydrogen fuel cell cars. However, different pathways within this range, and beyond this range, are also possible. All three 2050 pathways are consistent with the sector emissions levels in the 2032 pathway presented in this Strategy. They do not represent the most likely or preferred pathways to meeting the 2050 target, but show that the 2032 pathway would leave open a wide range of options for 2050.

A detailed overview of the three pathways is given below, together with an explanation of the methodology used to develop these pathways.

Details of the three 2050 pathways

Pathway 1: Electricity

This pathway sees UK electricity generation increasing to around 650 TWh in 2050. All cars and vans are electric and four in five buildings use electric heating. Electricity is also the main low carbon energy source to the industry sector, making up around one-third of fuel demand. Around one in five buildings use a largely low carbon district heat network. In this pathway carbon capture, usage and storage (CCUS) technologies are not available, which means there are no negative emissions. Hydrogen production is very low and industry sector emissions are higher than in the other two pathways.

Pathway 2: Hydrogen

This pathway sees a key role for low carbon hydrogen in decarbonising our vehicles and buildings. All cars and vans are fuelled by hydrogen and the majority of buildings use a hydrogen grid. Electricity and district heat still play a role in both residential and commercial/public buildings. Overall hydrogen production is around 700 TWh in 2050, with Steam Methane Reforming and CCUS being the primary generation method. The role for CCUS in this pathway is greater than the other pathways with over 170 $MtCO_2e$ being captured and stored in 2050. Because hydrogen is the main energy source for heating and transport, electricity demand and therefore generation is lower than the other pathways at around 340 TWh (around the same level as today).

Pathway 3: Emissions removal

This pathway illustrates the role that a negative emissions technology (in this case bio-energy with carbon capture and storage) could play in meeting the 2050 target. Here negative emissions in the electricity sector of around 20 $MtCO_2e$ create “headroom” for other sectors such as transport, buildings and agriculture to decarbonise more slowly. In this pathway total electricity generation is around 570 TWh. Around four of every five cars and vans on our roads are electric and three in every five buildings are heated by low carbon electricity. Around one in every five buildings uses a largely low carbon district heat network.

Table 10: Characteristics of the 2050 pathways in 2050

		Pathway 1: Electricity	Pathway 2: Hydrogen	Pathway 3: Emissions removal
Non-industrial business and public sector	Emissions ($MtCO_2e$)	3	1	1
	Share of district heat use in heating (per cent)	17%	24%	18%
	Share of electricity use heating (per cent)	83%	13%	80%
	Share of hydrogen use in heating (per cent)	0%	56%	0%
Industrial business	Emissions ($MtCO_2e$)	58	59	48
	Share of electricity use (per cent)	33%	23%	30%
	Share of hydrogen use (per cent)	0%	32%	28%
	Share of bioenergy use (per cent)	20%	15%	9%
	Captured emissions from industrial businesses ($MtCO_2e$)	0	165	37
Homes	Emissions ($MtCO_2e$)	8	6	19
	Share of district heat use in heating (per cent)	17%	17%	17%
	Share of electricity use in heating (per cent)	76%	14%	60%
	Share of hydrogen use in heating (per cent)	0%	62%	0%
Transport	Emissions ($MtCO_2e$)	3	5	15
	Share of car and van km in battery electric vehicles (per cent)	100%	0%	85%
	Share of car and van km in hydrogen fuel cell electric vehicles (per cent)	0%	100%	0%
	Share of HGV km in zero emission vehicles (per cent)	55%	19%	93%
Power	Emissions ($MtCO_2e$)	4	3	-22
	Electricity generation (TWh)	647	339	572
	Share of clean electricity generation (per cent)	99%	99%	99%
Natural resources	Emissions ($MtCO_2e$)	46	46	60
Aviation and shipping[346]	Emissions ($MtCO_2e$)	44	44	44
Total	Emissions ($MtCO_2e$)	165	165	165

[346] Includes domestic and international aviation and shipping, in line with advice from the Committee on Climate Change. CCC (2015) Sectoral scenarios for the fifth carbon budget https://www.theccc.org.uk/publication/sectoral-scenarios-for-the-fifth-carbon-budget-technical-report/

Overview of the methodology used to develop 2050 pathways

The 2050 analysis uses UK TIMES, a model of the whole UK energy and greenhouse gas system covering the period 2010 to 2060[347]. The model identifies the least cost technology pathway capable of both producing an assumed set of outputs (e.g. industrial output, space heating, and passenger distances travelled) and an emissions reduction profile. The technology pathway identified by the model will vary according to the input assumptions for technology and resource performance, cost and availability. The model can also be set up to roll out specific technologies in line with a given deployment profile. When the model is used in this way it will take account of the deployment profiles for specific technologies, and identify the least cost mix of remaining options.

The 2050 pathways analysis has two primary objectives.

First, it examines three substantially different "pathways" of economy-wide decarbonisation to understand the range of possible long-term outcomes.

Through previous modelling, research and external engagement, BEIS has identified the three areas of technology and resource uncertainty likely to have a big impact on the 2050 energy system. The pathways were then developed in consultation with internal sector experts to illustrate potential futures based on contrasting roles for these factors:

- The role of electrification;
- The role of hydrogen;
- The role of bioenergy production with CCUS to produce 'negative emissions'.

Second, it confirms all of the pathways are consistent with meeting the 2050 and fifth carbon budget emissions reduction targets.

The modelled pathways were constructed in UK TIMES by varying input assumptions for:

- Availability of technologies. For example, CCUS is not available in pathway 1 and negative emissions technologies are only available in pathway 3.
- The extent or speed at which technologies can be rolled out e.g. faster growth in hydrogen production is allowed in pathway 2, whilst expansion of electric heating is more restricted.
- Entering fixed deployment profiles for some technologies e.g. 100 per cent of cars and vans are set to be powered by electricity or hydrogen in pathways 1 and 2 respectively.

Other assumptions were kept the same across the pathways. For instance the consumption and output projection assumptions are consistent with current official economic growth and population projections and were the same for each of the modelled 2050 pathways. Technology and resource costs and performance assumptions were also kept the same and sector emissions were aligned to those in the 2032 pathway described in this Strategy.

Impact of international aviation and shipping on 2050 emissions

International aviation and shipping emissions are not currently included within the UK's targets under the Climate Change Act. However, carbon budgets have been set in a way that takes these emissions into account – the UK is on a trajectory that could be consistent with a 2050 target that includes emissions from international aviation and shipping.

[347] For this analysis, model version v1.2.3_d0.6.0_DNP has been used.

The Government has not reached a final view on the appropriate level of international aviation and shipping emissions in 2050. The CCC in their advice on the fifth carbon budget advised leaving space in the 2050 target of around 41 $MtCO_2e$. This has been the modelling assumption used throughout this Strategy[348].

We have undertaken sensitivity analysis to test the potential impact of higher or lower aviation emissions on how the UK could meet its 2050 target (focusing on aviation emissions as they are greater than shipping emissions).

There are a number of policy measures available, both at the domestic and international levels, to address aviation emissions. It is likely that a combination of approaches and policy measures will be required. Examples of action available to countries include: international level action to tackle aviation emissions (such as through international standards and offsetting schemes) and domestic action to tackle aviation emissions (such as through support for sustainable alternative fuel uptake in aviation or improved operational efficiency).

We have explored the feasibility of taking domestic policy action to offset aviation emissions to 2050 above the CCC planning assumption. We have analysed a scenario from the Airports Commission's (AC) work on aviation capacity. For the case of expansion at Heathrow (a new northwest runway), the AC estimated UK gross aviation emissions in its "carbon traded" scenario to be around 44 $MtCO_2e$ in 2050[349].

This scenario for gross UK aviation emissions above the CCC planning assumption provides a useful basis for a sensitivity test. Our analysis shows that it is possible to meet the 2050 target under the Climate Change Act domestically if aviation emissions are 44 $MtCO_2e$[350] – this is the case for our three pathways to 2050. Further action could be taken after the fifth carbon budget in order to offset these higher aviation emissions through action elsewhere in the UK. The action taken in the remaining UK sectors depends on the wider pathway to 2050.

Consideration of wider circumstances

The Climate Change Act requires the Government to take into account a range of factors in developing its plan for meeting carbon budgets. These factors are discussed throughout the Strategy and its annexes. For a number of these factors it is not currently possible to know the full impacts as these will depend on the detailed design of the individual policies that will be developed in the coming years as the Strategy is delivered.

Nevertheless, it is possible to estimate the nature of potential impacts and the considerations that will need to be made as policies are developed. In delivering the Strategy, the Government will undertake analysis to inform policy development. Where appropriate, impact assessments supporting the policy design will be produced.

[348] CCC (2015) Sectoral scenarios for the fifth carbon budget https://www.theccc.org.uk/publication/sectoral-scenarios-for-the-fifth-carbon-budget-technical-report/. The CCC's central scenario allows 37.5 $MtCO_2e$ for aviation emissions in 2050, of which 36.2 $MtCO_2e$

[349] The AC used two scenarios – one called "carbon capped", and one called "carbon-traded". In the "carbon-capped" scenario, the AC's analysis showed that policies are available to limit UK aviation emissions to the CCC planning assumption of 37.5 $MtCO_2e$ in 2050 (domestic and international). In the "carbon traded" scenario, there is a global carbon market allowing reductions to be made where they are most efficient across the global economy resulting in UK aviation emissions of 44 $MtCO_2e$ (domestic and international).

[350] 47 $MtCO_2e$ total international aviation and shipping emission assumed in this scenario

Economic circumstances

Impacts on growth and competitiveness of the UK economy can arise through a number of channels, as a result of actions taken to deliver the Strategy. These arise due to:

- Impacts on the timing and scale of investment spending;
- Impacts on business output resulting from improvements in energy efficiency, and changes in expenditure on capital assets;
- Reorientation of consumption patterns away from emissions-intensive products and towards more energy-efficient products;
- Impacts from changes to energy prices as a result of energy demand changes, and any changes in the costs of policy delivery mechanisms included in energy bills;
- Long-term benefits from innovation, including the development of nascent industries, associated spillover benefits into other sectors, and the increase in exports of knowledge and new technologies;
- Indirect effects on growth through changes in exposure to energy price volatility and supply disruptions;
- Transition costs that could materialise, for example the potential impact of stranded assets and any transitional unemployment; and
- Multiplier effects associated with the above impacts, including any impacts on employment.

The Government has undertaken analysis to assess the likely range of impacts from meeting the range of budgets. This analysis was undertaken in order to inform the setting of the fifth carbon budget and is set out in section 4.1 of the impact assessment.

Fiscal circumstances

Impacts on taxation, public spending, and public borrowing can arise for a number of reasons:

- The Government currently provides financial support for the take-up of low carbon technologies. Changes to existing policies or new policies may affect this expenditure;
- Impacts on GDP, for the reasons set out above, can affect tax revenues;
- Behaviour change can affect revenues relating to environmental taxes (e.g. landfill tax);
- Decisions may be taken in the future with regards to the wider tax system to take account of the broader fiscal position.

Social circumstances

Delivering the Strategy may have impacts on fuel poverty in the UK and its nations. The UK Government has a statutory target to raise as many English fuel poor homes as is reasonably practicable to energy efficiency Band C by 2030, with milestones of Band E by 2020 and Band D by 2025. The Devolved Administrations in Scotland and Wales have separate legal fuel poverty targets.

The pathway set out in the Strategy could affect fuel poverty through a number of channels. These include impacts on energy prices, impacts on the energy needs of households through improved building fabric, and changes in the way heat is supplied. We will assess the impact on fuel poverty as part of the implementation of the individual policies outlined in the Strategy.

Energy policy and energy supplies

Energy security is about ensuring secure, reliable, uninterrupted supplies to consumers, and having a system that can effectively and efficiently respond and adapt to changes and shocks. It is made up of three characteristics: flexibility, adequacy and resilience. The Government is committed to ensuring there are secure supplies for consumers whatever the energy mix.

The energy intensity of the UK economy has fallen significantly since 1990 and this trend is expected to continue. The energy intensity of the UK economy in 1990, as measured through final energy demand, was 1,530 MWh of energy per million pounds of GDP. In comparison, the energy intensity of the UK economy is projected to be around 630 MWh per million pounds of GDP in 2032, under the EEP 2016 reference emissions scenario based on existing policies. In the 2032 pathway, energy intensity could be as low as 548 MWh per million pounds of GDP by 2032.

Delivering the 2032 pathway would result in changes in fuel consumption across the whole economy, with estimated impacts set out in Table 11. In total, the 2032 pathway would reduce final consumption by around 13 per cent in 2032 relative to projected energy consumption under existing policies, as a result of further improvements in fuel efficiency. The reduction in fossil fuel consumption will help improve energy security but the pathway is also characterised by a shift from end-user fossil fuel consumption towards biomass and electricity.

Table 11: Change in annual final energy consumption in 2032, relative to the existing policies scenario

	Potential saving (-) or additional consumption (+) in 2032 (TWh/year)	Percentage impact relative to existing policies
Electricity	+14	+4%
Gas	-124	-23%
Coal	-6	-38%
Oil	-126	-25%
Bioenergy	+28	+29%
Total	**-215**	**-14%**

The capacity mechanism will use competition to find the most cost-effective mix of technologies to ensure we have sufficient reliable capacity to meet electricity demand.

The power sector's response to these changes in demand has been modelled using BEIS's Dynamic Dispatch Model (DDM)[351]. All other things being equal increased electricity consumption results in overall increases in the marginal costs of power supply, due to the need to dispatch more expensive generating technologies to meet consumption. The precise impacts depend on a range of factors, including the technology mix, technology costs, and fossil fuel and carbon prices.

While electricity consumption is lower than the reference case projections (existing policies) in the early 2020s, over the fifth carbon budget as a whole 1.5 per cent more electricity is used. This is met through additional supply from clean generation, gas generation and interconnection.

A smarter electricity system reduces the additional capacity and costs from higher electrification of transport and heat through deploying energy storage technologies, and shifting electric vehicle charging and heat pump demand. Smart flexibility and technologies have the effect of reducing electricity consumption at peak times and shifting consumption to times when overall consumption is lower and more low-cost electricity generation capacity is available.

Sustainability (including the impact on natural capital)

Section 13(3) of the Climate Change Act 2008 states that proposals and policies for meeting carbon budgets must, when taken as a whole, '*be such as to contribute to sustainable development*'. Tackling climate change is essential for maintaining a healthy, resilient natural environment, and the Government is committed to ensuring that the value of nature is appropriately reflected in all relevant policy decisions.

Actions taken to meet our carbon budgets can create both risks and opportunities relating to the quality of our environment. We refer to the stocks of natural assets (e.g., forests, clean air, soils, species, freshwaters, oceans and minerals) that provide flows of natural resource inputs and ecosystem services as natural capital. Government set up the Natural Capital Committee (NCC) in 2012 to advise it on the sustainable use of natural capital, and how the services provided by, and risks to, natural assets can be better accounted for and valued in decision-making. This thinking is informing revisions to the HM Treasury Green Book to ensure a structured and consistent approach to assessing impacts on natural capital in policy appraisal.

To produce an assessment of natural capital impacts for the Strategy, a screening exercise was conducted to identify which policies and proposals might be expected to have natural capital impacts. For these an assessment framework was designed to ensure that potential impacts on natural capital assets and their services were considered in a consistent way. Assessments prompted consideration of the spatial effects of each measure, the timeframe of these effects and a range of environmental assets that could be affected.

[351] DECC (2014) Dynamic Dispatch Model https://www.gov.uk/government/publications/dynamic-dispatch-model-ddm

The detail of the assessments showed that impacts can vary depending on the context and policy approach which is important to consider when developing policy.

Important risks and opportunities identified included:

- Increasing forestry cover can have a number of benefits to natural capital including creating new habitats for animals and reducing flood risk. Likewise changes to farming practices can reduce the demands placed on natural resources and aid biodiversity. However, context is very important when changing land use. For example, benefits vary by species of tree planted, or the previous use of land converted to produce less emission intensive crops.
- Transport sector measures such as the deployment of ULEVs may provide significant opportunities to reduce emissions of harmful air pollutants including Particulate Matter (PM) and nitrous oxides. There are also potential benefits in less pollution running off from road and reduced noise levels.
- Burning biomass for heat or power and biofuels for transport can create some harmful emission including Particulate Matter (PM) and Volatile Organic Compounds (VOCs). More broadly, while there are some risks, there are significant opportunities to both reduce greenhouse gas emissions while also reducing harmful air pollutants.

The work also highlighted the need to consider natural capital impacts across groups of policies. These considerations will be taken forward as specific measures are designed and appraised in detail in accordance with Green Book guidance.

Assumptions and evidence base

The analysis of the 2032 and 2050 pathways are underpinned by a common set of assumptions about future economic and demographic trends, which align with those used for the 2016 Energy and Emissions Projections[352]. The EEP 2016 Reference scenario, representing future emissions under the UK's current suite of climate policies, is also used as the reference for GHG emissions and energy consumption in each sector. The analysis uses assumptions about future energy prices, published as part of supplementary Green Book appraisal guidance.

Wherever possible technical assumptions on costs, performance and availability of technologies have been aligned between the UK TIMES model used for the 2050 pathways analysis and the models used to for the 2032 pathway analysis, although due to differences in modelling approaches there are some minor differences.

[352] BEIS (2017) Updated energy and emissions projections 2016 https://www.gov.uk/government/publications/updated-energy-and-emissions-projections-2016

Evidence base

Commercial and public buildings: 2032 pathway analysis was based on the BEIS Non-domestic Building model using evidence from the Digest of UK Energy Statistics, Energy and Emissions Projections, ECUK and the Building Energy Efficiency Survey (BEES) to estimate heating, cooling and ventilation demand to 2032. Technology evidence was taken from BEES; RHI statistics and an interim heat pump performance report; an AECOM report on heat network costs and performance; and cost data from Heat Networks Delivery Unit (HNDU) sponsored projects. The Products Policy model was used for ventilation scenarios. For the 2050 pathways additional assumptions were taken from Carbon Trust; Valuations Office Agency and Poyry.

Industry: The 2032 pathway was developed using BEIS Industry Pathways Models, split into eight industry sectors. A capital cost uplift of 10 per cent has been applied in the 2032 analysis to reflect potential hidden costs of delivering measures. For iron and steel, paper, cement and a part of chemicals actual production steps are modelled, using evidence from the Usable Energy Database[353]. The remaining sectors (other chemicals, non-metallic minerals, non-ferrous metals, food and drink and 'other' industry) are split into the different energy service demand categories (e.g. high temperature heat, low temperature heat) and generic technologies that produce these types of energy are modelled. Assumptions for these sectors are mainly based on UK MARKAL. Evidence from the Government's 2050 Industrial Decarbonisation and Energy Efficiency Roadmaps, published in 2015, was incorporated into the modelling; in particular, the timing and extent of technologies deployed in the 2032 pathway analysis.

Transport: The 2032 pathway was developed using the Department of Transport's National Transport Model (NTM)[354] for road measures and the Rail Emissions Model for rail measures. The NTM forecasts emissions and traffic accounting for impacts on vehicle fuel efficiency and fuel mix. The ECCo model was used to develop uptake scenarios for Ultra Low Emissions Vehicles. Impacts of sustainable travel measures were based on evidence from the evaluation of the Sustainable Travel Towns[355]. The NTM covers Great Britain, so an uplift has been applied to account for transport emissions from Northern Ireland. This is the standard approach taken by DfT. For 2050 pathways analysis, nine vehicle groups are represented (e.g. car, bus, lorry), each with different types of vehicle choice (e.g. electric or hydrogen). Car and LGV assumptions were based on Element Energy's ECCo Cost and Performance Database; HGV assumptions from a Ricardo report to the CCC (A review of the efficiency and cost assumptions for road transport vehicles to 2050); and maximum growth and delivery rate assumptions from DfT/ University College London (UCL).

[353] UKERC Energy Data Centre, Industrial Energy use: http://tinyurl.com/k8nohc7

[354] DfT (2012) Transport appraisal and modelling tools https://www.gov.uk/government/collections/transport-appraisal-and-modelling-tools

[355] Sloman et al. (2010) The effects of smarter choice programmes in the sustainable travel towns: research report https://www.gov.uk/government/publications/the-effects-of-smarter-choice-programmes-in-the-sustainable-travel-towns-full-report

Domestic buildings: The 2032 pathway for existing buildings covers energy efficiency, heating technologies, heat networks, and behaviour change. The pathway was developed through the BEIS Domestic Buildings Scenario Model. Cost and performance assumptions for energy efficiency and heat measures is based on published analysis for the Renewable Heat Incentive (RHI) and Energy Company Obligation. For new homes, build rate assumptions were taken from the 2015 Housing Standards Review Impact Assessment, and impacts of low carbon heat measures was based on analysis conducted by an AECOM-led consortium. Additional assumptions for the 2050 pathways analysis are taken from UCL, Office of National Statistics (ONS) and Energy Consumption in the UK (ECUK).

Power: The power sector's response to the changes in demand under the 2032 pathway has been modelled using BEIS's Dynamic Dispatch Model[356]. The DDM is a comprehensive fully-integrated power market model covering the market in Great Britain over the medium to long-term. The model enables analysis of electricity dispatch from GB power generators and investment decisions in generating capacity from 2010 through to 2050. It considers electricity demand and supply on a half-hourly basis for sample days. Investment decisions are based on projected revenue and cash flows taking into account policy impacts and changes in the generation mix. The full lifecycle of power generated plant is modelled, from planning through to decommissioning. The modelling accounts for risk and uncertainty involved in investment decisions. UK TIMES 2050 modelling uses the same technology assumptions as the DDM where possible, and also includes additional evidence from UCL, National Grid, EPRI and Carbon Trust.

Agriculture and land use: Agriculture: Evidence has been scaled from England to cover all of the UK Greenhouse Gas Emissions Inventory for England, Scotland, Wales and Northern Ireland (1990-2015). The scaling factor is based on a five-year average of the national contributions to overall agricultural emissions from the national inventory report (the 2014 common reporting format tables). From that data the average English contribution to agricultural GHGs is 63 per cent and estimates are scaled up on this basis.

Forestry: Emissions reductions are projected using an off-line version of the CARBINE carbon accounting model with policy specific mixes of woodland types. Biomass supply from relevant harvest fractions are included in the scenario analysis, but carbon storage and emissions reductions associated with the use of harvested wood products are not. This evidence has been scaled from England to cover all of the UK, based on both the share of current and historical activity[357] and afforestation scenarios developed with DA forestry leads through the LULUCF GHG inventory and projections project funded by the BEIS Science team.

Soils: The 2032 pathway analysis for England uses analysis of the potential GHG savings from different types of peatland restoration. Emission reductions are estimated using preliminary findings from an forthcoming BEIS-funded research project combined with cost data from the peatland code, agri-environment payments and reports for the CCC Adaptation sub-Committee. In order to cover the UK as a whole the England-only data has been scaled based on estimates of total UK peatland area. Agriculture and land use is represented in the 2050 pathway analysis by applying a fixed emissions profile with a series of mitigation options available. This profile combines components from land use, crops and livestock.

[356] DECC (2014) Dynamic Dispatch Model https://www.gov.uk/government/publications/dynamic-dispatch-model-ddm

[357] Forestry Commission (2017) Forestry Statistics https://www.forestry.gov.uk/forestry/infd-7aqdgc

Waste: The emission saving from waste in the 2032 pathway has been informed by a variety of sources. Food waste prevention savings are based on WRAP analysis associated with the Courtauld Commitment 2025. Landfill diversion was based on Defra's Routemap. Projections of waste arising are a key input to the model. Landfill gas capture and oxidation assumptions were developed in an expert elicitation exercise with the Environment Agency. Cover the UK as a whole, the England only data has been scaled based on the Greenhouse Gas Emissions Inventory for England, Scotland, Wales and Northern Ireland (1990-2015).

Economic growth and demographic changes: The 2032 pathway analysis used the same growth assumptions as the 2016 Energy and Emissions projections. In the UK TIMES model used for 2050 pathway analysis, there are 60-plus growth drivers which are exogenous to the model and based on a variety of assumptions including: BEIS Energy Demand Model outputs, GDP growth assumption, ONS population growth, Department for Communities and Local Government (DCLG) household projections and Department for Transport (DfT) transport driver estimates.

Fossil fuel prices: Fossil fuel prices assumptions are based on the BEIS Fossil Fuel Price Assumptions 2016[358].

Carbon Values: The Government's current approach to carbon valuation was adopted in 2009 based on a "target-consistent" methodology. This is set out here https://www.gov.uk/government/collections/carbon-valuation--2.

Aviation and Shipping (A&S): The CCC planning assumption is used to set the aviation and shipping "headroom" level in 2050. Domestic aviation and shipping is modelled as part of carbon budgets leading up to 2050.

Bioresource: Bioresource availability is based on the Bioenergy Feedstock Availability Model[359]. The assumed land area available for energy crops has been limited by excluding a wide range of sensitive sites on both landscape and biodiversity grounds. Domestic and imported bioresource costs are from a range of sources including CCC, E4tech, Carbon Trust and Nix Farm Management.

Air quality: Air quality emissions factors are provided by the National Atmospheric Emissions Inventory and Aether. Air quality damage costs are consistent with COMEAP guidance on air pollution.

Hydrogen: Hydrogen assumptions were developed by University College London[360]. The costs are based on the assumption that a new network would need to be built to allow heating to be supplied by hydrogen.

EU ETS: Assumptions for the UK's share of EU ETS allowances are aligned with the levels assumed at the time of setting the respective budgets. These are 1,078 $MtCO_2e$ (second carbon budget); 985 $MtCO_2e$ (third); 690 $MtCO_2e$ (fourth); and 590 $MtCO_2e$ (fifth).

[358] BEIS (2016) Fossil Fuel Price Assumptions 2016 https://www.gov.uk/government/publications/fossil-fuel-price-assumptions-2016

[359] BEIS (2017) The UK and global bioenergy resource model

[360] Dodds PE, Mcdowall, W. (2012) A review of hydrogen production technologies for energy system models http://discovery.ucl.ac.uk/1402719/

Source information for metrics see Annex D: Changes that illustrate how our pathway could be delivered

Overarching: Emissions estimates for these metrics are taken from the BEIS (2017) GHG emissions statistics[361] and 2032 pathway analysis. Population data (historical and projected) are sourced from the Office for National statistics (2017)[362]. Energy data are taken from the BEIS (2016) Digest of UK Energy Statistics (DUKES)[363] and 2032 pathway analysis. Gross Domestic Product (GDP) estimates to 2015 are taken from the Office for National Statistics[364]. Emissions and energy use projections are based upon BEIS (2017) Energy and Emissions Projections 2016[365]. GDP projections are taken from the Office for Budget Responsibility (OBR) Economic and Fiscal Outlook November 2016.

Business and public sector: Emissions estimates for these metrics are taken from the BEIS (2017) GHG emissions statistics and 2032 pathway analysis. Energy data are taken from the BEIS (2016) Digest of UK Energy Statistics and 2032 pathway analysis. Output gross value added (GVA) estimates for services and industry are sourced from the Office for National Statistics on a constant price basis[366]. There are no official projections of output GVA; estimated trends have been made consistent with assumptions used in BEIS (2017) Energy and Emissions Projections.

Homes: Emissions estimates for these metrics are taken from the BEIS (2017) GHG emissions statistics and 2032 pathway analysis. Energy data are taken from the BEIS (2016) Digest of UK Energy Statistics and 2032 pathway analysis. UK Household historical estimates have been taken from BEIS (2017) Energy Consumption in the UK[367] with projections sourced from BEIS (2017) Energy and Emissions Projections 2016, both of which are consistent with DCLG household modelling.

Transport: The road transport metrics cover cars, vans and freight only. Emissions estimates for these metrics are taken from the BEIS (2017) GHG emissions statistics and 2032 pathway analysis. Energy data for road transport are taken from BEIS (2016) Energy Consumption in the UK, consistent with DUKES. Projected energy estimates are taken from the 2032 pathway analysis. Road transport demand estimates (in vehicle kilometres) are taken from DfT (2017) Road Traffic statistics[368] (Table TRA0201) and 2032 pathway analysis.

[361] BEIS (2017) Final GHG Emissions Inventory Statistics, https://www.gov.uk/government/statistics/final-uk-greenhouse-gas-emissions-national-statistics-1990-2015

[362] ONS (2017) population and migration statistics, https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration

[363] BEIS (2016) Digest of UK Energy Statistics, https://www.gov.uk/government/collections/digest-of-uk-energy-statistics-dukes

[364] Office for National Statistics (2017), Gross Domestic Product: chained volume measures: https://www.ons.gov.uk/economy/grossdomesticproductgdp/timeseries/abmi/pn2

[365] BEIS (2016) Energy and Emissions Projections, https://www.gov.uk/government/publications/updated-energy-and-emissions-projections-2016

[366] ONS (2016) Annual and quarterly low level aggregates of UK output gross value added (GVA), https://www.ons.gov.uk/economy/grossdomesticproductgdp/datasets/ukgdpolowlevelaggregates/current

[367] BEIS (2017) Energy Consumption in the UK, https://www.gov.uk/government/statistics/energy-consumption-in-the-uk

[368] DfT (2017) Road Traffic Statistics, www.gov.uk/government/organisations/department-for-transport/series/road-traffic-statistics

Power: Emissions estimates for these metrics are taken from the BEIS (2017) GHG emissions statistics and 2032 pathway analysis. Low carbon generation data are taken from BEIS (2016) Digest of UK Energy statistics, chapter 5, with projections sourced from 2032 pathway analysis.

Natural Resources: Emissions estimates for these metrics are taken from the BEIS (2017) GHG emissions statistics and 2032 pathway analysis. Estimates of biodegradable waste to landfill are taken from the Defra (2017) Digest of Waste and Resource statistics[369] and 2032 pathway analysis. Estimates of total conventional woodland cover are sourced from the Forestry Commission's (2017) Forestry statistics[370] and 2032 pathway analysis. Output gross value added (GVA) estimates for agriculture are sourced from the Office for National Statistics on a constant price basis. There are no official projections of output GVA; Defra analysts have estimated future GVA based on historic trends.

[369] Defra (2017) digest of waste and resource statistics, https://www.gov.uk/government/collections/digest-of-waste-and-resource-statistics

[370] Forestry Commission (2016) Forestry Statistics, https://www.forestry.gov.uk/forestry/infd-7aqdgc

Image references

Page 4, Burbo Bank offshore wind farm

Page 20, Construction of the Blyth offshore wind farm

Page 29, Mathioya site for mini-hydro plant in West Kenya

Page 30, Gateshead combined heat and power (CHP) plant

Page 38, Engineer in wind turbine nacelle

Page 46, Electric taxi factory, Coventry

Page 55, BBOXX staff, Rwanda

Page 60, Electric vehicle charging point

Page 63, Crane in Felixstowe port equipped with CRESS technology

Page 67, Anglian Water installation

Page 70, Power plant with NET Power technology installed

Page 81, Econovate recycled waste blocks

Page 88, Sue Bentley and her electric car

Page 90, Installed articulated vehicle trailer design by The Centre for Sustainable Road Freight at the University of Cambridge

Page 96, Oxis Energy laboratory

Page 98, Clayhill solar farm

Page 105, Manchester City of Trees planting scheme at Snipe Clough, Oldham, Greater Manchester

Page 109, Recycling Technologies equipment

Page 116, Dryden School, Gateshead

Page 119, Cornwall County Council community renewable project

Page 120, Loft insulation being installed

Page 124, UK landscape and town