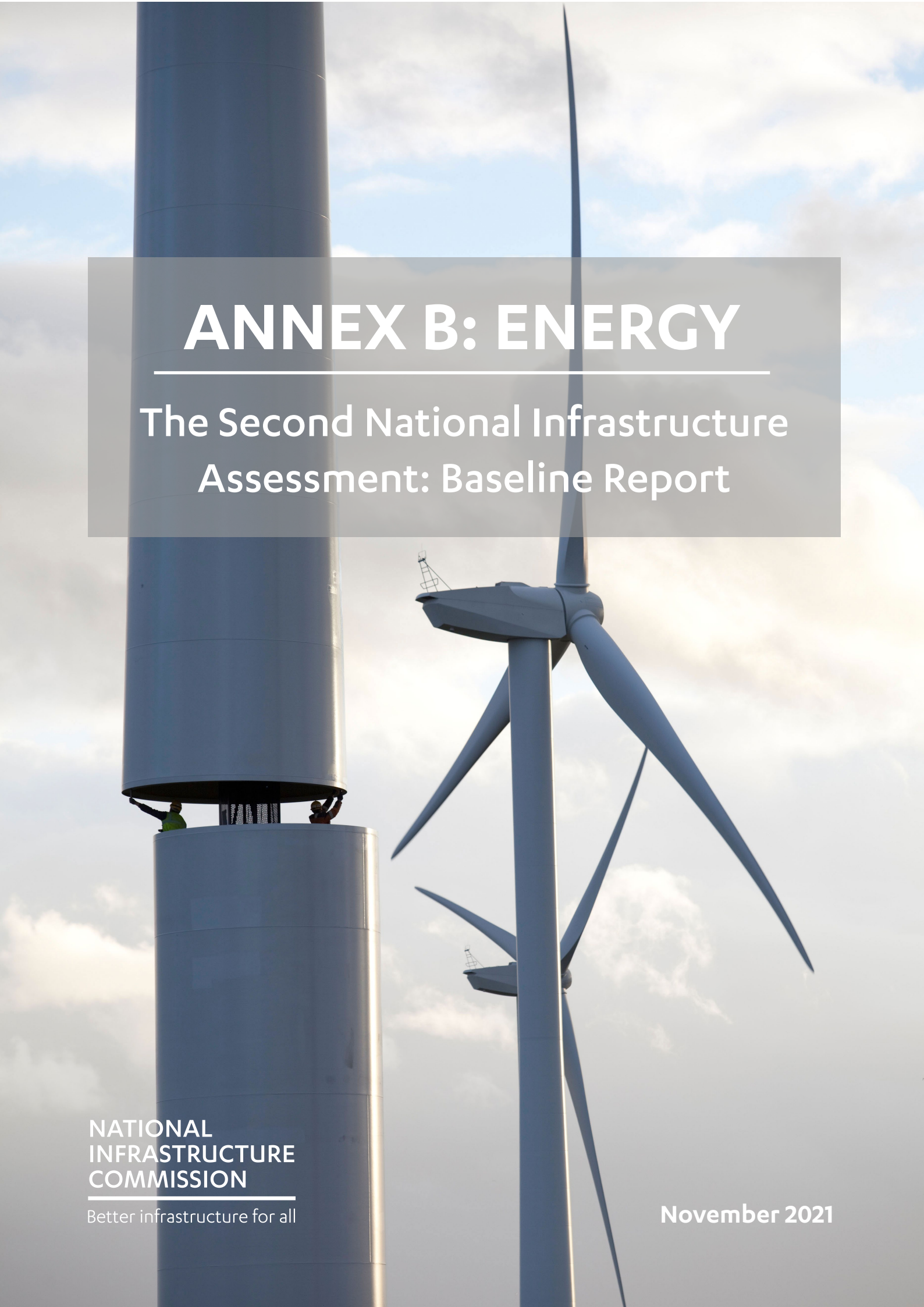


ANNEX B: ENERGY

The Second National Infrastructure Assessment: Baseline Report

NATIONAL INFRASTRUCTURE COMMISSION

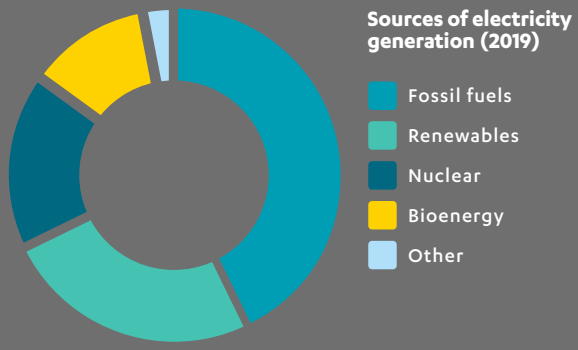
Better infrastructure for all

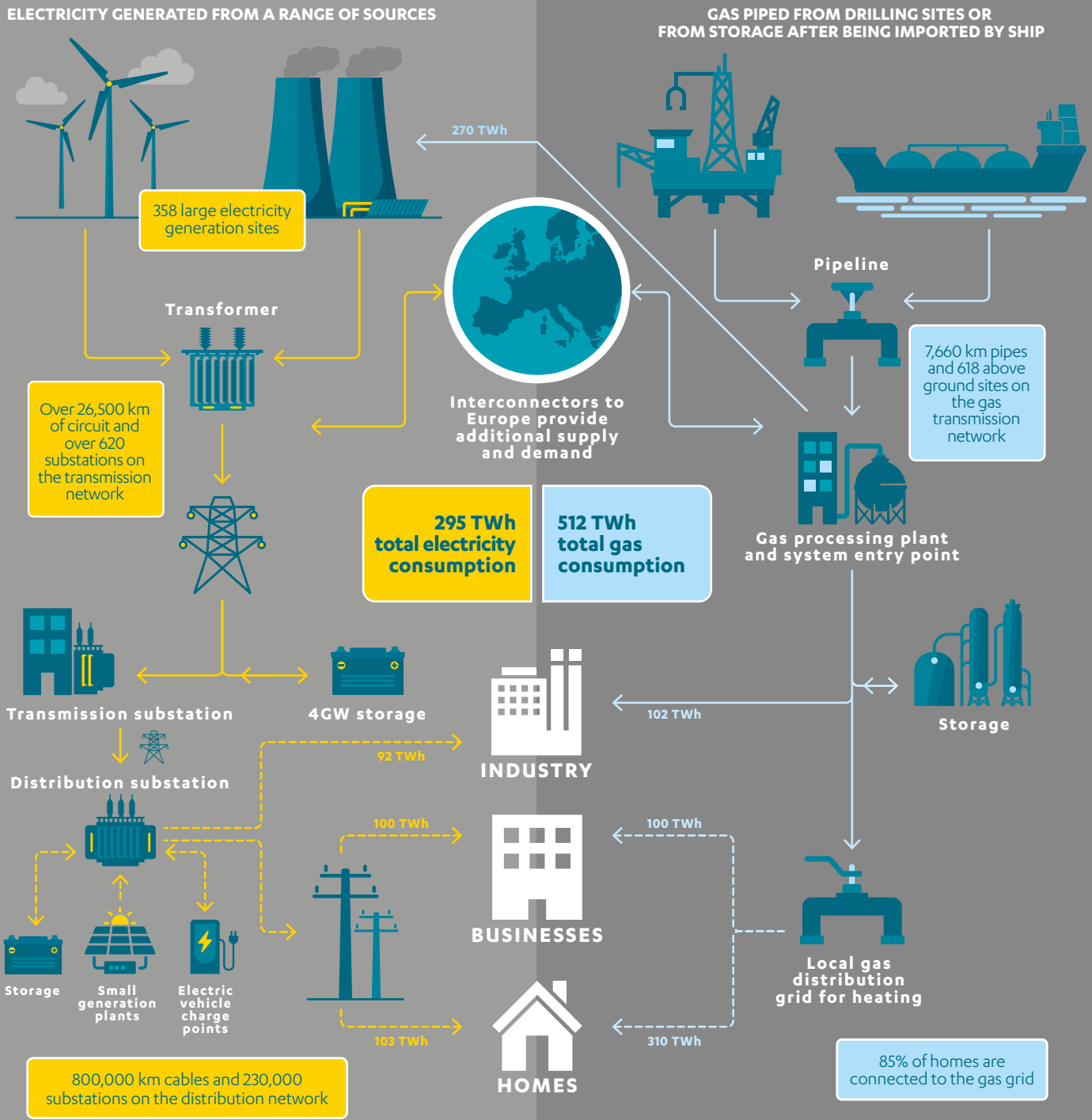
November 2021

Contents

THE ENERGY SYSTEM

Fossil fuels generate a decreasing proportion of electricity – **down from 70% in 1996 to 43% in 2019**





Sources: Department for Business, Energy & Industrial Strategy (2019, 2020), National Grid ESO (2021), Vivid Economic & Imperial College London (2019), Western Power Distribution (2013), National Grid (2021)

B.1 Sector overview

Energy is an essential utility. Electricity powers people's lights, fridges, internet, computers, and other staples of modern life. Other infrastructure sectors are also highly dependent on electricity – the transport, digital and water sectors all depend on electricity to various degrees. Most homes are heated with natural gas, which also provides energy for cooking and hot water. Disruptions to the energy supply can therefore be high impact, with the potential for multiple cascading failures. Fortunately, the UK's energy sector is one of the most reliable in the world, with comparatively few interruptions in supply that affect consumers.[1]

Energy infrastructure consists of two key networks: electricity and natural gas. Energy inputs for transport, including the electricity and charging points needed for the switch to electric vehicles, are covered under Annex F: Transport.

Electricity networks supply the vast majority of homes and businesses. The natural gas network is connected to around 85 per cent of homes.[2] Other sources of energy, such as oil and biomass, are used in much smaller quantities within homes and businesses and do not use extensive infrastructure systems.

The electricity system consists of infrastructure that generates electricity, which includes wind turbines, solar panels, nuclear power stations and gas-fired power stations, batteries and other infrastructure that can store electricity, and transmission and distribution networks to transport electricity.

The gas system consists of entrance and processing points for gas, and like electricity, there is a transmission and distribution network that transports gas to homes, businesses, industrial users, and power plants. The UK's gas supply comes from a mix of natural gas piped directly from the point of extraction or shipped over long distances as liquefied natural gas. In 2019, over half of the UK's gas supply was produced domestically, with Norway being the highest source for imports.[3]

In homes and businesses, energy infrastructure includes meters, heating systems and energy efficiency improvements, like loft insulation and double glazing, that reduce demand for energy.

In 2019, electricity consumption was around 300TWh, and gas consumption was around 500TWh. In addition there was 270TWh of gas used to generate electricity.[4] Domestic consumption constitutes a significant part of overall consumption, with 35 per cent of electricity and 61 per cent of gas.[5] The current average annual consumption for typical households is 12,000 kWh a year for gas, and 2,900 kWh a year for electricity.[6]

Infrastructure used in the generation and supply of energy is capital intensive. The system has been growing year on year and in 2019 the net capital stock of energy assets in the UK totalled £117 billion in real terms (2019-20 prices).[7] This expansion is largely due to overall growth in the economy as there are similar trends in other sectors, but there has also been a significant proportion of investment in recent years into new electricity generation.

Energy and the Commission's remit

The Commission's remit covers the energy system as a whole, including energy efficiency. The Commission does not look at upstream energy extraction and processing.

Where energy policy is devolved it falls outside of the Commission's remit. This means that, except for nuclear policy, the Commission's remit does not cover Northern Ireland and it does not cover energy efficiency policy in Scotland and Wales.

B.2 Governance and regulation

The supply of gas was privatised in 1986 and electricity in the early 1990s. Prior to privatisation the government owned and operated all parts of the system from generation to supplying energy to homes and businesses. There are now several companies that generate electricity and supply gas, regulated monopolies that transport and distribute energy, and a competitive retail market to supply energy to homes and businesses.

The sector is governed and regulated by several bodies. The key actors are:

- **The Department for Business, Energy & Industrial Strategy**, the government department responsible for the overall policy framework for the sector in Great Britain, set through legislation, National Policy Statements, strategy and policy statements, and guidance.
- **Ofgem**, the economic regulator for the electricity and gas sectors in Great Britain. Its principal objective is to protect the interests of existing and future consumers. It must have regard to government's strategy and policy statements.
- **System operators**, one for gas and one for electricity, support the effective functioning of the systems to ensure a reliable and safe supply. They provide a critical role in balancing supply and demand, and ensuring technical standards are met.
- **Code administrators**, which look after the regulatory framework that underpins the energy market, mandating technical standards and standards of conduct.
- **Citizens Advice**, the statutory consumer advocate for energy. It represents consumers and investigates complaints that have not been resolved by energy companies.

There are other regulatory bodies that support the functioning of the energy sector, including the Health and Safety Executive and the Office for Nuclear Regulation.

While competition exists in the generation and supply of energy, the transmission and distribution networks have primarily remained natural monopolies. In Great Britain there are three onshore electricity transmission network operators, six electricity distribution network operators, one gas transmission network operator, and four gas distribution network operators. There are also some smaller network companies competitively winning contracts to serve very local areas, such as new housing developments. Transmission networks have also been built to connect offshore windfarms and to connect Great Britain to neighbouring countries through interconnectors. Ofgem regulates these network companies to ensure they deliver an agreed level of service and charge a fair price.

Box B.1: The growth of the energy sector

Early energy development and industrialisation was fuelled by waterpower and coal, with the first public gas supply, manufactured from coal, in 1813 and the first public electricity supply provided by hydropower in 1881.[8]

Energy production generally grew organically in small and isolated ventures close to demand. The interwar years led to greater standardisation of the energy sector, as well as efforts to centralise regulation. The development of alternating current transmission made it practical for the small and isolated electricity networks to connect with each other, which eventually culminated in the first integrated national grid being established in 1935.[9]

The energy sector was nationalised following the Second World War. Legislation in 1947 nationalised local and privately owned electricity generators (almost all of which were coal powered) and suppliers, with gas and other fuel industries following in 1949.[10] The discovery of large natural gas fields in the 1960s enabled Great Britain to switch entirely from manufactured gas to natural gas, and Britain's gas infrastructure (including domestic appliances) was upgraded to enable the shift between 1967 and 1977.[11]

The 1980s unwound the consensus in Great Britain that energy should be nationalised, with British Gas privatised in 1986, and the Electricity Act 1989 paving the way for full privatisation of the industry. The 1990s saw a sustained move to competition and a large increase in gas-fired electricity generation. The 2000s saw concerns over security of supply and greater awareness of the impacts that energy generation had on the world's climate.

The 2010s saw an expansion in support for renewables and an increase in their affordability, including a 65 per cent reduction in the cost of offshore wind.[12] By 2016 roughly a quarter of electricity generation was produced by renewables – and a combination of this and other factors squeezed coal further out of the energy mix.[13] At the end of the decade, the UK made a landmark commitment to bring all greenhouse gas emissions to net zero by 2050.

B.3 Funding and financing

Funding

Energy infrastructure is paid for through customers' bills. A customer's energy bill covers the costs of generating or purchasing energy; transporting it; and the retail services needed to supply it – i.e. customers ultimately pay all the costs that privately owned companies incur at each step in the process. Total sales of gas and electricity in 2019 were £60 billion.[14]

Some government policy costs are also recovered through customer bills. The most material of these over recent years has been the cost of government support for the development of different forms of low carbon electricity generation like wind turbines and solar panels.[15] These schemes – the Renewables Obligation, the Feed-in Tariff and Contracts for Difference – subsidise investment in renewable electricity generation.[16] They have driven the increase in renewable electricity sources and the associated reduction in emissions from the electricity sector.

The cost of transporting energy through the transmission and distribution networks is regulated by Ofgem. Ofgem sets the revenue that can be recovered by network operators via customer bills in return for operating and maintaining infrastructure assets that make up the networks. It also takes into account the financing costs of the companies that operate them. Ofgem sets this revenue allowance through multiyear settlements called price controls.[17]

Funding models for smaller networks serving very local areas and offshore transmission can be set differently. For example, offshore transmission revenue is determined through competitive tender, instead of being set by Ofgem.[18]

Financing

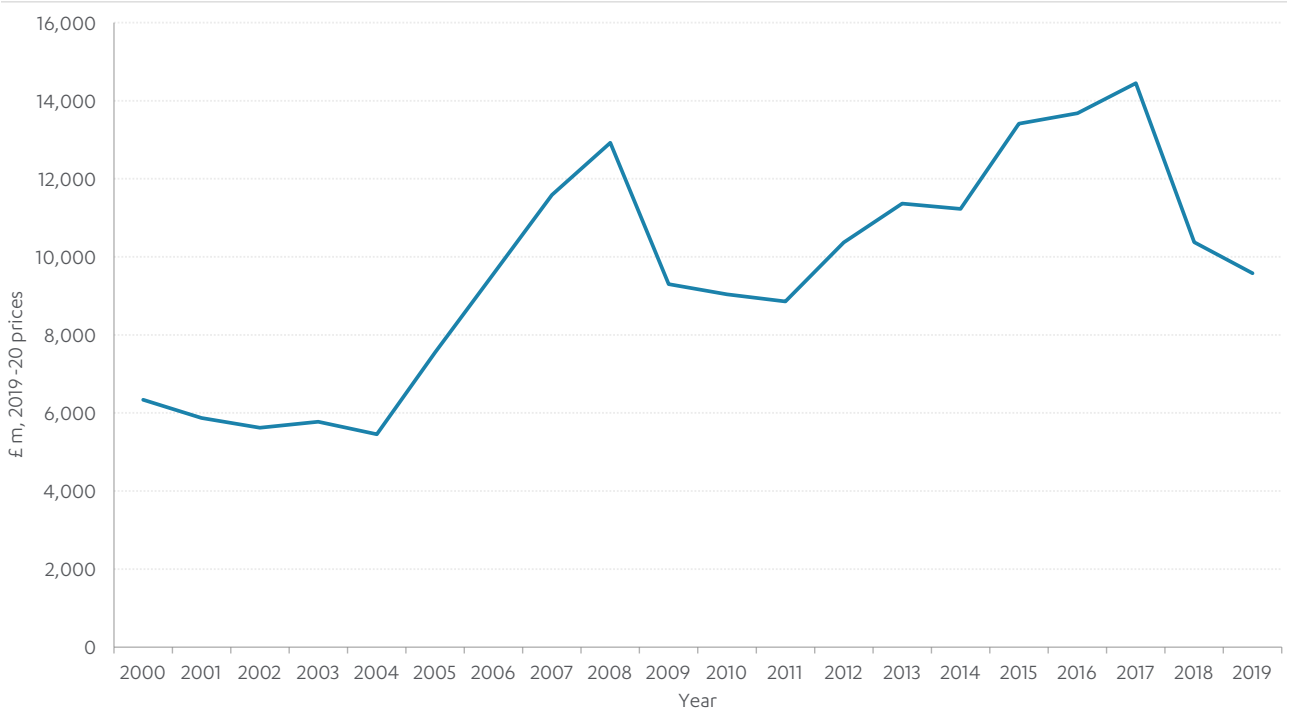
The majority of investment in energy infrastructure is financed through private investment.[19] This includes the building of new assets and the renewal of existing assets, some of which have been in use for many decades. The government also invests in energy infrastructure through research and development funding of new technologies or via specific investment plans to support new technologies.

Total annual investment in the energy sector has increased since 2000 (Figure B.1). From 2000 to 2019, the gross capital added has risen from £6 billion to £10 billion per year (2019-20 prices).

Companies issue debt or raise equity to finance investment. For the regulated energy networks the cost of financing investment is assessed by Ofgem and a return is provided to cover financing costs as part of the multiyear price controls. Ofgem's assumptions about the weighted average cost of capital, or the allowed return on investment, play an important role in how it sets allowed revenues. In making its decision, Ofgem seeks a balance between rewarding investors with a reasonable return and ensuring consumers do not pay too much. In line with reductions in the cost of capital around the world, the allowed returns used by Ofgem have decreased since 1990 whilst maintaining the sector's ability to raise finance.

Figure B.1: Total investment in the energy sector has increased since 2000

Gross fixed capital formation for the electricity, gas, steam and air conditioning sector in the UK, 2000 to 2019



Source: Office for National Statistics (2020), Annual gross fixed capital formation by industry and asset

B.4 Performance of the sector

Summary

The Commission has assessed the performance of each sector against four criteria: quality, price, environment, and resilience. These are described at a high level below, and in more depth within their own sections.

The energy sector delivers electricity and gas of reliable quality to consumers and satisfaction has been stable. The Commission's social research, carried out in June 2021, showed respondents had relatively high levels of confidence that energy infrastructure will meet people's needs over the next 30 years, with confidence increasing since the last Assessment.

Average energy bills rose from the mid-2000s until the mid-2010s and then gradually declined. However, gas prices have risen significantly in recent months and are expected to rise further. This pushes up the price of both gas and electricity, as gas remains a significant input into electricity generation. Domestic consumers have been shielded from some of this volatility due to the regulated cap on energy prices introduced from 2017. Businesses have also been affected, especially those that are energy intensive. This inevitably creates serious problems for some households and firms.

The most material environmental impact from the energy sector is greenhouse gas emissions. The emissions intensity of the energy sector has reduced. Emissions associated with electricity generation fell by 74 per cent from 1990 to 2019, driven by changes in the generation mix. But more needs to be done to meet decarbonisation targets in both electricity – where the sector must decarbonise by 2035 – and heat, where limited progress has been made so far in a system currently reliant on natural gas. The energy efficiency of buildings has been improving but there is a long way to go.

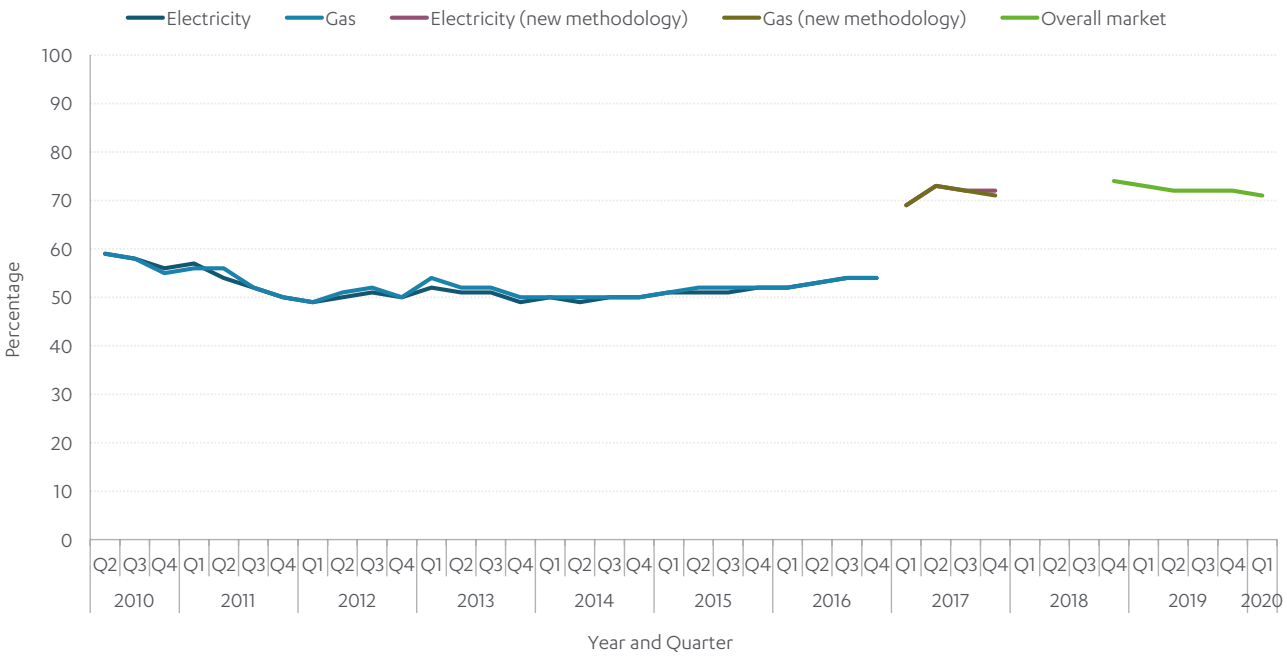
The supply of energy has been resilient to shocks and stresses with incidents causing a loss of supply rare and reducing over time.

Quality

Overall, energy customers are satisfied with their suppliers (Figure B.2). Satisfaction levels have been broadly stable in recent years.[20] The Commission's social research found that 80 per cent of the public felt confident that energy infrastructure in general would meet their needs over the next 30 years, with five per cent being not very confident or not confident at all.[21] This has increased from 66 per cent confidence ahead of the Commission's previous Assessment.[22] However, this research was undertaken before the most recent increase in energy prices.

Figure B.2: Customer satisfaction has remained stable level over time

Overall satisfaction with the energy supply in Great Britain, 2010 to 2019



Source: Ofgem (2021), Customer service data. Note, a change in methodology in 2017 has resulted in breaks in the data presented and caution should be applied to compare trends before and after this break

Energy network operators are also rated on customer and stakeholder satisfaction by Ofgem. This information is collated through a range of surveys, key performance indicators, panels, and stakeholder engagement. Performance for the last reporting period (2019-20) was rated overall as positive, with scores mostly above the annual performance targets.[23]

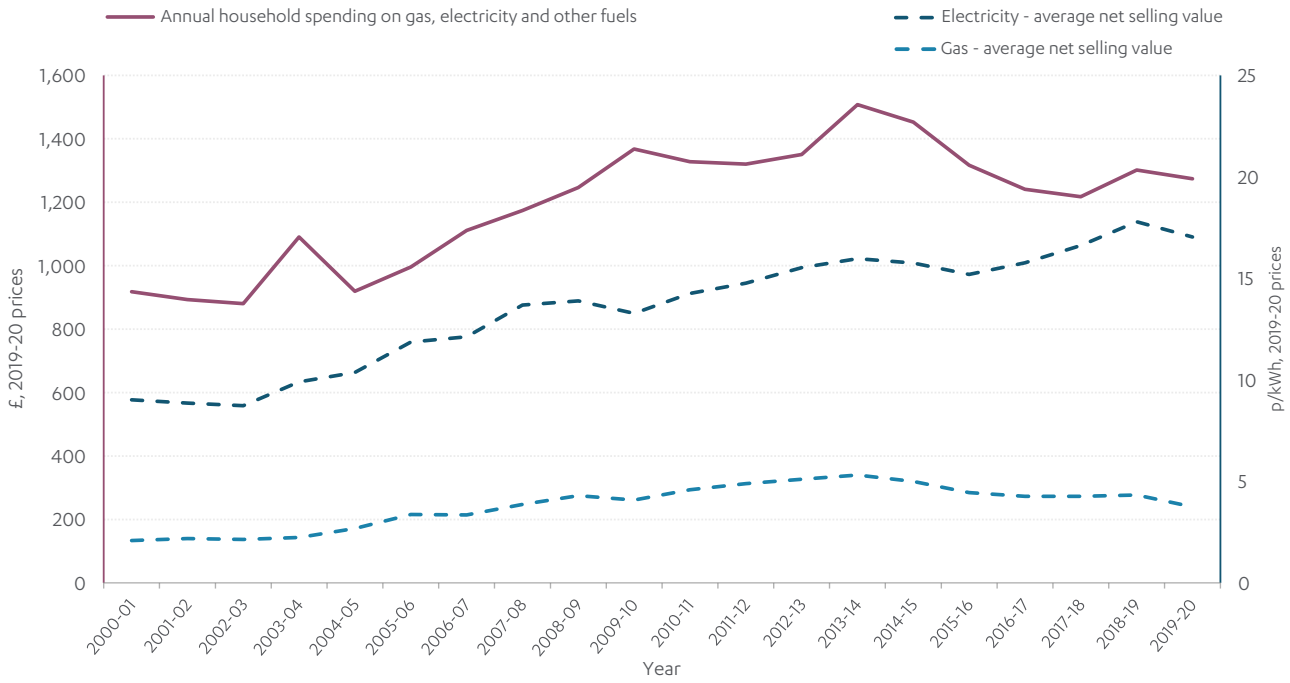
The electricity and gas markets and networks in Great Britain are integrated and held to common standards allowing for national trading and transporting. Standards for electricity (frequency, voltage) and gas (calorific value, pressure) are nearly always met.

Price

Consumer bills have varied over time, and consumer spending on energy has increased (Figure B.3).

Figure B.3: Consumer spending on energy has increased over time and the price of electricity has risen more than gas

Average annual household spending and gas and electricity unit prices in the UK, 2000 to 2019

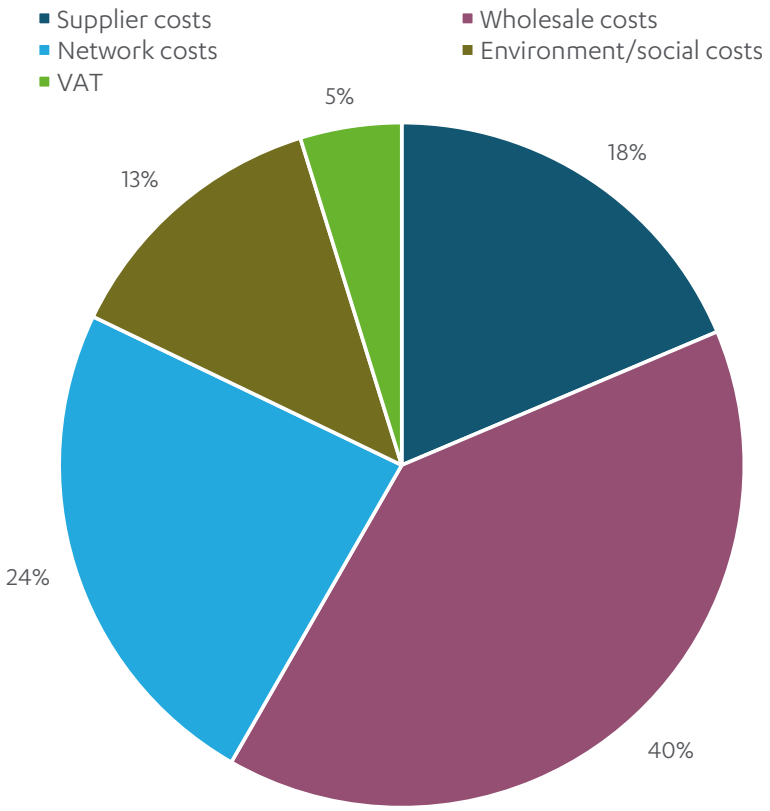


Source: Commission calculations using Office for National Statistics (2018), Average weekly household expenditure on fuel by gross income decile group, UK, financial year ending 2017; Office for National Statistics (2021), Family spending workbook 1: detailed expenditure and trends

In 2019, a typical annual domestic dual fuel (electricity and gas) bill from a large energy supplier was around £1,200.[24] An energy bill is made up of different costs (Figure B.4). The cost of buying the electricity and gas (the wholesale cost) form the largest proportion of the bill. It also includes supplier operating costs and profit, the cost of transporting the energy (network costs), policy costs for environmental and social programmes and VAT. Policy costs for environmental and social programmes mostly fall on the cost of electricity rather than gas.

Figure B.4: Wholesale costs make up the highest proportion of consumer bills

Breakdown of a typical domestic dual fuel bill, 2019



Source: Ofgem (2021), Retail market indicators

A price cap for energy bills was introduced in 2017 and by 2019 it covered the entire domestic energy supply market. The cap provides an upper limit on what suppliers can charge domestic customers for their energy use. The cap is set by Ofgem based on analysis of how much it costs an efficient supplier to provide gas or electricity.

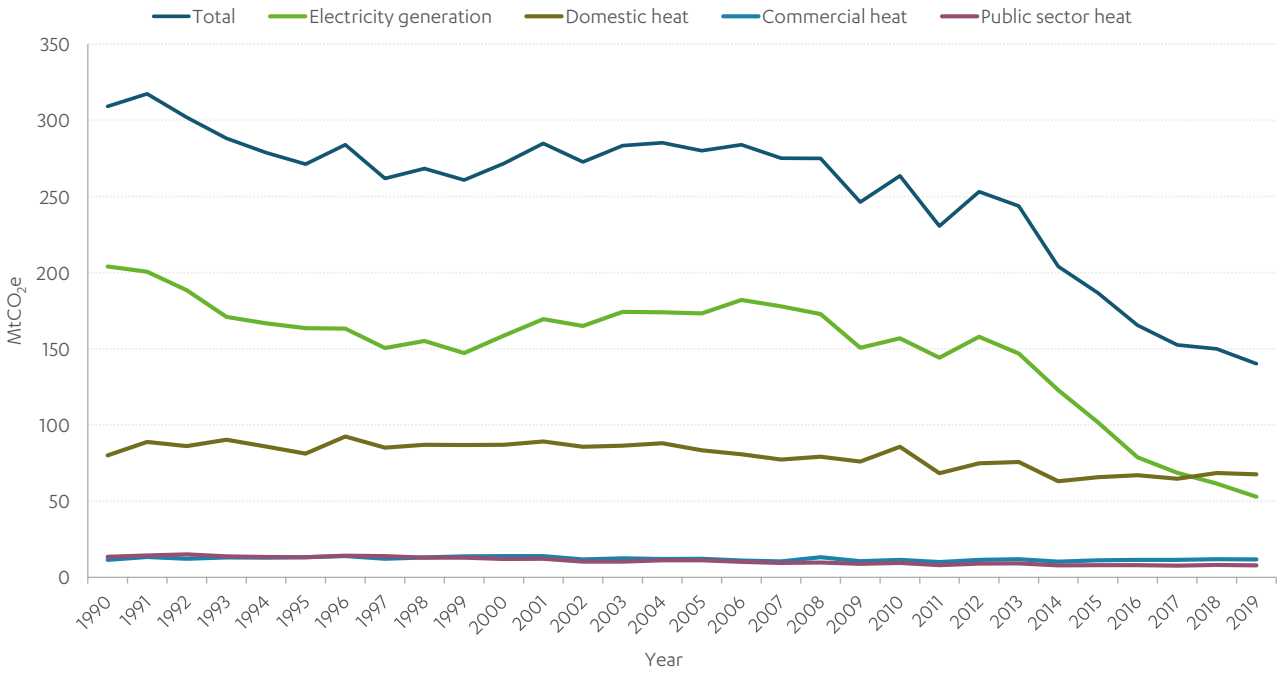
In October 2021 the price cap was increased to £1,277 per year.[25] This figure, which represents a household on a dual fuel bill with typical consumption, is an increase of £139 on the previous cap set six months earlier. The rise in the cap was a result of the material increase in the wholesale price of gas this year.[26] The cap is expected to rise further when it is next due to be reviewed in April 2022. Fluctuations in the price of gas affects both the wholesale price of gas and electricity, because around 40 per cent of electricity is generated from gas.[27]

Environment

Energy is one of the largest contributors to greenhouse gas emissions, accounting for 28 per cent of UK greenhouse gas emissions in 2019.[28] However, the electricity sector has already made strong progress towards decarbonisation, with emissions falling by around 74 per cent from 1990 to 2019 (Figure B.5), driven by changes in the generation mix.[29] The change in generation mix has been driven by a combination of decarbonisation policies, including carbon pricing, market conditions such as the reducing cost of renewable generation technologies, and regulations to minimise air pollution impacts.

Figure B.5: Total emissions in energy supply have fallen rapidly, driven by changes in the electricity generation mix

Greenhouse gas emissions from energy supply by category ($MtCO_2e$)



Source: Department for Business, Energy & Industrial Strategy (2021), Final UK greenhouse gas emissions national statistics

Between 1990 and 2019 the use of coal to generate electricity declined from 80 per cent to two per cent.[30] Renewables rose to over 37 per cent of supply in 2019, from less than two per cent in 1990.[31] Natural gas is currently the largest single source of electricity generation.

This change in the generation mix has led to a sustained reduction in the total emissions from electricity generation. This has been coupled with a reduction in demand, despite an increasing population, in part because appliances that use electricity have become more efficient.[32]

Heating homes and other buildings remains a major source of emissions, making up 17 per cent of the UK's carbon emissions in 2019.[33] Unlike electricity, there has been less progress in reducing emissions from heating, given its reliance on natural gas. Emissions from residential combustion (mostly heat) fell by 15 per cent between 1990 and 2019.[34] This reduction has been driven by improvements in the efficiency of heating systems and improvements in the overall efficiency of buildings.[35]

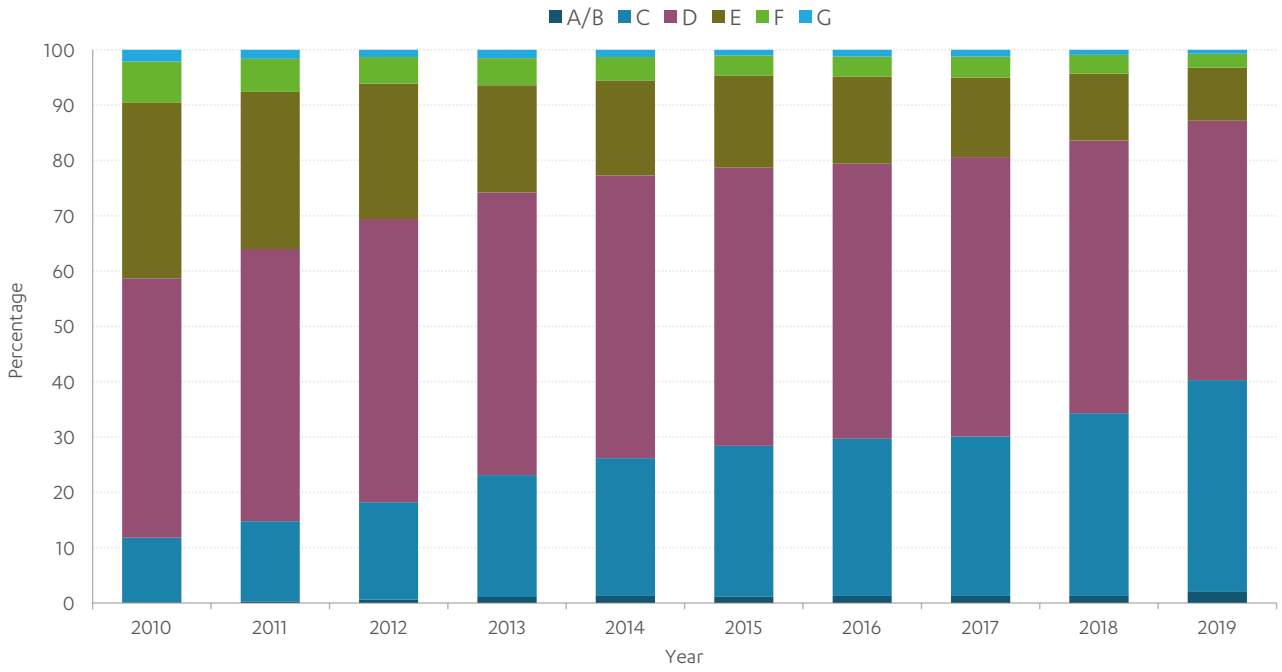
Heating also has a natural capital impact, generating significant local pollution, with the domestic combustion of coal and wood one of the two biggest sources of urban air pollution, along with road traffic.[36] The two main options to decarbonise heat are hydrogen heat and electrified heat, most likely using heat pumps.

One way to reduce emissions from heat is to reduce demand for energy by increasing the energy efficiency of homes and businesses. Domestic heating demand makes up the majority of space heating demand in the UK, at 76 per cent of total demand, and is therefore the primary focus.[37] Homes are becoming more energy efficient (Figure B.6). The proportion of homes in the least energy efficient categories (E, F, and G) has fallen from around 40 per cent in 2010 to 13 per cent in 2019, and homes rated EPC C or better rising from 12 per cent in 2010 to 38 per cent in 2019.

Government schemes to support energy efficiency improvements have at times created a boom and bust cycle for energy efficiency.[38] In 2019, the number of energy efficiency installations installed through government schemes averaged 4,200 per week, far below prior levels, which peaked in 2012.[39]

Figure B.6: The energy efficiency of buildings has been improving over time with a gradual reduction in the number of the least efficient homes

Energy efficiency rating band of dwellings, England 2010 to 2019



Source: Department for Levelling Up, Housing and Communities (2021)

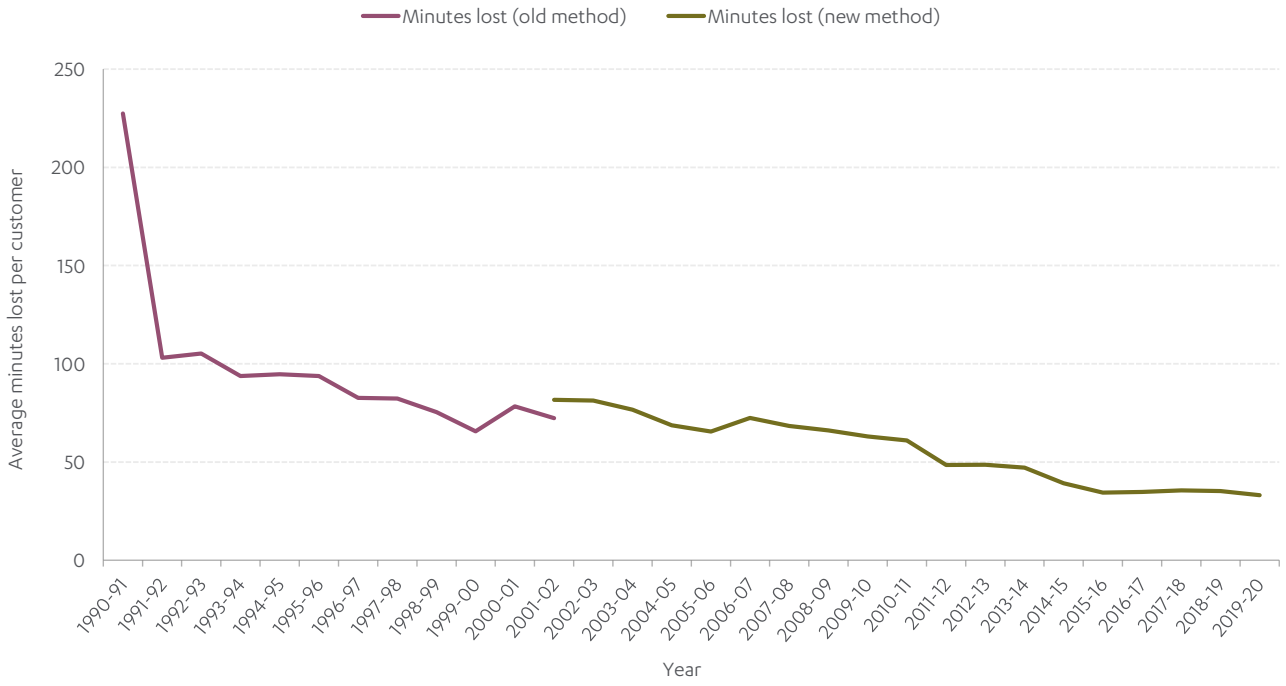
Resilience

The supply of energy has been resilient to shocks and stresses. The Commission's social research found people viewed the energy sector as the most reliable out of the regulated utilities, with very few respondents recalling any major problems with their energy supply.[40]

Energy network operators are rated on a range of resilience metrics by Ofgem, including metrics on safety, reliability and availability. Average interruptions to electricity supply (measured as minutes lost per customer) have been falling since 1990 (Figure B.7). In 2002 Ofgem introduced incentives for companies to improve reliability.[41] Since then, there has been an almost 50 per cent reduction in the frequency of power cuts, and an almost 60 per cent reduction in the length of power cuts.[42] Performance for the last reporting period (2019-20) met targets, with high levels of reliability overall. Major events do happen but are rare. In 2019 a notable incident caused the disruption, disconnection, and loss of power to more than one million customers.[43] In 2021, Ofgem introduced an updated Electricity System Restoration Standard, that aligns existing standards with other parts of the regulatory framework, and also requires the System Operator to have the capability to restore all British electricity demand within five days.[44]

Figure B.7: Interruptions to supply have been on a downward trend

Average minutes lost per customer per year, 1990-91 to 2019-20



Source: Ofgem Data Request (2021). Note, a change in methodology in 2001-02 has resulted in a break in the data presented and caution should be applied in comparing trends before and after this break.

Cyber security also poses an issue for resilience. The National Cyber Security Centre, which provides advice and support for the energy sector in avoiding cyber security threats, has noted an upward trend in targeted cyber attacks and has highlighted an increasing number of attacks on operational technology, that can control critical infrastructure.[45] In 2020, Elexon (the code administrator responsible for balancing and settlement in the electricity market) was subject to a ransomware attack, but this did not lead to any notable disruption.[46]

B.5 Looking ahead

The Commission's first Assessment recommended sustaining progress on reducing emissions from the energy sector by taking action to enable an increasing deployment of renewables and building the evidence base for alternatives to the current reliance on natural gas for heating.[47] Since the Assessment was published in 2018 government has made significant new commitments to decarbonising the UK economy. The UK now has legally binding targets to reduce greenhouse gas emissions by 78 per cent by 2035 relative to 1990 levels,[48] and to net zero by 2050.[49] The energy sector has a vital role to play to support the economy in meeting these carbon targets.

In October 2021 the government published its Net Zero Strategy, a summary of the actions it is taking, and plans to take, to deliver against its commitment to reach net zero emissions by 2050.[50] This includes a commitment to decarbonising the electricity system by 2035 (subject to being able to maintain security of supply). The Government has set an ambition and is taking action to increase the capacity of low carbon generation, including a commitment to 40 GW of offshore wind by 2030 and including onshore wind and solar in future contracts for difference auctions, as recommended by the Commission.[51]

Reaching near zero emissions by 2035 will require an acceleration in the current pace of decarbonisation. And this must all be delivered without jeopardising the security of supply. Renewable electricity generation from solar or wind cannot be turned on like a gas power plant can, so flexibility and storage will be vital for a highly renewable electricity system. Ensuring that the current level of reliability of the energy system is not compromised by this transition is key.

The transition of the electricity system comes against a backdrop of increasing electricity demand as other sectors decarbonise. The pandemic led to the largest fall in annual electricity demand ever recorded.[52] However, these demand reductions and the resulting reductions in emissions from energy infrastructure are ultimately expected to be temporary. Demand for electricity is forecast to grow significantly over the coming decades, as heating, surface transport, and other sectors of the economy are electrified and there is potential for cooling to be more widely required as climate change impacts maximum summer temperatures.[53]

While electricity decarbonisation has to date been swift, heating is still predominantly reliant on natural gas. This will need to change if the legally binding carbon targets are to be met. The Climate Change Committee's balanced pathway scenario to reach net zero sees emissions from buildings falling by close to 50 per cent by 2035 and reaching close to zero by 2050.[54] In heat, the technologies to decarbonise exist, but how to deliver the necessary changes in homes and businesses is not clear.

Delivering the transition to zero carbon heat presents a significant challenge to policymakers, as it directly affects individuals and causes significant disruption in homes, buildings and at street level. The government has recently published its strategy for decarbonising heat.[55] It sets out plans to cut emissions via a gradual transition which will start by incentivising consumers and driving down costs of low carbon heating systems. It contains new funding commitments to support installation of low carbon heating systems in homes and outlines measures to promote improved efficiency to business and public sector buildings. The lack of progress to date in decarbonising heat, and the legislated sixth Carbon Budget creates urgency in understanding and resolving the challenges that the UK will face in decarbonising its homes and businesses.

There are major questions to be answered, including what level of insulation will be needed in different homes to efficiently operate heat pumps, whether hydrogen for heating will be available as a source of heat for all homes, what this means for the continuing use of the gas network, and how to deliver these major changes in people's homes.

Reaching net zero emissions will also require new infrastructure networks to support the energy sector. Hydrogen currently plays an extremely limited role as a source of energy but has the potential to do more and be used widely across the economy.[56] And carbon capture and storage can support the production of low carbon hydrogen and more broadly support the decarbonisation of sectors that could continue to rely on fossil fuels to operate and provide essential infrastructure for engineered greenhouse gas removals.[57] The government's recently published Hydrogen Strategy committed to a target of 5GW of low carbon hydrogen production capacity by 2030.[58] Additionally, after a stop start approach to policy, government is now signalling a strong commitment to delivering carbon transport and storage infrastructure with the Net Zero Strategy noting an increased ambition to capture and store 20 to 30 $MtCO_2e$ a year by 2030.[59] Hydrogen and carbon capture and storage are complementary networks, but they will also compete as routes to decarbonise some parts of the economy. There will be challenges in how quickly these networks can be delivered, at what scale, and how plans can be coordinated.

Delivering this transition will require high levels of investment. This investment will ultimately be funded by either consumers (via bills) or taxpayers. The Commission will consider funding challenges in the second Assessment, including the overall affordability of required investment, the distribution of costs and savings across groups in society, and who should pay.

B.6 Challenges and opportunities

The second Assessment will carry out new analysis and develop recommendations on three challenges that will affect the energy sector:

Challenge 2: Decarbonising electricity generation – the Commission will consider how a decarbonised, secure and flexible electricity system can be achieved by 2035 at low cost.

Challenge 3: Heat transition and energy efficiency – the Commission will identify a viable pathway for heat decarbonisation and set out recommendations for policies and funding to deliver net zero heat to all homes and businesses.

Challenge 4: Networks for hydrogen and carbon capture and storage - the Commission will assess the hydrogen and carbon capture and storage required across the economy, and the policy and funding frameworks needed to deliver it over the next 10-30 years.

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