ENERGY POLICIES OF IEA COUNTRIES

United Kingdom

2019 Review

International Energy Agency
Secure
Sustainable
Together

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INTERNATIONAL ENERGY AGENCY

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Foreword

The International Energy Agency (IEA) has conducted in-depth peer reviews of its member countries' energy policies since 1976. This process not only supports energy policy development but also encourages the exchange of and learning from international best practices and experiences. In short, by seeing what has worked – or not – in the "real world", these reviews help to identify policies that achieve objectives and bring concrete results. Recently, the IEA has moved to modernise the reviews by focusing on some of the key energy challenges in today's rapidly changing energy markets.

The United Kingdom is a global leader in decarbonising energy supply. The UK five-year carbon budget approach, with the fifth period covering 2028-32, has served as a model for the Paris Agreement, and the United Kingdom leads in terms of actual emission reductions. The UK Clean Growth Strategy puts energy technology development and innovation at the centre of its decarbonisation policy.

I am very pleased that the United Kingdom is a strong partner for the IEA and its member and association countries in energy technology collaboration, notably in Mission Innovation. I recall with pleasure our International CCUS Summit in Edinburgh in November 2018, which Minister Claire Perry and I co-chaired and where we launched a new era for CCUS, a technology that is critical to meeting climate goals and can also strengthen energy security and boost economic growth.

IEA member and partner countries are keen to learn from the UK experience to manage power markets in transition. UK energy-related CO_2 emissions have decreased to the lowest levels since 1888. Within only five years, the UK carbon price floor supported a significant coal-to-gas switching and - combined with a record investment in offshore wind and solar PV -, led to the transformation of the power sector. By 2030, the share of variable renewables is expected to reach more than 50%, which will require a more pronounced focus on system integration. The UK already pilots some of the most interesting regulatory solutions for flexibility markets. Amid the retirement of the existing coal and nuclear fleet in the coming years and the weak investment outlook for new nuclear, I am convinced that open trade will remain a top priority for the government going forward. Energy markets are strongly integrated with Europe, which contributes significantly to the security of supply.

There is another success to highlight: despite the long term decline, the United Kingdom has been quite successful in boosting the production from the North Sea offshore oil and gas fields and has become a leader in offshore wind power. The UK offshore expertise is a strong basis for the country to scale up innovative technologies, such as CCUS, hydrogen, along with improving energy efficiency of the existing infrastructure and gaining experience with the eventual decommission of offshore installations.

It is my hope that this review will further guide the United Kingdom in its energy transition and help it achieve the energy policy goals of providing affordable, secure and clean energy to its population, while adapting to a fast-changing, international energy landscape.

Dr. Fatih Birol

Executive Director

International Energy Agency

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1. Executive summary

The energy policy of the United Kingdom has undergone a major transformation during the seven years since the International Energy Agency (IEA) presented its previous in-depth review (IDR) in 2012. The government has continued its leadership on climate action, implemented the Electricity Market Reform (EMR), and strengthened policies for security of supply. The Industrial Strategy and Clean Growth Strategy, presented by the new Department for Business, Energy and Industrial Strategy (BEIS) progress the energy policy ambitions of the UK towards decarbonising heat and electrifying transport, while delivering both growth in technology development and innovation and improvements in domestic energy efficiency across the economy.

This IDR illustrates the lessons learned from the United Kingdom's energy transition, which can be instructive for many countries' low-carbon transitions. For this review, the government asked the IEA to assess the framework for climate action and the cost-effectiveness of climate measures, notably in the transport and heat sectors, as well as the experience from the EMR in the context of the fast transformation of the energy system and the need to ensure clean, affordable, and secure energy.

Energy system transformation

The United Kingdom has led the way in the transition to a low-carbon economy by taking ambitious climate action at international and national levels. These efforts are consistent with its goal to reduce greenhouse gas (GHG) emissions by at least 80% by 2050 from 1990 levels, as defined under the 2008 Climate Change Act. In 2016, the government adopted the fifth carbon budget (for the period 2028-32), which targets a 57% reduction in GHG emissions relative to 1990 levels. To move the energy system towards this goal, the United Kingdom's Clean Growth Strategy, of 2017 sets out policies and government funding of British pounds (GBP) 2.5 billion for innovation and low-carbon investment up to 2021. Together with Canada, the United Kingdom launched the Powering Past Coal Alliance: to date a total of 30 countries, 22 subnational states and 28 businesses have joined the Alliance, which commits them to the rapid phase out of unabated coal.

The country's energy system has seen a very rapid growth in the share of low-carbon energy, which accounted for over 50% of the electricity mix in 2017: natural gas (41%), nuclear (21%), wind (15%, up from 3% in 2010), solar (3%), bioenergy and waste (11%), coal with 7% (down from 29% in 2010) and hydro (2%). The United Kingdom has committed to phasing out all remaining unabated coal-fired power generation by 2025. UK energy-related CO_2 emissions have declined by 35% on 1990 levels, and total GHGs are down by 40%, reaching some of the lowest levels recorded since 1888. Power and heat, which were once the number one source of energy-related CO_2 emissions in the United Kingdom, have declined significantly (to 25% of the total) and are now far below those of transport (34%).

As the United Kingdom has set the power sector well on the path to decarbonisation, the government is focusing on transport, buildings, industry, and heat. The Carbon Price Support (CPS) policy demonstrates how suitable price signals can help accelerate the transition towards a lower carbon intensive energy use. Carbon pricing applies to electricity (with the Carbon Price Floor (CPF), industry is exempt if they implement energy efficiency agreements).

The Clean Growth Strategy does not set quantitative emissions targets for the sectors under the fifth carbon budget, but it sets a comprehensive list of policy actions and funding programmes. The United Kingdom met the first and second carbon budgets with headroom and is projected to meet the third one. In its 2018 review of the Strategy, the independent Climate Change Commission, however, warns of a delivery risk for the fourth carbon budget and a policy gap between the current policies and the ambitions under the fifth carbon budget.

Special focus 1: The cost-effectiveness of climate measures

In common with many countries, the decarbonisation of transport and heat brings with it questions as to the potential for energy efficiency, electrification, the direct use of renewables, a change in consumer behaviour, and the relative cost-effectiveness of different measures. As the power sector continues to decarbonise with growing shares of wind and solar, opportunities to electrify heat and transport are expected to increase.

In 2016, 85% of UK dwellings had gas central heating, 6% of heat demand was met from renewables, and less than 2% from district heating. The UK Boiler Plus policy has increased the energy efficiency of existing gas heaters and the Renewable Heat Incentive promoted a range of alternative technologies with 65 000 residential renewable heat installations. However, the rate of adoption to date suggests that barriers remain. The new government mission to “at least halve the energy use of new buildings by 2030” sets out policies and funding programmes aimed to improve the energy efficiency of existing buildings. Improved energy performance in buildings may benefit from making more explicit linkages and synergies between energy efficiency, electrification, and renewable heat deployment.

Transport is the second-largest energy-consuming sector and, as in all countries, still holds significant potential for GHG emission reductions (shipping, rail, and aviation) and energy efficiency gains. The United Kingdom plans to end the sale of new conventional petrol and diesel cars and vans by 2040, which would facilitate an accelerated roll-out of low-emission vehicles, such as electric vehicles (EVs). In 2017, EVs accounted for around 2% of new car sales in the United Kingdom. The government has created the Office for Low Emission Vehicles, an excellent opportunity to bring together the efforts of BEIS and the Department for Transport.

The energy intensity of the UK economy has dropped significantly over time (it has the third-lowest total final energy consumption (TFC) per GDP among IEA countries) as has its actual final energy use (TFC has declined by 10% over the past decade). The United Kingdom has led the design of energy efficiency policies through energy supplier obligations and voluntary agreements with industry, which have been upgraded over time. The United Kingdom now has 12 million smart and advanced meters, which are expected to take GBP 300 million off domestic consumer bills by 2020. The wide range of UK energy efficiency policies and programmes are evidently yielding results, and may yield yet more if pulled together into a unifying, coordinated framework for energy efficiency policies and programmes.

The government seeks to increase general research and development (R&D) spending to 2.4% of the gross domestic product (GDP) by 2027, with public R&D investment to reach GBP 12.5 billion in 2021-22, and a cumulative total of up to GBP 80 billion over the next ten years. Programmes for nuclear power and carbon capture and storage, both essential for long-term global decarbonisation, continue to be progressed in the United Kingdom, despite earlier setbacks. The government established a carbon capture, usage, and storage (CCUS) Cost Challenge Taskforce to provide advice on the steps needed to reduce the cost of deploying CCUS in the United Kingdom, and its leadership in this area could prove to be a valuable input to global efforts in CCUS cost reductions and commercialisation. In November 2018, the government published its CCUS Action Plan, which set out a new approach for industry and government to enable the development of the first CCUS facility in the UK, commissioning from the mid-2020s, to achieve the government's ambition to have the option to deploy CCUS at scale during the 2030s, subject to costs coming down sufficiently. The government has stepped up the coordination and funding under the new Energy Innovation Board, in line with its commitments under Mission Innovation (MI) and the Clean Energy Ministerial. The United Kingdom's leadership of global innovation efforts, such as MI, is commendable. At home, the Clean Growth Grand Challenge of the Industrial Strategy is an opportunity to deliver concrete missions in areas where the United Kingdom faces the most acute decarbonisation challenges – the mission on energy use in buildings is a welcome recognition of this.

Special focus 2: The Electricity Market Reform

The EMR of 2013 was conceived as a series of targeted interventions to manage the transition to a decarbonised electricity market. The EMR supplemented the energy-only market with a new design that included the Great Britain capacity market (GB CM), contracts for difference (CFD) for low-carbon electricity, a carbon price floor (CPF) of GBP 18.08 per tonne of carbon dioxide, and an emissions performance standard (EPS) of 450 g/tCO_2. By 2018, BEIS and the Office of Gas and Electricity Markets (Ofgem) had further adapted and improved these policies.

The EMR started out as a supply-side reform, but brought about encouraging lessons for the power sector transition – the benefit of market approaches and competition (competitive auctions) and the need for flexible regulations that can be adapted to fast technology developments, which include the benefits of taxation to drive the decarbonisation.

The CFDs provided revenue certainty and led to a boom in renewable investment through competitive allocation. Although the government initially set an administered strike price, competitive auctions have since become the standard approach and are an important mechanism to ensure competitive pricing (which has brought significant cost reductions) and benefit from lower costs of capital and risk to investors. The government announced that auctions will be run every two years after Auction Round 3. Depending on auction prices and eligibility criteria, BEIS expects the delivery of between 1 and 2 gigawatts (GW) of new offshore wind capacity every year in the 2020s, provided costs continue to fall, which will result in 10 GW of new offshore wind capacity built in the 2020s. To maintain the attractiveness for renewable investment in the United Kingdom, the government needs to adopt a timetable for the auctions for established and non-established technologies.

CPF underpinned the value of carbon in the power sector to supplement the EU Emissions Trading System (and protect against its volatility) and was able to drive coal-to-gas switching, whereas the EPS constrained the prospects for new coal power plants. The government recently confirmed that the CPF will stay at its current level until 2021. However, there is a lack of visibility about the future level and scope of the UK carbon pricing beyond this date and, as the power sector becomes decarbonised, the role of carbon pricing should be reviewed.

The Great Britain CM places a value on security of supply through a market-wide auction process, which has brought down prices. Contrary to initial expectations, the CM encouraged mainly capacity remunerations for existing plants, smaller-scale new-build plants and often flexibility sources and innovative technologies. Lessons have been learned from the early CM auctions which have been an effective discovery tool for the cost of energy storage, demand-side response, and new interconnectors. In fact, the latter dominate the new capacity committed under the CM.

Investment in new nuclear power is currently below the United Kingdom's target of 16 GW of new nuclear capacity by 2030, with only one project, Hinkley Point C (HPC), of 3.2 GW underway as several other projects were put on hold. Based on a CFD with an administered price of GBP 92 per megawatt hour (MWh), HPC is a welcome step but it is not sufficient to carry the momentum of the UK nuclear development towards an internationally competitive UK supply chain or to achieve cost reductions. The Nuclear Sector Strategy and the Nuclear Sector Deal are positive efforts made by the government in 2018 to build a stronger case for new nuclear development.

The EMR "legacy costs" of the support for low-carbon deployment that arise from administratively set prices for the Renewable Obligation and early CFDs were judged to be high, according to the independent cost of energy review led by Professor Dieter Helm. In his review, Helm called for a simplification of the EMR towards one firm power auction, an economy-wide carbon price, and competition in the networks. The inquiry of the Competition and Markets Authority of 2014-16 also found that the retail market was not delivering efficient outcomes for consumers.

To remedy rising electricity prices, in 2018, the government introduced a temporary retail price cap on default tariffs that entered into force on 1 January 2019, bringing the total amount of consumers under regulated price caps up to 11 million in 2019. However, the IEA finds that price caps can risk distorting in the market, with business charging up to the cap and consumers becoming less active. Even if a temporary measure, a clear exit strategy is important, based on a solid and regular assessment of the retail and wholesale market performance. The government is aware of these issues and a major review by BEIS and Ofgem is going to look at options to make the retail market fit for the future. Equally, Ofgem's standards and code review will be an opportunity to ensure a level playing field for all the market participants, incumbents, and new entrants.

Special focus 3: Maintaining energy security

The United Kingdom has a strong focus on energy security and continues to maintain robust policies and market-based approaches, based on collaboration with industry. The government created the independent Oil and Gas Authority, charged with the implementation of a strategy for the maximisation of the economic recovery (MER). UK continental shelf production increased by 16% from 2014 with the unit operating costs halved because of the new fiscal regime and a tax relief for decommissioning. Although domestic oil and gas production has fallen since the last IDR in 2010, thanks to the MER strategy and major cost-cutting efforts by industry, a reversal and increase in production was achieved in recent years.

United Kingdom's security of gas supply remains strong – the United Kingdom has a liquid gas market, robust infrastructure, and a diverse supply from domestic production, liquefied natural gas, and pipeline imports. Price signals are used to ensure flexibility, to cover potential shortages, and to allow gas to flow to the United Kingdom. The gas emergency preparedness proved robust at the end of February 2018 during a period of cold weather (referred to as the "Beast from the East"), despite the closure of Rough storage, previously the largest in the country. The first gas deficit warning by National Grid Gas System Operator (NGGSO) since 2012 provoked the appropriate market responses. Amid the expectation that domestic gas production is likely to decline in the North Sea region over the long term, and the high share of natural gas in power generation, the security of gas supply has to be kept under review, with the coordination of gas and power emergencies by NG, as the power mix becomes more variable.

Oil security continues to be robust and the United Kingdom remains well supplied. The United Kingdom became a net importer of refined oil products in 2013. Supply sources are well diversified, which reduces the potential impact of a supply disruption. In 2018, the country held oil stocks at a level of 238 days of net imports (all of which are industry stocks), one-third of its stocks abroad, all much above the IEA's required minimum of 90 days. As North Sea oil production decreases, net imports are set to rise significantly in the short-to-medium term. UK stockholding obligations are expected to rise in step, which will require the monitoring and assessment of the adequacy of storage capacity.

The power system of the United Kingdom will experience a major renewal in the next ten years with the final phase out of remaining coal-fired capacity and the closure of the oldest nuclear reactors (half of the total capacity of 8.9 GW) by 2025, with another six reactors closing by 2030. Electricity security has been a priority for the government, which sets the reliability standard (loss of load expectation of 3 hours per year or a 5% capacity margin), based on the forecasts of NG, to determine the needs in the GB CM. The power system is moving towards high shares of variable renewables and a lower baseload, so interconnections will continue to be an important source of flexibility, encouraged by the CM and Ofgem's cap and trade regime. The government's review of the reliability standard and of the CM should ensure market rules support this energy system transformation, in line with digitalisation of the electricity supply, better energy efficiency, and the BEIS/Ofgem Smart Systems and Flexibility Plan.

The United Kingdom's Energy Resilience work is exemplary, with a National Security Risk Assessment conducted every two years, contingency planning, and exercises, which feed into annual Sector Security and Resilience Plans across the energy sector.

In 2019, uncertainty remains over the timing and format of the UK exit of the European Union (Brexit). Its impact on the energy market and the rules applicable in the UK may undermine investment and open trade. The government is encouraged to ensure that open and efficient trade and their benefits for security of supply of the UK are maintained.

Key recommendations

The UK government should:

- Streamline and adjust the regulatory framework for electricity markets by removing barriers to efficient wholesale and retail market pricing and outcomes, with a view to take full advantage of innovation and competition, while boosting decarbonisation through cost-effective measures.
- Ensure fiscal policies continue to support the achievement of the United Kingdom's decarbonisation targets, particularly as the focus shifts to sectors such as transport and heat.
- Capture the various aspects of energy efficiency policy within a single dedicated energy efficiency strategy to provide for a greater visibility of government action and a more integrated and coordinated framework, aligned with a flexible and smart energy system.
- Continue to lead international energy R&D collaboration and efforts to scale-up energy technology innovation under Mission Innovation and other fora, including nuclear power and CCUS.
- Maintain open, free and efficient energy trade over different timeframes to safeguard the benefits for the flexibility and security of the United Kingdom energy system. Continue efforts to ensure that exiting the European Union and the EURATOM treaty will not impact trade or the supply chain, notably in the United Kingdom nuclear sector.

2. General energy policy

Key data

(2017)

TPES: 175.9 Mtoe (natural gas 38.6%, oil 34.5%, nuclear 10.4%, biofuels and waste[1] 7.1%, coal 5.4%, wind 2.4%, electricity 0.7%, solar 0.6%, hydro 0.3%) -16.7% since 2007

TPES per capita: 2.7 toe/cap (IEA average: 4.1 toe)

TPES per unit of GDP: 68 toe/USD million PPP (IEA average: 105 toe)

TFC: 127.3 Mtoe (oil 43.4%, natural gas 30.1%, electricity 20.3%, biofuels and waste 3.4%, coal 1.7%, heat 1.0%) -10.5% since 2007

Energy production: 120.2 Mtoe (oil 40.2%, natural gas 30.0%, nuclear 15.3%, biofuels and waste 8.2%, wind 3.6%, coal 1.5%, solar 0.9%, hydro 0.4%), -31.8% since 2007

Country overview

The United Kingdom consists of Great Britain (England, Wales, and Scotland) and Northern Ireland with a total area of 244 000 square kilometres (Figure 2.1). The United Kingdom's population was around 66 million in 2016, an increase of over half a million people since 2014, and is expected to continue to grow as a result of immigration and increased life expectancy. The third-largest economy in Europe after Germany and France, in 2018, the United Kingdom's gross domestic product (GDP) was USD 3 trillion and its annual GDP growth rate was 1.3% (OECD, 2019).

The United Kingdom is a parliamentary democracy with a monarchy under Her Majesty Queen Elizabeth II. The legislative power is vested in the two chambers of the parliament – the House of Commons and the House of Lords – and the judiciary is independent of the executive and the legislature. Her Majesty's government (HMG) is the central government of the United Kingdom and the current head of HMG is the Prime Minister Theresa May of the Conservative Party. The centre-right conservative government failed to obtain the majority after the election in June 2017 and is governing with a hung parliament. The United Kingdom has devolved powers to the Scottish government, Welsh government, and Northern Ireland Executive. The United Kingdom has been a member of the European Union (EU) since its accession in 1973, but it remained outside the Economic and Monetary Union with its own currency.

[1] Biofuels and waste in this report mean solid and liquid biofuels, biogases, industrial waste and municipal waste.

Figure 2.1 Map of the United Kingdom

This map is without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries and to the name of any territory, city or area.

Note: km = kilometre.

In June 2016, former Prime Minister David Cameron initiated a referendum on the EU membership, which saw a public decision to leave the EU (or Brexit). Uncertainty remains over the format and timing of Brexit in 2019 (with or without the withdrawal agreement (UK Government 2018a) as well as the future relationship with the EU (UK Government, 2018b and 2018c).

Institutions

The central government of the United Kingdom leads the overall energy policy strategy. Administrative, executive, or legislative authority is transferred to the so-called devolved administrations, which were created for Scotland, Northern Ireland, and Wales. Much of energy policy is reserved to the UK Parliament, notably European Union and international energy relations, competition, consumer protection, and transport. Devolved administrations have to act in areas where they have either exclusive or shared competence, such as the consent of small-scale generation, climate change, or energy efficiency, as outlined below.

Table 2.1 Devolved administration

Energy policy area	Wales	Scotland	Northern Ireland
Climate change mitigation	√	√	√
Company law	X	X	√
Consumer Protection	X	X	√
Consumer advice and advocacy	X	√	√
Competition policy	X	X	=
Economic development	√	√	√
Energy efficiency by prohibition or regulation	X	X	√
Energy efficiency other than by prohibition or regulation	√	√	√
Energy generation consent (large scale – 50 MW up to 350 MW)	√	√	√
Energy Generation consent (small scale – under 50 MW)	√	√	√
Energy policy	X	X	√
Enterprise and financial assistance to industry (concurrent powers)	√	√	√
European Union and international affairs	X	X	X

Note: MW = megawatt.

Energy in the United Kingdom is also governed by EU law. The regulatory and policy framework that govern the Great Britain (GB) energy markets are set out in UK legislation and in licences that are granted by the Office of Gas and Electricity Markets (Ofgem) to energy market participants, as well as in industry codes and detailed multilateral industry agreements.

The **Department for Business, Energy and Industrial Strategy (BEIS)** takes the main responsibility for ensuring the United Kingdom's secure, clean, and affordable energy supplies and promotes international action on energy security, climate change, and technology innovation. BEIS was created in July 2016 as a result of a merger between the Department of Energy and Climate Change and the Department for Business, Innovation and Skills.

Several companies are under the authority of the BEIS Secretary of State to deliver policy objectives. The **Low Carbon Contracts Company** and the **Electricity Settlements Company** are both private limited companies to deliver on the decarbonisation of the UK electricity sector.

The **Oil and Gas Authority (OGA)** regulates and promotes the UK oil and gas industry to maximise the economic recovery of offshore oil and gas resources. It is in charge of the licensing of oil and gas exploration and development in England and on the UK continental shelf and it promotes investment along the oil and gas supply chain. In 2016, the OGA became a government company with the BEIS Secretary of State as the sole shareholder.

Her Majesty's Treasury (HMT) sets the direction of the United Kingdom's economic policy to achieve strong and sustainable growth and controls over public spending. **The Department for Environment, Food and Rural Affairs (Defra)** is the government department responsible for policy and regulations on environmental, food, and rural issues, which include the domestic adaptation to climate change. Defra works with BEIS to ensure specific government policies on low-carbon energy and decarbonisation measures are sustainable and aligned with Defra's environmental objectives.

The Ministry of Housing, Communities and Local Government (housing) and **the Department for Transport (DFT)** co-operate with BEIS on sectoral policies and measures. The **Office for Low Emission Vehicles (OLEV)** is a joint unit between BEIS and the Department for Transport that supports the early market for ultra-low emission vehicles (ULEVs).

The Office of Gas and Electricity Markets (Ofgem) is the main regulator of the UK gas and electricity networks. Its central role is to protect the consumer interests, which include reducing greenhouse gas (GHG) emissions, ensuring the security of supply, and regulating competitive markets in gas and electricity supply and retail. Ofgem is independent of the government and accountable to the UK Parliament. Ofgem is governed by the Gas and Electricity Markets Authority and funded by annual licence fees paid by licenced companies.

The **Competition and Markets Authority (CMA)** is the United Kingdom's primary competition and consumer authority. It is an independent non-ministerial government department with responsibility for carrying out investigations into mergers, markets, and the regulated industries and enforcing competition law. During 2014-16, CMA investigated the supply and acquisition of energy in the United Kingdom and published a report (CMA, 2016) on energy market reform, which set out a wide range of measures to modernise the UK energy market.

The **Nuclear Decommissioning Authority** is a non-departmental public body that owns 17 civil nuclear legacy sites across the United Kingdom, plus the associated liabilities and assets. **The Office for Nuclear Regulation** is the United Kingdom's independent nuclear regulatory authority, set up by the Energy Act 2013 to regulate nuclear safety, security, and conventional health and safety at licensed nuclear sites.

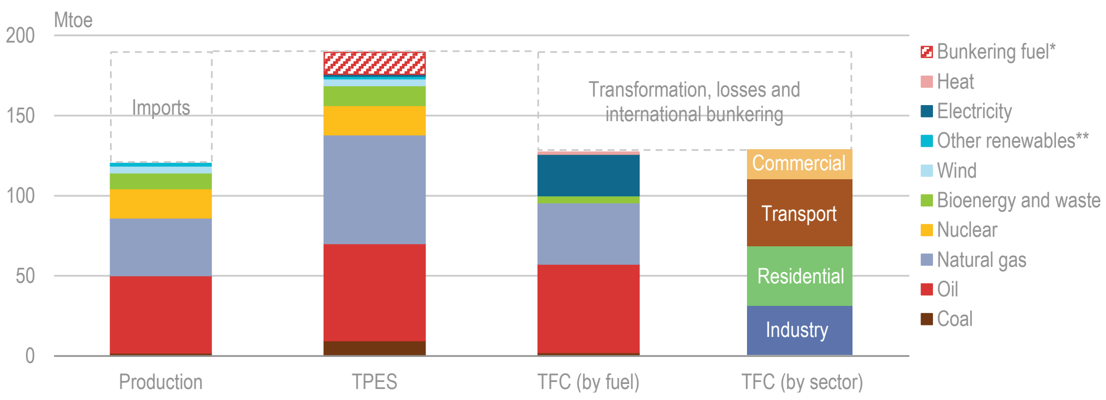
National Grid plc is a British multinational electricity and gas utility company with activities in the United Kingdom and North-eastern United States. **National Grid Electricity Transmission** owns and operates the electricity networks and partly the interconnectors. **National Grid Gas** plc owns and operates the gas transmission network (from terminals to distributors), known as the National Transmission System (NTS). As of 1 April 2019, within the National Grid Group a new Electricity System Operator (ESO) entity (NGESO) is being established, that is legally separate from the transmission owner, NG Electricity Transmission. The separation will allow the ESO to play a more proactive role in managing an increasingly flexible electricity system that can realise benefits for consumers.

Supply and demand trends

Once a large producer of oil and gas from the North Sea, UK oil and gas production has declined significantly since the peak year of 2000. The United Kingdom became a net importer of natural gas in 2004, of crude oil in 2005, and of oil products in 2012.

The United Kingdom's energy system is characterised by a large share of natural gas and oil, which in 2017 accounted for 73% of the total primary energy supply (TPES[2]) and 70% of domestic energy production (Figure 2.2).

Figure 2.2 Overview of the United Kingdom's energy balance, 2017



Natural gas and oil dominate the energy supply in the United Kingdom, and increasingly are imported as domestic production has declined.

* Bunkers includes international aviation and marine bunker fuel. Not included in the definition of TPES.

** Other renewables includes hydropower, geothermal energy, and solar energy.

Source: IEA (2019), *World Energy Balances 2019 First edition (database)*, www.iea.org/statistics/.

Nuclear energy is the third largest energy source, with 10% of TPES and 21% of total electricity generation in the United Kingdom. The amount of nuclear energy is expected to decrease, as most of the existing nuclear power stations will close during the 2020s

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[2] TPES is made up of production + imports – exports - international marine and aviation bunkers ± stock changes. This equals the total supply of energy that is consumed domestically, either in transformation (e.g. power generation and refining) or in final use.

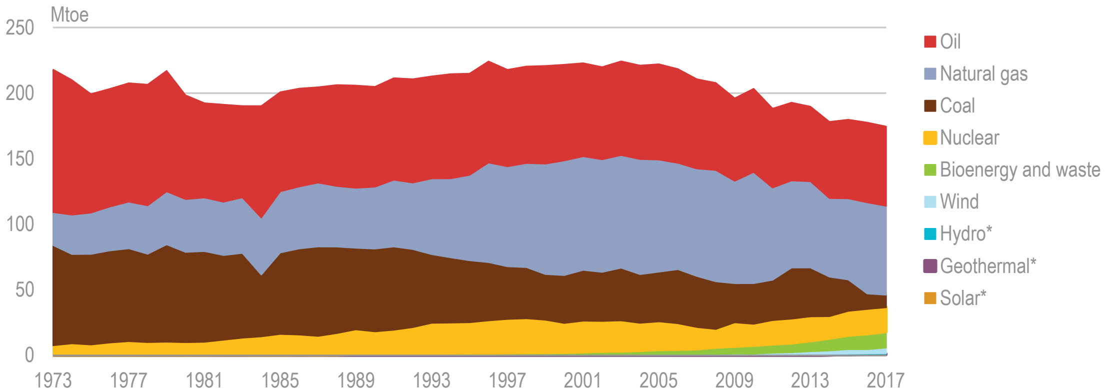
and only one new plant is being developed (Hinkley Point C). Renewable energy sources (RES) are rapidly increasing with a notable strong growth in biofuels and waste, solar photovoltaics (PV), and wind power.

The transport sector was the largest energy-consuming sector in 2017, at a third of total final consumption (TFC[3]), followed by the residential, industrial, and commercial sectors. Natural gas, oil, and electricity are the main energy sources, with a total share of 94% of TFC. Oil dominates the energy consumption in the transport and industry sectors, whereas natural gas is the most important fuel in the residential and commercial sectors. International bunkers for aviation and maritime transport make up a large part of domestic oil consumption (but are counted as an export).

Primary energy supply

In 2017, the United Kingdom's TPES was 176 million tonnes of oil-equivalent (Mtoe), a decline since its peak of 225 Mtoe in 2003 (Figure 2.3). In 2017, fossil fuels accounted for 78% of the TPES, a decrease from 90% in 2007. All fossil fuels have declined over the past decade, particularly the use of coal fell by more than half. The share of renewables in the TPES has increased from 2% in 2007 to 10% in 2017. By international comparison, the United Kingdom is placed at the IEA median when it comes to the share of fossil fuels in the TPES (Figure 2.4).

Figure 2.3 TPES by source, 1973-2017



The TPES decreased by 17% in the past decade, with the decline in coal, oil, and natural gas supply, whereas biofuels and other renewables are increasing.

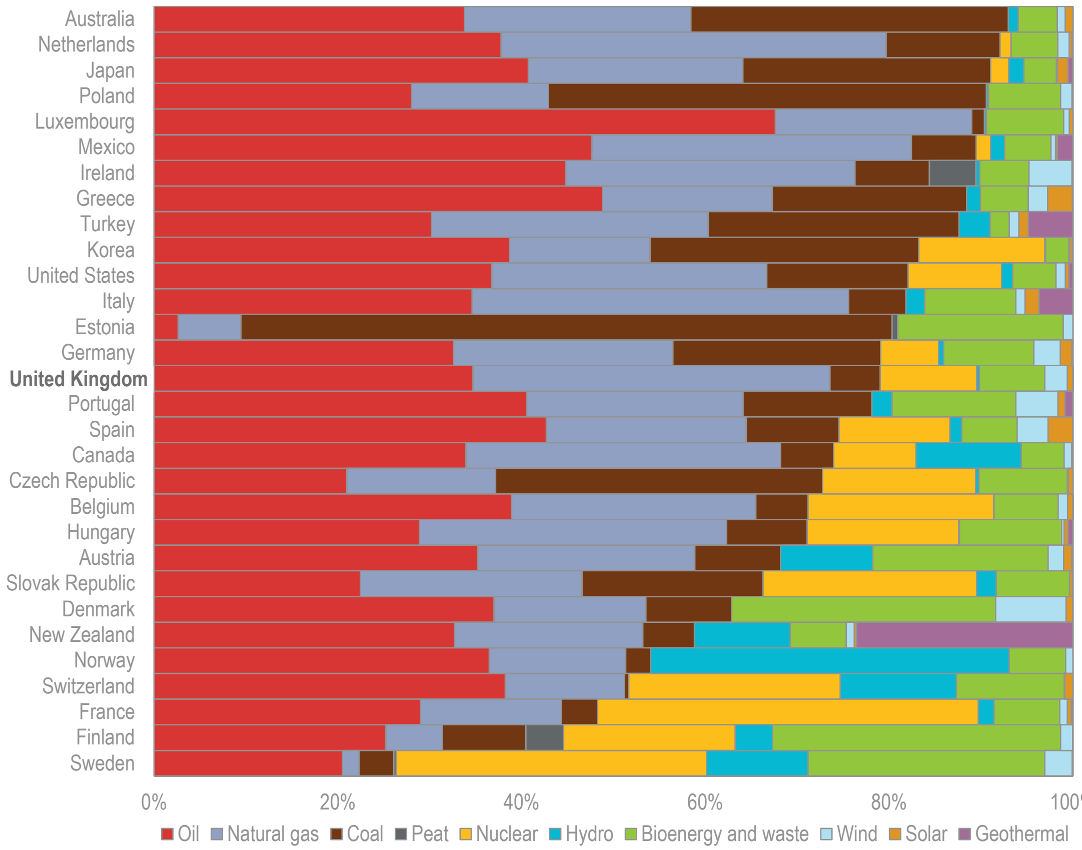
* Negligible.

Note: The sudden decrease in coal supply in 1984 was due to the miners' strike of 1984-85.

Source: IEA (2019), *World Energy Balances 2019 First edition (database)*, www.iea.org/statistics/.

[3] TFC is the final consumption of energy (electricity, heat, and fuels, such as natural gas and oil products) by end users, but does not include the transformation sector (e.g. power generation and refining).

Figure 2.4 Breakdown of TPES in IEA member countries, 2017



The United Kingdom's share of fossil fuels in TPES is around the median among IEA countries, after a gradual decline of fossil fuel supplies over the past decade.

* Estonia's coal is represented by oil shale.

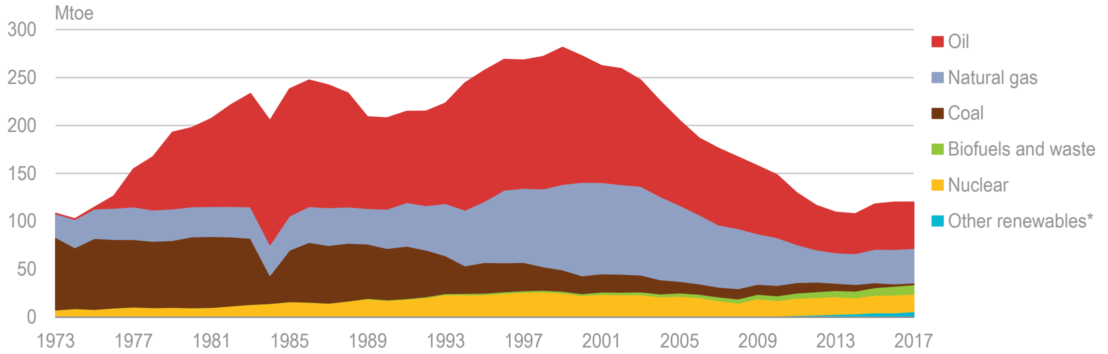
Source: IEA (2019), *World Energy Balances 2019 First edition (database)*, www.iea.org/statistics/.

Energy production

In 2017, the United Kingdom's total energy production was 120 Mtoe, which saw a 57% decrease since the peak of 282 Mtoe in 1999 because of a decline in oil and gas production (Figure 2.5). Oil production fell by 39% over a decade and gas production dropped by 45%. Meanwhile, the country's renewable energy production more than tripled from 5 Mtoe in 2007 to 16 Mtoe in 2017. Today, oil accounts for 40% and natural gas for 30%, with the remainder coming from nuclear (15%), biofuels and waste (8%), wind (4%), coal (2%), solar (1%), and hydro (0.4%). Domestic coal production in the United Kingdom has fallen over the past four decades and many mines have closed (Figure 2.6). In 2015, hard coal mining ended.

The significant drop in energy production made the United Kingdom more dependent on energy imports (Figure 2.7). During the decade 2007-17, natural gas and oil net imports more than doubled. The trend has been reversed over the three years 2014-17, as crude oil and gas production increased by 14% and thereby stabilised the import dependency. Coal demand has dropped significantly in recent years, both in industry and in power generation (Figure 2.6). The overall energy import dependency has declined from 50% in 2013 to 38% in 2017.

Figure 2.5 Energy production by source, 1973-2017

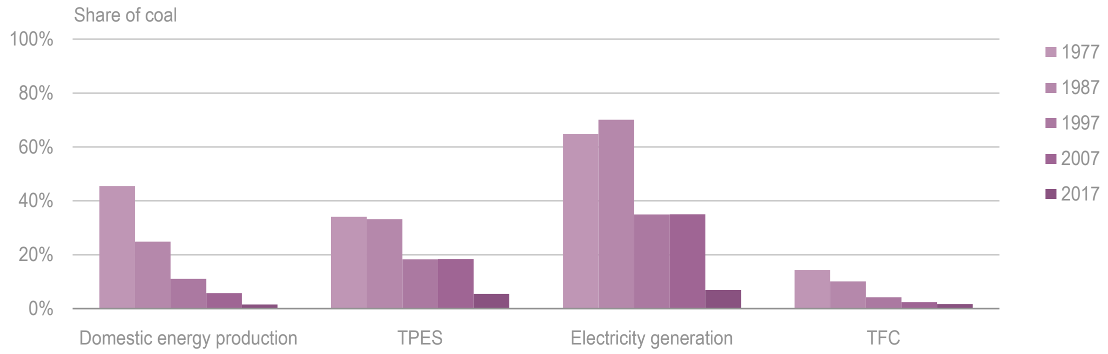


Total energy production dropped by 57% from the peak in 1999 due to the sharp fall in oil and gas production, although production has picked up slightly in recent years.

* Includes wind, hydro, solar and geothermal.

Source: IEA (2019), *World Energy Balances 2019 First edition (database)*, www.iea.org/statistics/.

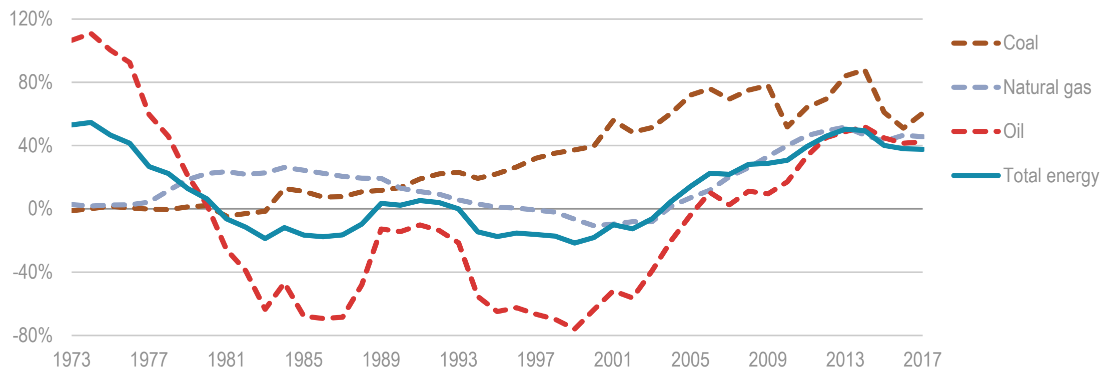
Figure 2.6 Share of coal in different energy metrics, 1977-2017



The share of coal in electricity generation and the coal production significantly decreased in the past decade.

Source: IEA (2019), *World Energy Balances 2019 First edition (database)*, www.iea.org/statistics/.

Figure 2.7 Energy import dependency by source, 1973-2017



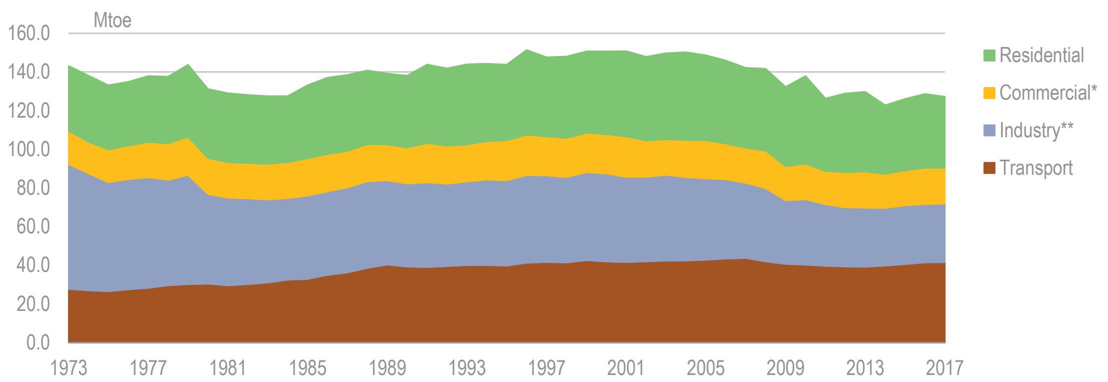
Falling domestic production has made the United Kingdom more dependent on oil and gas imports, although the total import dependency has declined since 2013.

Source: IEA (2019), *World Energy Balances 2019 First edition (database)*, www.iea.org/statistics/.

Energy consumption

In 2017, the United Kingdom's TFC was 127 Mtoe, 11% lower than in 2007. The largest drop in TFC was in the industry sector, falling by 22%, whereas the residential sector decreased its consumption by 11% and the transport and commercial sectors remained relatively stable. Since 2014, energy consumption in all sectors saw a slight rebound. The transport sector is the largest energy-consuming sector (33% of TFC in 2017), mainly road transport. The residential sector is the second largest (29%) with industry the third (24%), as illustrated in Figure 2.8.

Figure 2.8 TFC by sector, 1973-2017



The transport sector is the largest energy consumer with 32% of TFC and the total energy consumption slightly increased in recent years.

* Commercial includes commercial and public services, agriculture, and forestry.

** Includes non-energy consumption.

Source: IEA (2019), *World Energy Balances 2019 First edition (database)*, www.iea.org/statistics/.

Energy policy framework

The United Kingdom has an integrated energy and climate policy framework and maintains a strong international leadership on climate change, electricity (and gas) market reforms, and the security of supply.

During 2012-16, the energy and climate policy framework was geared towards implementing a major reform to support the security of supply and the decarbonisation of the power sector. Building on the 2012 White Paper on the Electricity Market Reform (or EMR, see UK Government, 2012), the Energy Act 2013 introduced four mechanisms to support investment in low-carbon electricity generation: a carbon price floor, an emissions performance standard, a capacity market (CM) and contracts for difference (CFDs). In addition to the EMR, the government also announced, on 18 November 2015, the closure of all coal-fired power plants without carbon capture and storage (unabated coal) by 2025.

Since 2016, the United Kingdom has streamlined its energy and climate policies towards efforts to strengthen the innovation, productivity, and competitiveness of the industry. This is reflected in the new institutional governance, with the integration of the energy and climate portfolio into a wider, newly created department, BEIS.

The United Kingdom has been at the forefront of recognising climate change threats and adopting regulations and policy solutions to support low-carbon investment. Based on the UK's Climate Change Act (the Act), adopted in 2008, the UK targets emissions reductions by at least 80% by 2050 on 1990 levels. Under the Act, the government has to set legally binding five-year caps on emissions – carbon budgets – 12 years in advance and then to publish a report with policies and measures to meet that budget and the previous ones. Five carbon budgets have been set to date; the fifth one was set in July 2016 and covers the period 2028-32.

The **Clean Growth Strategy**, adopted in October 2017, outlined a large number of proposals to meet the fifth carbon budget through measures across the economy and in targeted sectors – transport, business and industry, residential, the heat and the power sector, and agriculture and forestry. The Strategy was underpinned by a pledge to invest British pounds (GBP) 2.5 billion in low-carbon innovation over five years (UK Government, 2017a):

- **Accelerate the shift to low-carbon transport** by working with industry under the Automotive Sector Deal, ending the sales of new conventional petrol and diesel cars and vans by 2040, developing a charging network across the UK, including through public funding and legal obligations under the Automated and Electric Vehicles Bill, as well as supporting the take-up of ultra low emission vehicles (ULEV) and low-emission taxis and buses, based public funding, including GBP 1 billion to support consumers to afford a ULEV.
- **Improve energy efficiency in business and industry** by at least 20% by 2030, including through an Industrial Energy Efficiency scheme for large companies, strengthened energy efficiency standards in new and existing commercial buildings and rented property, joint industrial decarbonisation and energy efficiency action plans, international and domestic actions to deploy carbon capture, usage, and storage (CCUS) and other GHG removal technologies,
- **Improve the energy efficiency of homes**, including by providing investment support to upgrade around one million homes through the Energy Company Obligation (ECO), stronger standards for new buildings, upgrading all fuel poor homes to Energy Performance Certificate (EPC) Band C by 2030 and as many homes as possible to be EPC Band C by 2035.
- **Foster the roll-out of low-carbon heating** by reforming the Renewable Heat Incentive, phasing out carbon-intensive fossil fuel heating (in new buildings off the gas grid) as well as recycling of industrial process heat, building and extending heat networks with public funding and develop new energy efficiency and heating technologies based on innovation funding.
- **Deliver clean, smart, and flexible power** through measures to reduce costs for households and businesses (price cap, reform of NG to an independent system operator), phasing out the use of unabated coal to produce electricity by 2025; delivering new nuclear power (Hinkley Point C and a new pipeline of projects), improving the route to market for renewable technologies, such as offshore wind, through a Sector Deal and another round of auctions for contracts of difference with public funding of around GBP 560 million, as well as providing certainty of the total carbon price in the power sector.
- Enhance the benefits and value of the **UK's natural resources** to focus better on environmental outcomes, including addressing climate change more directly, through a Resources and Waste Strategy, new agriculture support and boost larger-scale woodland and forest creation as well as UK timber production.

- **Lead in the public sector** with a voluntary public sector target of 30% reduction in carbon emissions by 2021, the promotion of government leadership in clean growth and the **green finance** capabilities, including green mortgages and the creation of a Green Finance Taskforce.

The Industrial Strategy of 2017 (UK Government, 2017b) aims to boost productivity, innovation, and prosperity, to bring down the costs of UK decarbonisation policies, and to upgrade energy infrastructure in line with the next generation of technologies. As part of the Strategy, the government is building long-term strategic partnerships with businesses, the so-called sector deals. To date, sector deals are agreed for the nuclear and automotive industries, among others. The Budget 2018 announced a GBP 315 million Industrial Energy Transformation Fund.

The Clean Growth Strategy and the Industrial Strategy refocused the energy policy framework towards competitiveness and affordability. The government has adopted a long-term roadmap to minimise business and household energy costs, which started with the cost of energy review in 2017, the reform of the levy control and various initiatives to bring down the cost of achieving decarbonisation in the power and industrial sectors. The government is adapting existing support schemes to support further reductions in line with decreases in technology costs (for offshore wind), while ensuring planned investments are delivered, notably through the CFD.

The government commissioned an independent review into the cost of energy led by Professor Dieter Helm, who recommended ways to deliver the carbon targets and ensure the security of supply at a minimum cost (Helm, 2017). Helm underlines that the various low-carbon support schemes have contributed to the high cost of electricity. He recommends a single economy-wide carbon price coupled with carbon border tariffs (which adjust for the trade impacts of a UK carbon system different to that of the European Union Emissions Trading System [EU ETS]), abolishing existing RES/CFD support schemes in favour of firm energy capacity auctions, encouraging flexible capacity and renewables investment, and moving to competition for energy networks (instead of regulation).

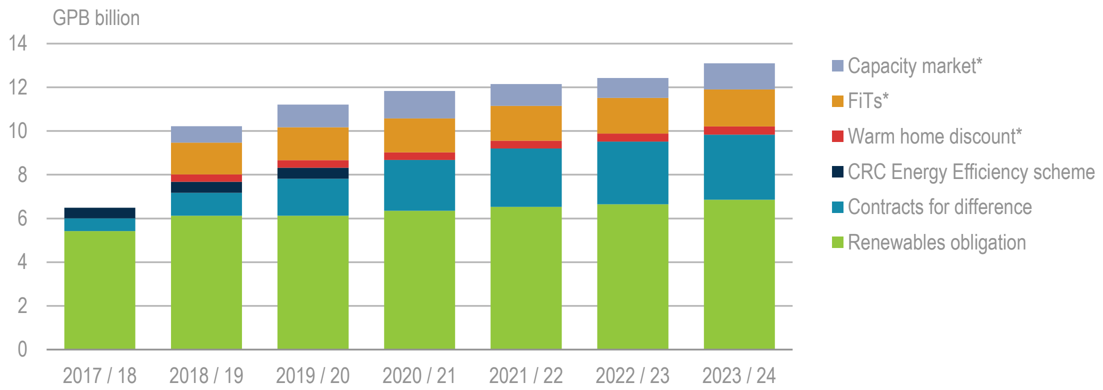
Energy and climate taxes and levies

The United Kingdom has a levy control framework (LCF) in place, linked to the annual budget process, to control the costs of low-carbon electricity support schemes, which are levied on consumers' energy bills through wholesale prices. The framework covers electricity only and no other sectors, such as transport or heat. The LCF includes the costs of the CFD, the renewables obligation (RO), and the feed-in tariff (FIT) scheme, as well as early CFDs awarded under the "final investment decisions enabling for renewables" process.

In the autumn of 2017, the United Kingdom introduced a Control for Low Carbon Levies ("the Control") to replace the LCF. The Control covers all existing and new low-carbon electricity levies. The government decided not to introduce new low-carbon electricity levies until the level of existing costs ("legacy cost") falls. Based on the government's forecast, this means there will be no new low-carbon electricity levies until 2025. The existing schemes covered by the Control will continue. The announced government's commitments – including up to GBP 557 million (in 2011/12 prices) for further CFDs (May 2019 CFD Pot 2) – have been confirmed. According to updated forecasts published by the Office for Budget Responsibility in October 2018, low-carbon levies will reach GBP 10.2 billion in 2020/21, which is equivalent to GBP 8.0 billion in 2020/21 in 2011/12 prices, not counting the warm home discount, CM, or FITs (Figure 2.9).

In Great Britain, the Total Carbon Price (TCP) for energy generation is made up of the EU Emissions Trading System ETS price and the Carbon Price Support (CPS) rate of the Climate Change Levy (CCL). The CPS was implemented to support the EU ETS and underpins the price of carbon at a level that drives low-carbon investment by taxing fossil fuels used to generate electricity. The CPS rate does not apply to energy generators in Northern Ireland. HM Treasury confirms CPS rates in advance of the delivery of the Budget, and all revenue from the CPS is retained by the Treasury. In 2018-19, the revenue is forecast to be around GBP 0.9 billion.

Figure 2.9 Environmental levies forecasts



The RO is forecast to provide the largest environmental levy, but the CFDs will grow the most.

* The Office of National Statistics has yet to include the warm home discount, FITs and CM auctions in their outturn numbers. If included, they would have been GBP 0.3 billion, GBP 1.4 billion, and GBP 0.2 billion, respectively.

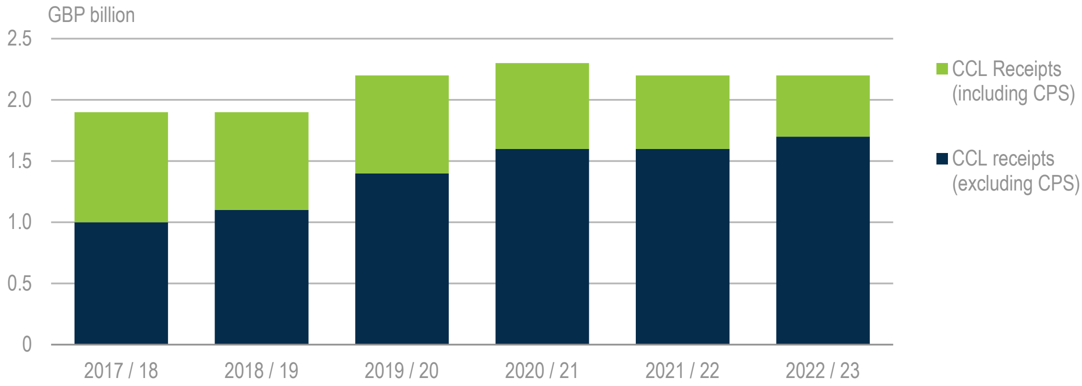
Note: CRC = Carbon Reduction Commitment.

Source: UK Government (2018d), Economic and Fiscal Outlook – March 2018, Supplementary Fiscal Table 2.7, https://cdn.obr.uk/EFO-MaRch_2018.pdf.

The CPS was introduced in 2013/14 at a rate of GBP 4.94 per tonne of carbon dioxide (GBP/tCO_2). In the budget of 2014, the government announced that the CPS rate would be capped at 18 GBP/tCO_2 from 2016/17 to 2020/21 to limit the competitive disadvantage faced by businesses and to reduce energy bills for consumers. In the Budget of 2016, the cap was maintained at 18 GBP/tCO_2 from 2016/17 to 2019/20. In the Budget of 2018, the government announced that CPS rates will be frozen at 18 GBP/CO_2 in 2020/21 following the rise in the EU ETS price. From 2021/22, the government will seek to reduce CPS rates if the TCP remains high.

Introduced in 2001, the CCL is levied on the supply of energy (generators) to business and public sector consumers (households, charities, and most small businesses are excluded) per unit of energy used in four commodities (electricity, gas, coal, and liquefied petroleum gas). Energy-intensive industries have a discount on the CCL if they meet negotiated energy efficiency targets through voluntary agreements (Climate Change Agreements [CCAs]). This relief currently provides a 90% discount on the levy on electricity and 65% on gas and other taxable fuels. Businesses with CCAs are also exempt from other energy efficiency and carbon reduction schemes.

Figure 2.10 Carbon levy receipts



Most of the carbon levies receipts will be without CPS.

Source: Office for Budget Responsibility (2018), *Economic and Fiscal Outlook – March 2018*, Supplementary Fiscal Table 2.13, https://cdn.obr.uk/EFO-MaRch_2018.pdf.

Assessment

Since the previous International Energy Agency (IEA) in-depth review of the United Kingdom in 2012, the government has undertaken significant reforms to the energy market, most notably through the implementation of the EMR in 2012. The United Kingdom leads among the Group of Seven countries in terms of emission reductions. The UK carbon budget approach has served as a model for the Paris Agreement. The United Kingdom maintains ambitious emission reduction targets, as confirmed in the fifth carbon budget (which covers 2028-32), adopted in 2016. In 2017, the government released a Clean Growth Strategy, which contains a comprehensive set of policies and proposals to meet the United Kingdom's ambitious emissions reduction goals, underpinned by considerable government funding to support innovation and low-carbon investment.

In short, the changes to the energy market, especially to the electricity market since 2012 reflect a wider set of goals, particularly emissions reduction, maintaining electricity reliability and affordability, and, more recently, industrial competitiveness. The reforms made to the electricity market, especially the establishment of a CFD for the procurement of renewables and nuclear power, and the CPS for wholesale electricity have made the United Kingdom a leader in emissions reductions. Emissions from coal-fired plants, in particular, have fallen dramatically with coal being substituted by renewables, especially offshore wind generation and gas-fired generation.

These reductions have captured the "low-hanging fruit" in the context of emissions reductions in the energy sector, notably in electricity supply. As the power sector advances in decarbonisation, electricity will become increasingly important to underpin the decarbonisation of other sectors, notably transport and heat. However, today's technologies, the regulatory framework and price signals, including taxation, are not reflective of these wider decarbonisation goals. As the exact pathway cannot be predicted, there is a role for government to guide the transformation and ensure a flexible and adequate regulatory framework.

Transport decarbonisation is a priority with the new targets and actions proposed, which include the end of the sales of new conventional petrol and diesel cars and vans by 2040, the Automated and Electric Vehicles Act, the establishment of the OLEV as a joint initiative of BEIS and the DFT, and funding for the charging infrastructure, as well as support for the roll-out of ultra-low carbon vehicles of GBP 1 billion.

The heat sector decarbonisation forms part of the Clean Growth Strategy. There are challenges given the need for cross-sector coordination and for action by devolved administrations, local authorities, and cities. As infrastructure investment needs to come forward during the 2020s, there is an urgent need for the government to set out pathways for heat use in different sectors given the broad range of technology choices (hydrogen, heat pumps, renewable heat, and heat networks) and costs, driven by consumer preferences and the ability to pay. The UK gas networks are taking forwards work to establish the feasibility of repurposing the gas network to carry hydrogen.

Markets and regulations are in place but not yet fully adapted to the evolving system, which no doubt creates uncertainty among incumbents and new entrants. The focus on emissions reductions in the power sector has increased electricity bills for consumers. With technological progress and the decreasing cost of renewable energy, the integration of renewables in the power system and the marketplace should be a priority to allow consumers to take full benefit of a clean and affordable power.

Competitiveness and rising consumer bills are high on the political agenda of the United Kingdom in 2018, and so create pressure from citizens on industry and government to reduce the costs of decarbonisation and create more competition and choice. The IEA welcomes the government review of the cost of energy. It is critical that government assesses the different drivers of these costs (environmental, regulatory, energy, risk and uncertainty, profit margins, and competition) to carefully tailor the most adequate government response.

The Industrial Strategy, as well as the merger of the energy and climate change portfolios into BEIS, reflect the objectives of decarbonisation of the energy sector, while fostering competitive energy costs for residential and business consumers.

Simplifying market arrangements and regulatory interventions should be a priority. The IEA considers this to be an opportunity for government to promote more efficient, transparent markets and reduce distortions, and thus costs. The government should place more emphasis on energy efficiency, simplify and remove outdated regulation, review environmental subsidies, and reform energy taxation. A rebalancing of decarbonisation efforts and costs across the economy is therefore essential.

The United Kingdom has well-established and comprehensive energy efficiency policies, as analysed in the Chapter on Energy Efficiency. However, coordination remains a challenge. A whole-government approach is useful to articulate a broader vision and encourage co-operation on cross-cutting issues. As a follow up to the Clean Growth Strategy, the United Kingdom may wish to consider developing a national energy efficiency strategy to give more visibility on government policies and actions and provide a clear framework for coordination and evaluation based on a sector-by sector approach.

The United Kingdom derives significant benefits from trade in gas and electricity through interconnectors with neighbouring countries. These trading arrangements give access to lower prices in the continental wholesale markets and thus increase the competitiveness of the UK economy. In addition to the security of supply arrangements, which provide for neighbouring countries assisting in the event of an emergency, market signals in the United Kingdom are able to attract supplies in the event of potential shortages. The flexibility provided to the electricity system by interconnections also allows greater levels of variable renewable electricity to be accommodated.

The decision to exit the European Union could lead to a change in the regulatory or trading arrangements that are in place between the United Kingdom and EU countries as well as between Ireland and Northern Ireland. Given the benefits derived from the current framework, any change will need to be considered carefully. The ongoing process is creating a level of uncertainty in the market. This is likely to lead to project developers factoring in a higher level of risk, which results in higher costs of capital and/or investment decisions being deferred or potentially cancelled. Commendably, the government has prepared contingency plans in the event of a "hard Brexit" to ensure continued nuclear supplies, the continuation of the current level of carbon price, and the SEM, and provided for a UK environmental authority.

Recommendations

The UK government should:

- ☐ Capture the various aspects of energy efficiency policy within a single dedicated energy efficiency strategy to provide a greater visibility of government actions and a more integrated and co-ordinated framework, aligned with a flexible and smart energy system.
- ☐ Ensure fiscal policies continue to support the achievement of the United Kingdom's decarbonisation targets, particularly as the focus shifts to sectors such as transport and heat.
- ☐ Maintain open, free, and efficient energy trade over different timeframes to safeguard the benefits for the flexibility and security of the UK energy system. Continue the efforts to ensure that exiting the European Union and the Euratom treaty will not impact trade or the supply chain, notably in the UK nuclear sector.

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3. Energy and climate change

Key data

(2016/17)

GHG emissions without LULUCF (2016): 486.3 $MtCO_2e$, -39% since 1990

GHG emissions with LULUCF (2016): 471.726 $MtCO_2e$, -41% since 1990

Energy-related CO_2 emissions (2017):

CO_2 emissions from fuel combustion: 358.7 $MtCO_2$, -35% since 1990, -33% since 2005

CO_2 emissions by fuel: oil 44.7%, natural gas 43.7%, coal 10.2%, other 1.4%

CO_2 emissions by sector: transport 34.0%, power and heat generation 24.5%, residential 17.6%, industry 10.3%, commercial 6.4%, other energy 7.2%

CO_2 intensity per GDP (PPP): 0.14 $kgCO_2$/USD PPP (IEA average: 0.23 $kgCO_2$/USD PPP)

Notes: LULUCF = Land use, land use change and forestry. PPP = Power Purchase Parity. Industry includes CO_2 emissions from combustion at construction and manufacturing industries. Other energy includes emissions from oil refineries, blast furnaces and coke ovens.

Overview

The United Kingdom takes comprehensive measures to both evaluate and mitigate climate change and is committed to finance low-carbon solutions. It is a signatory to the United Nations Framework Convention on Climate Change (UNFCCC), a party to the Kyoto Protocol and the Paris Agreement, and one of the largest global contributors of climate finance, with British pounds (GBP) 3.87 billion between 2011 and 2016 and committed to at least a further GBP 5.8 billion of climate finance up to 2020.

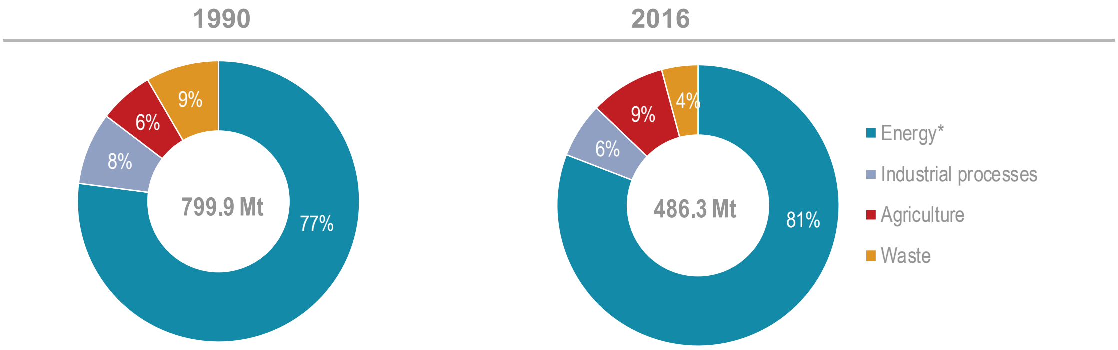
Since its adoption in 2008, the United Kingdom's Climate Change Act has established a long-term policy based on the target to reduce greenhouse gas (GHG) emissions by at least 80% by 2050 on 1990 levels. This Act provides the legal framework both to mitigate climate change by reducing GHG emissions and to adapt to the impacts of climate change. Given the dominance of energy-related emissions, the policy measures largely focus on the energy sector. Over the past decade, the United Kingdom made visible strides in reducing energy-related carbon dioxide (CO_2) emissions (reduced by 30% since 1990) and carbon intensity. Although decarbonisation of the power sector is progressing well, the government also targets emissions reductions in other sectors, particularly transport, buildings, heating, and industry, to be on track towards meeting its overall climate change objectives.

Emissions

GHG emissions

In 2016, the total emissions of GHGs without land use, land use change, and forestry (LULUCF) in the United Kingdom amounted to 486.3 million tonnes of carbon dioxide-equivalent ($MtCO_2e$). Since 1990, the United Kingdom's GHG emissions have declined by 39.2%. The largest contributors to the total GHG emissions in 2016 were energy-related emissions, which accounted for 81% of the total, followed by emissions from the agriculture sector (9%), industrial processes (6%), and the waste sector (4%) (Figure 3.1). The energy sector is responsible for the emissions from energy use in the power and heat generation, transport, industry, household, and commercial sectors. Besides the main GHG, CO_2, emissions consist of methane and nitrous oxide, which account for 11% and 5%, respectively.

Figure 3.1 GHG emissions by sector, 1990 and 2016



The United Kingdom's total GHG emissions have reduced by 40% since 1990 (without LULUCF), and energy-related emissions dominate the total emissions.

* Energy includes power and heat generation, commercial, households, industrial energy consumption and transport.

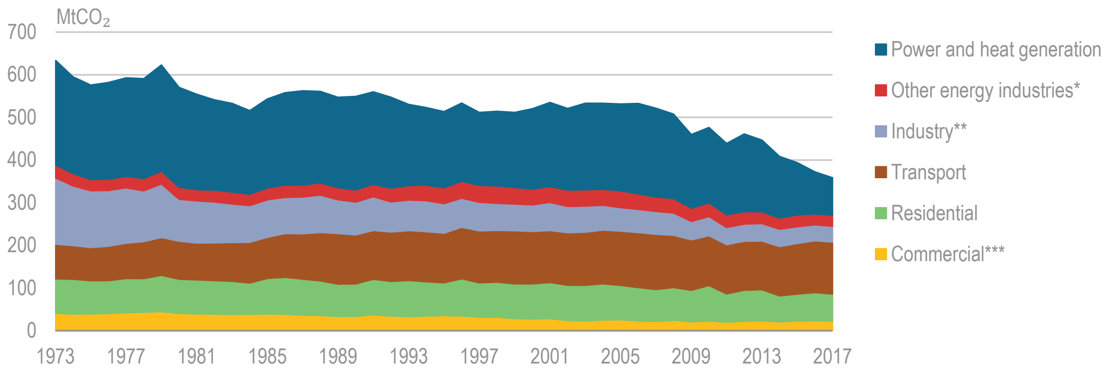
Source: UK Government (2018a), *Greenhouse Gas Emissions Inventory, 1990 to 2016*, https://uk-air.defra.gov.uk/assets/documents/reports/cat07/1804191054_ukghgi-90-16_Main_Issue1.1_UNFCCC.pdf.

Energy-related CO_2 emissions

The United Kingdom's energy-related CO_2 emissions were 359 million tonnes of carbon dioxide ($MtCO_2$) in 2017, a 35% reduction since 1990. As illustrated in Figure 3.2, transport (34% of the total) and power and heat generation (25%) were the main emitters, with the remainder from residential (18%), industries (10%), commercial (6%), and other energy industries (7%), such as oil refineries, coke ovens, and blast furnaces.

Emissions declined in most sectors over recent decades, but most prominently in power and heat production. In power generation, emissions declined as a result of the steady increase of natural gas and renewable energy use, which replaced carbon-intensive coal. Over the past decade, the share of renewables increased to almost 30% in power generation. Furthermore, total electricity generation has declined by 15% since 2007. Thanks to this significant emissions reduction, the power and heat generation sector is no longer the highest emitting sector, but comes second to the transport sector.

Figure 3.2 Energy-related CO_2 emissions by sector, 1973-2017



CO_2 emissions in power and heat generation have more than halved in a decade, whereas transport emissions have been stable and now account for the largest share.

* Other energy includes emissions from oil refineries, blast furnaces, and coke ovens.

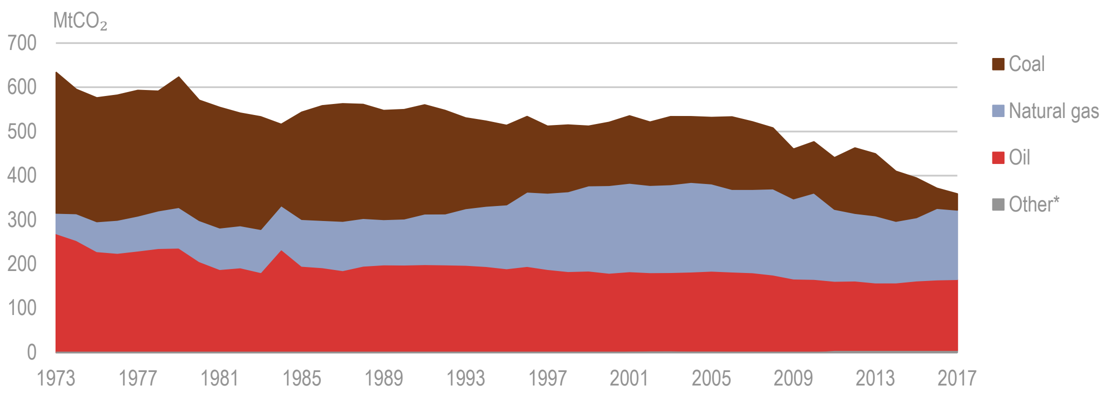
** Industry includes CO_2 emissions from combustion at construction and manufacturing industries.

*** Commercial includes commercial and public services, agriculture, forestry, and fishing.

Source: IEA (2019a), *CO_2 Emissions from Fuel Combustion 2019*, www.iea.org/statistics/.

In 2017, oil and natural gas were the two largest sources of energy-related CO_2 emissions, at 45% and 44%, respectively. Coal emissions reduced significantly, and in 2017 accounted for a record low of 10% of total CO_2 emissions (Figure 3.3). Natural gas and coal-related CO_2 emissions stem from electricity generation. Emissions from oil originate mainly in the transport sector. As the share of fossil fuels in the total primary energy supply (TPES) has decreased over the past decade, the emissions from all fossil fuels have also been reduced. From 2007 to 2017, emission from coal declined by 76%, those from natural gas by 17%, and those from oil by 10%.

Figure 3.3 Energy-related CO_2 emissions by fuel, 1973-2017



Total CO_2 emissions have dropped by 31% in ten years due to the sharp decline of coal-related emissions that resulted from the switch from coal power to renewables.

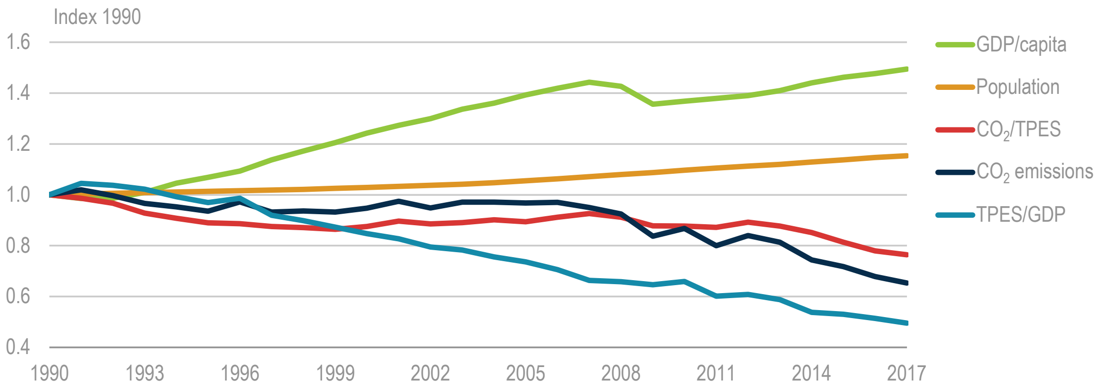
* Other includes emissions from peat and non-renewable waste combustion.

Source: IEA (2019a), *CO_2 Emissions from Fuel Combustion 2019*, www.iea.org/statistics/.

CO_2 drivers and carbon intensity

The United Kingdom has decoupled its economic growth from CO_2 emissions. From 1990 to 2017, the country's gross domestic product (GDP) per capita grew by 49%, while energy-related CO_2 emissions fell by 35% (Figure 3.4).

Figure 3.4 Energy-related CO_2 emissions and main drivers, 1990-2017



The United Kingdom's CO_2 emissions and TPES have fallen despite strong economic growth.

Notes: Real GDP in USD 2010 prices and purchase power parity (PPP).

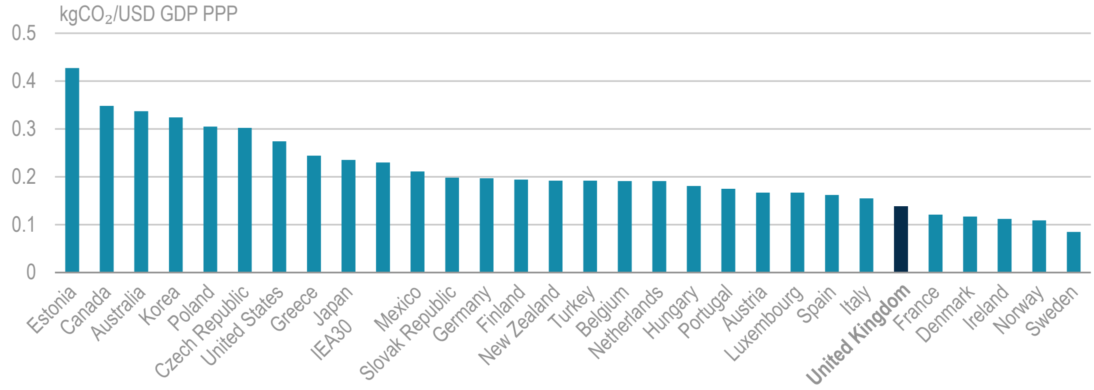
Source: IEA (2019a), *CO_2 Emissions from Fuel Combustion 2019*, www.iea.org/statistics/.

Emissions reductions were driven by the reduced carbon intensity of the energy supply (CO_2/TPES) as well as by a significant decline in the energy intensity of the economy (TPES/GDP). Carbon intensity, measured as the ratio of emissions per unit of GDP, was 0.14 kilogrammes of carbon dioxide ($kgCO_2$) per United States Dollar (USD)[1] in 2017, a decline by 38% from 2007, which places the United Kingdom sixth-lowest among the International Energy Agency (IEA) countries, almost twice as low as the IEA average (Figure 3.5).

The CO_2 intensity in power and heat generation has rapidly decreased in recent years, compared to that of neighbouring countries, to 248 grammes of carbon dioxide per kilowatt-hour (gCO_2/kWh), a 51% decline since 2007. Although this trend is consistent with that of other IEA member countries, the decline was more rapid in the United Kingdom after 2012.

[1] USD in 2010 real values and PPP.

Figure 3.5 CO_2 intensity in IEA member countries, 2017

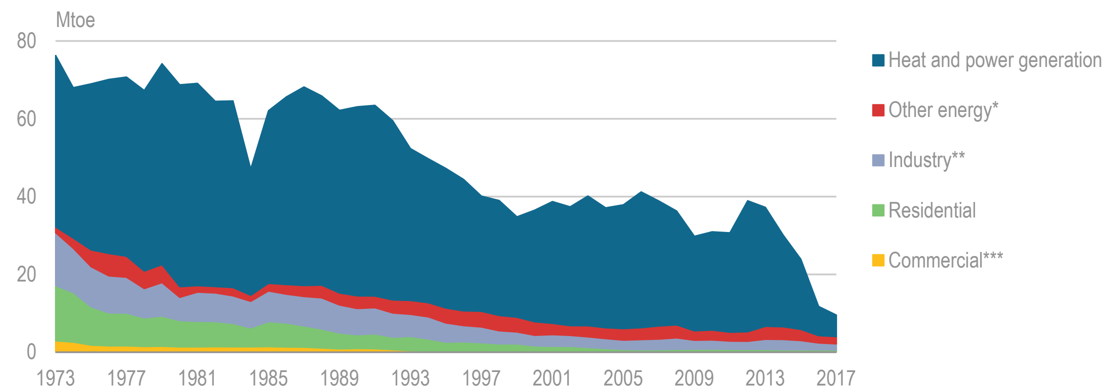


United Kingdom has the seventh-lowest CO_2 intensity among IEA countries.

Source: IEA (2019a), *CO_2 Emissions from Fuel Combustion 2019*, www.iea.org/statistics/.

Emission reductions were achieved mainly thanks to the decreasing use of coal in power generation (Figure 3.6). In 2017, coal made up 5.5% of the TPES and 7% of electricity generation. Coal use in heat and power generation fell by 83.9% between 2007 and 2011 and by 35% in industry (despite a rebound in 2012 because of higher gas prices), thanks to the strong increase of renewables and the strengthened UK carbon price floor (CPF). Several coal-fired power plants closed (Rugeley, Ferrybridge, and Longannet in 2016), several were supposed to close in 2018 (Kilroot will run as a back-up plant until 2019 and Eggborough closed in September 2018), and others are currently being converted to biomass and waste (Uskmouth and Lynemouth). This also includes the conversion of the third unit at Drax power station from coal to high-range co-firing (85% to <100% biomass) in 2015. Coal use in the residential sector fell from 43% in 1973 to just over 1% in 2017, but still 0.5 Mt were consumed in that sector, including in UK homes.

Figure 3.6 Coal consumption by sector, 1973-2017



Coal is mostly used in power generation, but the share of coal has declined rapidly since 2012 as a result of the strong UK CPF.

* Other energy includes consumption in coke ovens, blast furnaces, and energy industry losses.

** Industry includes non-energy consumption.

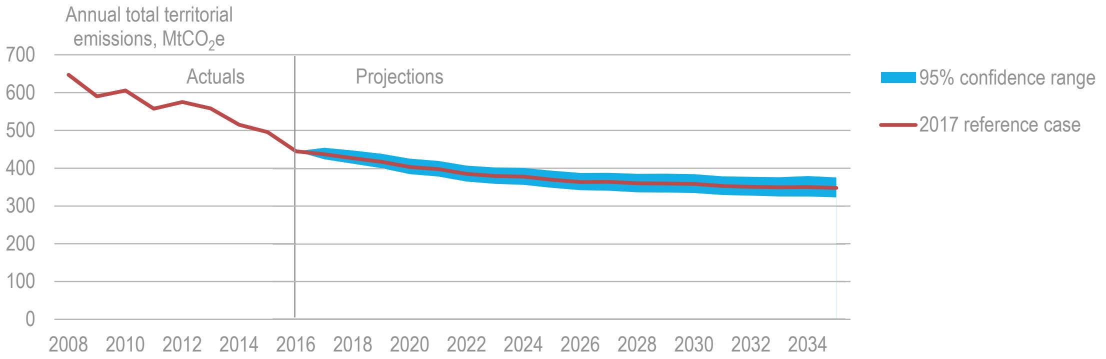
*** Commercial includes commercial and public services, agriculture, and forestry.

Source: IEA (2019b), *World Energy Balances 2019 First edition (database)*, www.iea.org/statistics/.

Projections

The 2017 energy and emissions projections of the United Kingdom show that overall emissions by 2030 are projected to be 50% below 1990 levels in the reference case, which considers implemented, adopted, and agreed policies (UK Government, 2018b). However, as demonstrated in Figure 3.7, these projections are highly uncertain because societal/behavioural trends, breakthrough technologies or other factors could have profound impacts on the energy mix and emissions, but are impossible to fully predict.

Figure 3.7 Uncertainty in projected territorial emissions

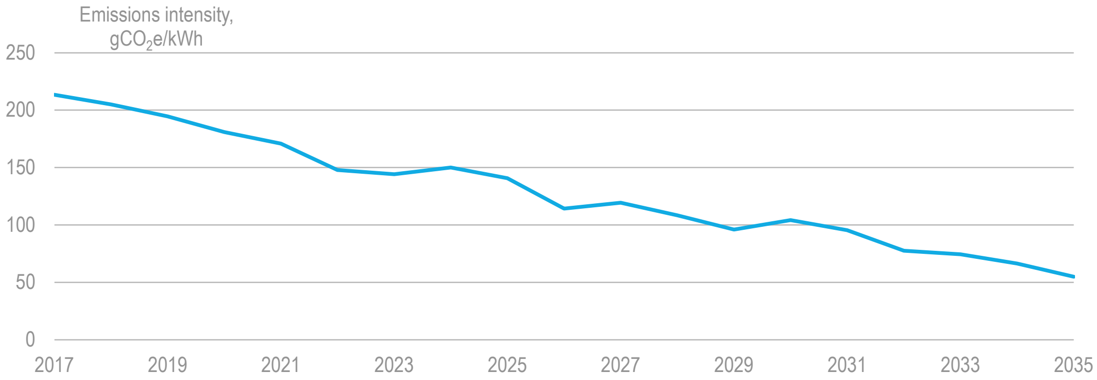


Emissions are projected to decline to around 350 $MtCO_2e$ by 2035.

Source: UK Government (2018b) *Updated Energy and Emissions Projections 2017*, www.gov.uk/government/publications/updated-energy-and-emissions-projections-2017.

The UK government expects emissions in electricity generation to decline steadily (Figure 3.8) with the closure of coal plants, the growth in renewables in the power mix, and eventually thanks to new nuclear generation in the 2030s (with several plants expected under these projections). Increased imports (via interconnectors) are projected until new nuclear capacity comes online. Consequently, emissions from electricity production are projected to fall steadily over the full period to 2035 (BEIS, 2018).

Figure 3.8 CO_2 emissions intensity from electricity supply forecast, 2017-35



The CO_2 intensity of power generation is projected to fall rapidly from over 200 gCO_2e/kWh in 2017 to around 50 gCO_2e/kWh by 2035, which will contribute to overall emission reductions.

Source: BEIS (2018), *Updated Energy and Emissions Projections 2017*, www.gov.uk/government/publications/updated-energy-and-emissions-projections-2017.

Given the cancellation of new nuclear projects in the UK in 2018-19, however, the role of nuclear will decline and the importance of imports increase. However, uncertainty over the future regime of interconnectors in a Brexit scenario might undermine investments and efficient operation of interconnectors and increase the price of power imports, as explained in the Chapter on Electricty.

Institutions

The **Department for Business, Energy and Industrial Strategy (BEIS)** is responsible, among other issues, for national energy and climate policies and to promote international action to address climate change. BEIS was created in July 2016 as a result of a merger between the former Department of Energy and Climate Change and Department for Business, Innovation and Skills. The **Department for Environment, Food and Rural Affairs (Defra)** is in charge of environmental policy and regulations, which include those for air quality, waste, water, and domestic adaptation. Defra works with BEIS to ensure specific government policies on low-carbon energy and decarbonisation measures are sustainable and aligned with Defra's environmental objectives. The **Office for Low Emission Vehicles (OLEV)** is a joint unit between BEIS and the **Department for Transport** that supports the early market for ultra-low emission vehicles (ULEVs).

Established under the UK Climate Change Act 2008, the **Committee on Climate Change** (CCC) is an independent advisory body with the task to advise the government and devolved administrations on emissions targets, to monitor and report to the parliament on meeting emissions targets and carbon budgets, and to conduct independent analysis into climate change science, economics, and policy. The CCC comprises a chairperson and eight independent members. The CCC is jointly sponsored by BEIS, the Northern Ireland Executive, the Scottish government, and the Welsh government. The CCC includes the Adaptation Sub-Committee (ASC), also established under the Climate Change Act 2008, to advice the CCC and report on the progress in adaptation. Its work is led by a chairperson, who also sits on the CCC, and six expert members. It is jointly sponsored by Defra, the Northern Ireland Executive, the Scottish government, and the Welsh government.

The **Natural Capital Committee (NCC)** is an independent advisory committee that provides advice to the government on the sustainable use of natural resources, i.e. forests, rivers, land, minerals, and oceans. The NCC's remit also includes air quality, clean water, and hazard protection.

Established by the Cabinet Office, the **National Infrastructure Resilience Council** brings together utility companies to share information about the locations of their assets and to take a coordinated approach to flood resilience.

Climate change mitigation

Emissions targets

The United Kingdom's Climate Change Act, adopted in 2008, established the United Kingdom's very ambitious legally binding target to reduce GHG emissions by at least 80% by 2050 on 1990 levels. This target is more ambitious than the target of the

European Union and its member countries of at least a 40% domestic reduction in GHG emissions by 2030 compared to 1990. The UK government recently sought the advice of the Committee on Climate Change on the implications of the Paris Agreement for the UK's long-term emissions target, including on setting a net zero target. Their advice was published on 2 May 2019 and recommended that the UK government set a net zero greenhouse gas target for 2050 (CCC, 2019a).

To achieve the long-term national target, the government is obliged to set legally binding five-year caps on emissions – "carbon budgets" – 12 years in advance and then to publish a report with policies and measures to meet that budget and the previous ones. The first carbon budget covered the period 2008-12. Budget levels are set for four further periods: 2013-17 inclusive, 2018-22, 2023-27, and 2028-32. In July 2016, the government set the fifth carbon budget (2028-32) at a level of 1 725 $MtCO_2e$, equivalent to an average 57% reduction on the 1990 emissions.

The CCC advises the government and the Devolved Administrations on setting and meeting carbon budgets. The United Kingdom's performance against its 2050 target and carbon budgets is assessed through the United Kingdom's net carbon account, measured in tonnes of carbon dioxide-equivalent. The United Kingdom met the first carbon budget with headroom of 36 $MtCO_2e$ and met its second carbon budget with a headroom of 384 $MtCO_2e$. It is projected to meet the third carbon budgets (CCC, 2019b). To meet the fourth and fifth carbon budgets, additional measures will be needed, as discussed below.

Although covered by the Climate Change Act, Scotland, Wales, and Northern Ireland have separate climate change policies.

In Scotland, the Climate Change (Scotland) Act 2009 commits Scotland to a 42% reduction in emissions by 2020 from 1990 levels and annual reductions between 2010 and 2050. The Scottish government introduced a more ambitious Climate Change Plan and the related Climate Change Act in 2018, which increased the target for the reduction of GHG emissions from 80% by 2050 to 90% and have recently pledged to set a net zero target by 2045, in line with the recommendation of the CCC. At the same time, Scotland will produce a second Scottish Climate Change Adaptation Programme to update the first programme of 2014.

Wales passed the Environment (Wales) Act in 2016, which provides for the setting of GHG emission reduction targets to 2050, including at least an 80% reduction (compared with 1990 levels) in 2050, and five-yearly carbon budgets. The first two carbon budgets (from 2016 to 2020 and 2021 to 2025) were set in December 2018.

The Northern Ireland Executive, in its Programme for government (2011-15), has set a target to continue to work towards reducing its GHG emissions by at least 35% (compared with 1990 levels) by 2025.

Clean Growth Strategy

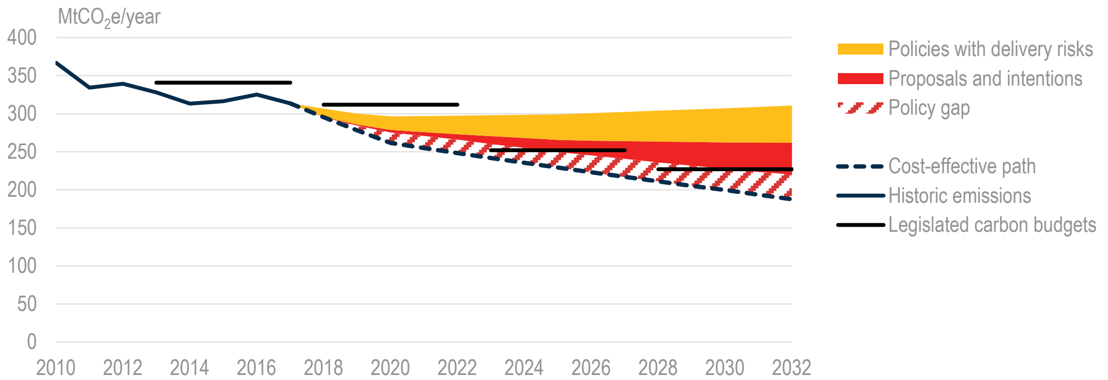
The UK Clean Growth Strategy sets out proposals to meet the fourth and fifth carbon budgets, while maintaining economic growth and affordability for consumers (UK Government, 2017a). Under the fifth carbon budget (2028-32), the United Kingdom aims at a reduction of 57% on 1990 levels. The government estimates that the combination of existing policies and new measures outlined in this Strategy could deliver over 90% of the required level of emissions savings for the fifth carbon budget, against the 1990 baseline. The carbon budgets do not provide for sectoral targets and are designed to encourage technology neutrality and emission reductions across the economy. However, the Clean Growth Strategy does set out polices by sector with subsectoral goals and objectives, contributing to an illustrative pathway for each sector.

The key challenges identified by the government in meeting these targets relate to 1) decarbonising beyond the power sector (transport, heat, and industry), 2) delivering affordable energy, and 3) establishing a post-Brexit framework (Box 3.1).

When assessing the Clean Growth Strategy, the CCC found a risk to the delivery of existing policies because of insufficient funding and judges the emission reductions from new proposals and intentions in the Clean Growth Strategy to bear a high risk. The CCC also identified a policy gap (CCC, 2018a), in which the existing potential for cost-effective emissions reduction policy has not been explored. Such a cost-effective path as defined by the CCC actually outperforms the carbon budgets. The whole gap would not need to be filled to meet the legislated fourth and fifth budgets. As such, it provides room for manoeuvre or a contingency to meeting longer-term targets.

The CCC concludes that the United Kingdom should significantly reduce the risks of underdelivery of existing policies, notably in car fuel efficiency, carbon capture, usage and storage, and nuclear generation, and bring forward new fully funded policies. The CCC urges the government to put in place contingency plans in case major infrastructure projects are delayed or cancelled. It also recommends introducing new policies and measures to address the sectoral imbalance in emissions reductions, as well as to make better use of low-cost opportunities to reduce emissions (often in areas of proven technology and established markets, such as onshore wind, renovation, and energy efficiency) (CCC, 2018b).

Figure 3.9 Gaps and risks to meet the fourth and fifth carbon budgets



Despite projected reductions in emissions compared to a baseline, there remains a gap towards the cost-effective emissions reduction path that needs to be covered with new policy.

Notes: The figure includes only emissions in the 'non-traded' sector (i.e. sources of emissions not covered by the EU ETS), as it is these emissions that determine whether or not a carbon budget is met.

Source: CCC (2018b), *Reducing UK emissions 2018: Progress Report to Parliament*, June, London, https://www.theccc.org.uk/wp-content/uploads/2018/06/CCC-2018-Progress-Report-to-Parliament.pdf

Box 3.1 Climate Change Committee's recommendations at a glance

Support the simple, low-cost options

Low-cost, low-risk options to reduce emissions are not being supported by government. This penalises the consumer. There is no route to market for cheap onshore wind; withdrawal of incentives has cut home insulation installations to 5% of their 2012 level; woodland creation falls short of stated government ambition in every part of the United Kingdom. Worries over the short-term cost of these options are misguided. The whole-economy cost of meeting the legally binding targets will be higher without cost-effective measures in every sector.

Commit to effective regulation and strict enforcement

Tougher long-term standards, for construction and vehicle emissions for example, can cut emissions, while driving consumer demand, innovation, and cost reduction. Providing long line of sight to new regulation also reduces the overall economic costs of compliance. Regulations must also be enforced to be effective: the consumer is cheated when their car's fuel consumption and real emissions exceed the quoted test-cycle numbers; or when high energy bills are locked-in for generations when stated building standards are not enforced.

End the chopping and changing of policy

A number of important programmes have been cancelled in recent years at short notice, including Zero Carbon Homes and the CCS Commercialisation Programme. This has led to uncertainty, which carries a real cost. A consistent policy environment keeps investor risk low, reduces the cost of capital, provides clear signals to the consumer and gives businesses the confidence to build UK-based supply chains.

Act now to keep long-term options open

An 80% reduction in emissions has always implied the need for new national infrastructure – to transport and store CO_2 for example, or to provide decarbonised heat. The deep emissions reductions implied by the Paris Agreement make these developments even more important. It is hard to define the 2050 systems for carbon capture, zero-carbon transport, hydrogen or electrification of heat, but the government must now demonstrate it is serious about their future deployment. Key technologies should be pulled through to bring down costs and support the growth of the low-carbon goods and services sector.

Source: CCC (2018a) *An Independent Assessment of the UK's Clean Growth Strategy: From Ambition to Action*, Londonhttps://www.theccc.org.uk/wp-content/uploads/2018/01/CCC-Independent-Assessment-of-UKs-Clean-Growth-Strategy-2018.pdf.

In its progress report of 2018, the CCC concluded that the United Kingdom is not on track to meet its legally binding fourth and fifth carbon budgets (delivery gap). The CCC also asked the government make use of all low-cost options available (policy gap), to commit to an effective and stable regulation and strict enforcement, and to act now to keep all the long-term technology options open.

In 2018, the UK government asked the CCC for advice on how to increase its domestic climate change ambition, in the light of IPCC Special Report on Global Warming of 1.5 degree Celsius (IPCC, 2018).

The EU Emissions Trading System

The emissions from the UK energy sector, heavy industry, and aviation – which collectively account for around 40% of the UK emissions under carbon budgets – have been regulated under the EU ETS. The installations covered by the EU ETS can either reduce their emissions where they consider it most cost-effective or buy allowances from other companies to offset their emissions. The future of the United Kingdom's carbon pricing policy will depend on the situation of the carbon market after the end of coal use in the power sector and the Brexit arrangements. The United Kingdom has several national carbon policies and also aims to maintain ambitious carbon policies in the future (Box 3.2).

Low-carbon electricity support schemes

The United Kingdom introduced a suite of national policies – to incentivise investment in low-carbon electricity generation, as a complement to EU-wide rules (EU ETS, the Large Combustion Plant Directive, and the Industrial Emissions Directive).

In 2013, the UK Electricity Market Reform introduced several mechanisms, such as: 1) the Carbon Price Support (CPS) rate, which supplements the EU ETS by increasing the cost of emitting CO_2, 2) an emissions performance standard on new fossil fuel capacity, and 3) contracts for difference (CFD) for low-carbon power generation. The United Kingdom has feed-in tariffs for small-scale renewable energy power, and a renewable heat incentive.

Climate Change Levy

The CCL was introduced in 2001 and is levied on the supply of energy to business and public sector consumers (not households, charities, and most small businesses). Each of the four taxable commodities (electricity, gas, coal, and liquefied petroleum gas) has its own main rate per unit of energy. For energy-intensive sectors, there is a discount scheme for the Climate Change Agreement (CCA). Companies can enter into these voluntary agreements to meet negotiated energy efficiency targets and obtain a discount on the CCL. This relief currently provides a 90% discount on the levy on electricity and 65% on gas and other taxable fuels. Businesses with CCAs are also exempt from the Carbon Reduction Commitment Energy Efficiency Scheme, which is being phased out (Chapter 5). The CCA scheme covers 53 sectors, from primary industries through to manufacturing and services.

Coal phase-out

Together with Canada, the UK launched the "Powering Past Coal Alliance" at COP23 in 2017. In November 2017, the government presented for consultation its proposal to end unabated coal generation by 2025. In January 2018, the government published an updated impact assessment, announcing a new emissions intensity limit on coal generating units of 450 gCO_2/kWh. The government is considering the appropriate legislation to introduce the emissions intensity limit for the period as of 1 October 2025, which will ban the construction of new coal plants after the planned closure of the oldest coal plants by 2025.

Box 3.2 The UK climate policy and Brexit

The UK 7th National Communication to UNFCCC confirms the stability of the government's climate change commitment (UK Government, 2017b). "Leaving the EU will not change any of the UK's statutory commitments to reducing greenhouse gas emissions under the 2008 Climate Change Act. Detailed future policies will emerge as negotiations between the EU and the UK proceed, but whilst the UK is a member of the EU, existing rules and regulations still apply, and will continue to engage constructively on new and existing legislation. As highlighted in the government's Clean Growth Strategy, the UK remains committed to the Paris Agreement." (UK Government, 2017b).

The White Paper on the Future Relationship between the United Kingdom and the European Union (UK Government, 2018c) confirms the interest of the United Kingdom to maintain its strong national environment and climate ambitions and related policies, while supporting the alignment with the European Union through a common rulebook. "The UK recognises the UK's and the EU's shared interest in global action on climate change and the mutual benefits of a broad agreement on climate change co-operation. The UK's world leading climate ambitions are set out in domestic law and are more stretching than those that arise from its current obligations under EU law. The UK will maintain these high standards after withdrawal."

The government remains committed to reducing emissions in "traded" sectors (power, heat, etc.) and to ensuring that the future UK approach is "at least as ambitious as the existing scheme and provide a smooth transition for the relevant sectors" (UK Government, 2017b). At the end of October 2018, the government announced its intention to introduce a Carbon Emissions Tax of 16 GBP/tCO_2 in the event of a no-deal Brexit as part of contingency plans to replace the EU ETS. Combined with the CPF of GBP 18 per tonne of carbon dioxide (GBP/tCO_2), emissions would be taxed at a fixed rate of 34 GBP/tCO_2 in the United Kingdom in a no deal scenario. The EU ETS price signal has grown stronger during 2017/18, ahead of the entry into force of the Market Stability Reserve, and the EU ETS price reached EUR 25/tCO_2 at the end of 2018. In case of an agreement, the Political Declaration also suggested a possible linking a UK carbon pricing scheme to the EU ETS. In May 2019, the UK is consulting on the future of UK carbon pricing which sets out a preferred carbon price policy the development of a tax to replace ETS, in event of the UK leaving the EU. The UK government has the choice to set up its own carbon emissions trading system, linked to the EU ETS or other carbon markets (UK Government, 2019).

In the Clean Growth Strategy, the United Kingdom points to three EU mechanisms for driving emissions reductions outside of the EU ETS, e.g. new car and van CO_2 regulations, the EU fluorinated gas quotas, and the EU minimum energy efficiency standards. The United Kingdom is committed to an approach that is at least as ambitious as the current arrangements. The EU Exit White Paper confirms that the government seeks a harmonised approach with the European Union through a common rule book (UK Government, 2018c): "Certainty around a common rulebook would be necessary to reassure the United Kingdom and the European Union that goods in circulation in their respective markets meet the necessary regulatory requirements, removing the need to undertake regulatory checks at the border."

Energy efficiency

The United Kingdom has a number of measures to stimulate energy efficiency in different sectors, which include industry, buildings, and transport (Chapter on Energy Efficiency). Energy efficiency improvements result in GHG emissions reductions, in addition to economic, environmental, and other benefits. One of the recently introduced measures (July 2018) is an obligation on large companies to report their energy use, carbon dioxide emissions, and energy efficiency measures in their annual reports from April 2019.

A new streamlined energy and carbon reporting framework will come into force in April 2019. This will replace the Carbon Reduction Commitment Energy Efficiency Scheme and extend the scope of existing mandatory GHG reporting regulations from quoted companies to all large businesses. Companies will be required to report on the energy efficiency actions taken over the previous year.

Low-carbon technologies

Transport

The government has started several initiatives to decarbonise transport, which include commitments to end the sales of conventional cars and vans by 2040, and to have most cars and vans zero emission by 2050. The UK Act on Automated and Electric Vehicles is the legal basis and is underpinned by a programme to support electric vehicles (EVs) and several other initiatives to improve efficiency and encourage cleaner fuels across the transport sector. This is led by the Office for Low Emission Vehicles (OLEV) as a joint unit of BEIS and the Department for Transport. A competitive EV industry has developed in the United Kingdom; reportedly, one in every five electric cars sold in Europe in 2018 was made in the United Kingdom.[2] Based on the 2017 Clean Growth Strategy, the United Kingdom is working on a range of measures to:

- End the sale of conventional cars and vans by 2040.
- Continue incentives to purchase zero tailpipe emissions vehicles (ZEVs) and ultra-low emission vehicles (ULEVs) over conventionally fuelled cars.
- Invest an additional GBP 80 million, alongside GBP 15 million from Highways England, to support a charging infrastructure deployment.
- Double supply of sustainable biofuels under the Renewable Transport Fuel Obligation (RTFO) by 2020 and implement indicative targets under a long-term strategy for renewable fuels to 2032, as set out in 2017 RTFO amendments.
- Accelerate the uptake of low-emission taxis and buses.
- Foster energy efficiency in both the maritime and aviation sectors.
- Support the development of automated vehicle and EV technologies and EV charging infrastructure, based on the Automated and Electric Vehicles Act of 2018.
- Plan to remove all diesel-only trains from the UK railway network by 2040.
- Work with industry as they develop an automotive sector deal to accelerate the transition to ZEVs.

[2] www.eafo.eu/vehicles-and-fleet/m1.

- Announce plans for the public sector to lead the way in transitioning to ZEVs.
- Position the United Kingdom at the forefront of research, development, and demonstration (RD&D) of connected and autonomous vehicle technologies, which includes through the establishment of a centre for connected and autonomous vehicles and an investment of over GBP 250 million, matched by industry.

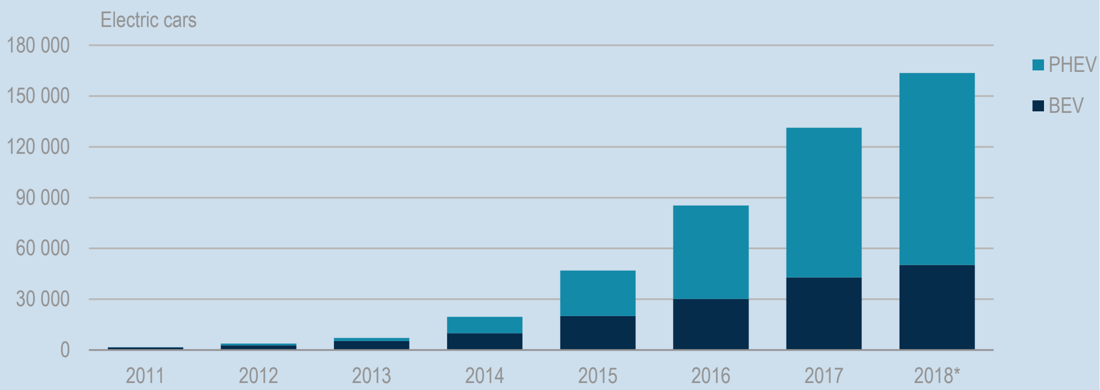
In 2018, the government published the Road to Zero Strategy (UK Government, 2018d), which sets out further measures to support the uptake of zero and low-emission vehicles. This included the ambition to see at least 50%, and as many as 70%, of new car sales being ultra-low emission by 2030 and ending the sale of new conventional petrol and diesel cars and vans by 2040 to ensure almost every car and van is zero emission by 2050. The government is committed financially to support the decarbonisation of transport through a range of financial commitments across government. OLEV provides subsidies for the installation of charging at home, at work, or on-street residential areas. The Go Ultra Low campaign, co-funded with industry to the magnitude of GBP 2 million in 2017/18, provides motorists with information on the benefits of making the switch to ULEVs.

Box 3.3 EV market development

A recent development in the transport sector has been the growth in EVs. As of May 2018, the United Kingdom had a total fleet of around 164 000 electric passenger cars, of which one-third were pure battery electric vehicles (BEVs) and two-thirds was plug-in hybrid electric vehicles (PHEVs) (EAFO, 2018).

EVs accounted for around 2.4% of new car sales in the United Kingdom in 2018 (EAFO, 2019). This share has increased rapidly, but EVs still account for only a minor share of the total vehicle fleet and energy consumption in transport. The United Kingdom has the largest fast-charging infrastructure network in Europe and Highways England has an ambition for motorists to be no further than 20 miles from a charger on 95% of the strategic road network.

Figure 3.10 Passenger EV fleet, 2011-18



EV sales have increased rapidly in the United Kingdom in recent years and accounted for around 2% of new cars in 2017.

* As of 15 May 2018.

Source: EAFO (2018), *United Kingdom*, www.eafo.eu/countries/united-kingdom/1758/summary.

Industry

The UK offshore geology presents excellent opportunities for CO_2 storage, which is well documented in the United Kingdom's online CO_2 storage appraisal database, with over 500 potential CO_2 storage sites around the offshore United Kingdom.[3] The United Kingdom's storage potential is estimated to be around 78 000 million tonnes (ETI, Pale Blue Dot, Costain and Axis (2016). Most potential sites are located close to industrial clusters. There could be enough potential storage capacity to meet the United Kingdom's needs for CO_2 storage to 2050 and beyond, even in high carbon capture, usage, and storage (CCUS) deployment scenarios, as well as potential for the United Kingdom to service the needs of neighbouring countries (ETI, 2017). Although the United Kingdom has no operational large-scale CCUS projects, the Energy Technology Institute (ETI) concludes that based on the appraisal work to date, there are no technical barriers to the CO_2 storage offshore that would limit the CCUS industry developing at scale (ETI, 2017).The CCC estimates that the current absence of a CCUS strategy is one of the major gaps for meeting the 2050 target at least cost. The CCC calls for a new strategic approach to deploy carbon capture, utilisation and storage (CCUS) at scale in the 2030s, which will require a programme of CCS deployment across industry and energy generation (i.e. power and/or hydrogen) to reach 10 $MtCO_2$ stored per annum in 2030, on a path to at least 20 $MtCO_2$ per annum in 2035 (CCC, 2018b).

Since 2011 the government has invested over GBP 130 million and has committed GBP 100 million up to 2021 from BEIS's Energy Innovation Programme[4] to support industry and CCUS innovation and deployment in the United Kingdom. In 2018 another GBP 40 million were announced to support cost reductions. Chapter 7 discusses the RD&D initiatives related to CCUS.

After the cancellation of the CCS Demonstration Programme in 2011 and the CCS Commercialisation Programme in 2015, the government outlined its new approach to CCUS in the Clean Growth Strategy. It aims to ensure that the United Kingdom has the option to deploy CCUS at scale during the 2030s, subject to costs coming down sufficiently. To this end, the government set out actions under three themes: 1) Re-affirming our commitment to deploying CCUS in the United Kingdom subject to cost reduction, 2) R&D and innovation, and 3) international collaboration.

The government established a CCUS Council, co-chaired by the Minister of State for Energy and Clean Growth and Mr James Smith (formally Carbon Trust and Shell), with senior representatives from across the CCUS sector to review the progress and priorities on CCUS. It also established a CCUS Cost Challenge Taskforce of over 50 representatives from the CCUS sector to provide advice on the steps needed to reduce the cost of deploying CCUS in the United Kingdom. The Taskforce presented its report to the government in July 2018 in which it set out the industry's view on how best to progress CCUS in the United Kingdom.[5] Work has begun to review the delivery and investment models for CCUS in the United Kingdom, notably for ongoing initiatives in Teesside, Merseyside, and Humberside (besides the South Wales and Scottish cluster)

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[3] www.co2stored.co.uk.

[4] www.gov.uk/guidance/funding-for-low-carbon-industry.

[5] *Delivering Clean Growth: CCUS Cost Challenge Taskforce Report*, www.gov.uk/government/publications/delivering-clean-growth-ccus-cost-challenge-taskforce-report.

to test the potential for development of CCUS industrial decarbonisation clusters. In November 2018, the government published its CCUS Action Plan, which set out a new approach for industry and government to enable the development of the first CCUS facility in the UK, commissioning from the mid-2020s, to achieve the government's ambition to have the option to deploy CCUS at scale during the 2030s, subject to costs coming down sufficiently.

As for international collaboration, in May 2018, the United Kingdom took on leadership (with Saudi Arabia and Mexico) of the Carbon Capture Challenge under Mission Innovation and hosted in November 2018, together with the IEA, a high-level international CCUS Summit in Edinburgh.

Adaptation to climate change

Legal and institutional framework

The 2008 Climate Change Act includes a requirement to conduct a Climate Change Risk Assessment (CCRA) every five years, followed by a National Adaptation Programme that will address the risks identified in the CCRA. The ASC under the CCC is responsible for evaluating progress on the adaptation programme; it reports to the UK Parliament every two years.

The Climate Change Act also provides the government with the so-called "adaptation reporting power" to require public bodies and infrastructure operators to report on their actions to address the impacts of climate change. The energy sector companies – electricity transmission and distribution, gas transportation, and energy generators – are required to report on risks such as flooding, high river flows and bank erosion, high winds and lightning, storms and high waves (for offshore infrastructure), etc. The energy regulator, the Office of Gas and Electricity Markets (Ofgem), also reports on the risks from climate change relevant to its responsibilities.

BEIS works to increase cross-sector understanding of energy interdependencies as part of the resilience planning and risk management strategies. The Infrastructure, Resilience and Security Working Group under the National Security Council is tasked to produce a tested methodology by which the government can identify cross-sector interdependencies. The group has reviewed several models and is working to clarify some of the issues identified, such as the high level of data input required by the models and security challenges (Defra, 2018b).

Evaluation of impacts and risks

The second CCRA, prepared by the ASC/CCC in 2017 after a request from the government, identified significant risks to the infrastructure (including the energy infrastructure) from flooding, rising sea levels, and increases in the frequency and severity of extreme weather. This resulted in the second National Adaptation Programme (NAP). According to the CCRA 2017 (CCC, 2017):

- Networks near rivers will become more vulnerable to higher flows and, along with coastal infrastructure, could become impacted by greater levels of erosion. Increases in maximum wind speeds would have significant implications for many infrastructure networks. Changes in temperature and rainfall will place additional pressures on infrastructure across all sectors. Climate change combined with population growth may also put greater pressure on water availability and increase risk of drought. Interdependencies, where infrastructure providers rely on each other in order to provide their services, are not well understood. It is important to build a clearer picture of what the risks are and how these are mitigated.

- In the power sector, it is estimated that 550 of 589 significant substations are currently at risk and will become resilient to floods with permanent defences in place by 2021 under current plans. All sites where defences are not yet built have been surveyed for their suitability for temporary defences.
- The CCRA also identified high winds as a significant cause of disruption to overhead electricity lines because of falling trees and branches that can damage the infrastructure. CCRA highlighted the need for a better understanding of the implications of increased vegetation growth rates on future risks of damage from falling trees during storms.
- In the gas sector, there is an inherent resilience of the gas networks because most of them are located underground. There could be an impact on some key above-ground assets, however these are unlikely to lead to supply disruptions. However, natural gas plays a major role in electricity supply, in 2017 amounting to 40%, which will require the closer integration and coordination of extreme weather events (winter peak demand for both gas and electricity).

The CCRA recommended further research to understand climate risks to existing and planned offshore renewable energy infrastructure.

Response measures

Taking into account the risks identified in the CCRA-2017, the government developed the second NAP published in July 2018 (UK Government, 2018e), which sets out the actions that the government and other actors are taking, the expected outcomes, and the means for measuring the progress made towards achieving the objectives.

According to the second NAP, both electricity and gas sector companies well understand the risks posed by climate change and take appropriate adaptation measures. BEIS collaborates with other departments to enhance cross-sector understanding of the interdependencies between different networks as part of the resilience planning and risk management strategies.

- In power transmission and distribution, electricity network companies spent GBP 130 million on flood defence work from 2010 to 2015 and will spend another GBP 100 million before 2021. Electricity network companies finance the activities to manage water flooding through the regulated tariffs. The current substation flood protection guidance is being strengthened further in line with National Flood Resilience Review recommendations. BEIS monitors the implementation of the adaptation programmes by network companies to ensure progress across the sector. As regards the possible risks related to falling trees during storms, the government does not currently list this issue among research priorities in view of the maturity of the electricity sectors' programmes to manage vegetation growth.
- In the gas sector, river and coastal erosion continues to be monitored around infrastructure that is recognised to be at risk, and investment strategies are implemented where needed. As regards the downstream oil sector, BEIS is examining the benefits of further investigation into climate change adaptation and will discuss this with the relevant stakeholders.

- The Office of Nuclear Regulation inspects licensees' safety submissions throughout the lifecycle of nuclear reactors and other installations. The submissions must reflect internal and external hazards, which include the reasonably foreseeable effects of climate change over the lifetime of the facility as well as other factors such as coastal erosion, extreme weather, and flooding.
- The applicants for authorisations for new offshore renewable energy plants are required to consider the potential impacts of climate change using the latest UK Climate Projections to ensure they have identified appropriate mitigation or adaptation measures.

Assessment

The United Kingdom is a global leader in climate change, as it both recognises the climate change threats and adopts policies to tackle the low-carbon investment challenge. The United Kingdom has a legally binding target, set by the 2008 Climate Change Act, to reduce GHG emissions by at least 80% by 2050 on 1990 levels and a world-class framework to achieve this target – via setting legally binding five-year caps on emissions ("carbon budgets"). This has served as an example to follow across the world.

The CPS rate has supported the switch from coal to gas and renewables in power generation. The government is providing longer-term certainty around strong carbon pricing. It decided to freeze the CPS rate until 2021 at the current level of GBP 18 and in October 2018 announced a carbon tax of 16 GBP/tCO_2 in the event of a no-deal Brexit, as part of contingency plans to replace the EU ETS. Combined, emissions would be taxed at a fixed rate of 34 GBP/tCO_2 in the United Kingdom.

The CFD and other support schemes have boosted investment in renewable energy and are a promising model to support nuclear generation. With major falls in the costs of renewable energy technologies, it has also led to a major growth in renewables. As a result of these developments, the United Kingdom has effectively decoupled GHG emissions from economic growth (except for transport).

The government is also to be praised for having met the 1st and 2nd carbon budgets and being on track to meet the 3rd budgets. The Clean Growth Strategy**,** adopted in October 2017, outlines proposals and measures across the economy to meet the 4th and the 5th carbon budgets, and identifies areas in which further actions will be needed. The devolved administrations of Northern Ireland, Scotland, and Wales have also adopted ambitious policies and strategies to combat climate change, which will contribute to meeting the country's target.

The Clean Growth Strategy rightly focuses on several key areas in which large emissions reductions are possible, including several "difficult to reach" sectors. The IEA particularly supports the government's ambitions as regards decarbonising heat, accelerating the shift to low-carbon transport, and enhancing the energy efficiency of homes and businesses. The IEA also applauds the Clean Growth Strategy's ambitious proposals to fund innovation.

Nevertheless, according to the assessment by the CCC, an independent advisory body, many of the proposed measures have delivery risks, and many more have not been fully confirmed yet. Since this assessment, the United Kingdom launched its CCUS Action

Plan in November 2018. However, specific policies and measures in several key areas – heat and transport – are still under development, and some of the ongoing initiatives may be delayed. Therefore, there is some uncertainty as to whether the 4th and 5th carbon budgets will be met. The IEA urges the government to continue to translate the Clean Growth Strategy into firmer plans, funded measures, laws, and regulations to close the gap between the ambitious targets and the reductions likely to be achieved with the existing policies for heat and transport.

The carbon intensity of the power sector has strongly declined, thanks to the switch from coal to gas and renewables. Coal, once the mainstay of the UK energy supply, now supplies only about 7% of electricity generation. Between 2012 and 2017, the total coal consumption fell by over three-quarters, which was only 6% of the TPES in 2017. The CPF policy was a successful policy to reduce coal-fired generation, which, as a result became uneconomic relative to natural gas and renewables support. As part of the international "Powering Past Coal Alliance", the government announced its policy to eliminate coal-fired generation without CO_2 abatement by 1 October 2025. It is expected that most of the remaining 10 gigawatts of coal capacity will close well before that date. In January 2018, the government presented its response on "implementing the end of unabated coal by 2025". The response sets out the government policy to limit the CO_2 emissions intensity of a coal-fired power plant to less than 450 grammes per kilowatt hour, effective as of 1 October 2025. The government still needs to introduce the legislation to provide legal force to this policy.

The heat sector has a largely untapped decarbonisation potential. Coal and other solid fuels are still used in around 170 000 homes in the United Kingdom. In March 2018, the government presented detailed plans for the decarbonisation of the heating sector, notably plans to halt the installation of oil and coal heating systems from 2020 onwards in new constructed homes. Although there is uncertainty about the heat technology options in the long term, some measures can be taken today to reduce the heat sector's carbon footprint. These include energy efficiency improvements in both existing and new buildings, and the encouragement of renewable heating and heat pumps in the buildings not connected to natural gas.

Reducing emissions from the transport sector is particularly challenging in all IEA countries, including in the United Kingdom where transport is the largest consumer of energy and the largest GHG emitter. The United Kingdom has made commendable commitments to phase out new conventional car and van sales by 2040, to have most cars and vans with zero emission by 2050, and has started an impressive programme to support EVs. The Clean Growth Strategy includes several other initiatives to improve efficiency and encourages cleaner fuels across the transport sector. In transport, the government published the Road to Zero Strategy in July 2018 with ambitious EV targets and commitments to support the infrastructure roll-out. The United Kingdom also hosted an international summit on ZEVs to encourage progress internationally. The government is encouraged to speed up the implementation of these initiatives.

CCUS has a clear position in the Clean Growth Strategy, as it could support decarbonisation, economic development, and future trade opportunities. The IEA welcomes the government's ambition to deploy CCUS in the United Kingdom, subject to cost reduction, and the commitment to collaborate internationally and to invest in CCUS R&D. The United Kingdom is very active in R&D both nationally and in international CCUS pilot projects, including through its international CCUS Programme under the

International Climate Fund and by hosting an international CCUS Summit in November 2018. The United Kingdom has mapped the CO_2 storage potential of sites in the North and Irish Seas that appear particularly promising. The IEA calls upon the government to present a timely proposition for CCUS, based on advice from the CCUS Council, the CCUS Cost Challenge Taskforce, and international collaboration. This new CCUS proposition should clearly state the government's vision for CCUS and the steps that need to be taken to realise its ambitions.

The government's objective to cut emissions while ensuring the continuous competitiveness of the United Kingdom's economy or avoiding excessive burden on households is commendable. Many measures – such as energy efficiency improvements and increased use of matured renewables technologies, such as onshore wind – can be cost-efficient and reduce cost to consumers. The IEA supports the government's efforts to meet the climate targets through a cost-effective approach to boost decarbonisation. As low-carbon technologies evolve rapidly, it is important to evaluate regularly the relative costs and benefits of GHG mitigation measures and adjust the support frameworks, if needed, to stimulate the most cost-efficient solutions. An increased focus on cost-effectiveness is also one of the key recommendations of the CCC.

At the same time, the magnitude of the decarbonisation challenge and the significant investments needed to accelerate the transformation of the energy system still require government support. Support is needed to stimulate innovation and the development of new, breakthrough technologies, to reduce the costs and facilitate market deployment of existing immature technologies, and to raise awareness and change people's behaviour. Therefore, it is important to continue measures that will have a longer-term transformational effect, even though they have costs. Engaging citizens is vital to ensure the necessary support to tackle the decarbonisation challenges.

Although the UK carbon targets are very ambitious, they could be reviewed by further building on the stocktaking process of the Paris Agreement. Building on its success in driving the global climate change agenda, the United Kingdom is well positioned to lead the world towards ambitious global GHG reductions. The government is therefore encouraged to continue to lead best-practise sharing and international collaboration with other countries on energy sector transformation and clean growth.

Recommendations

The UK government should:

- ☐ Continue to translate the Clean Growth Strategy into laws, regulations, and funding to deliver the necessary emission reductions to meet the 4th and 5th carbon budgets.
- ☐ Continue to evaluate and improve the framework for the cost-efficiency of mitigation measures.
- ☐ Increase public awareness about the decarbonisation challenges, benefits, and cost implications.
- ☐ Identify further opportunities for international collaboration to support the global clean energy transformation towards ambitious global emissions reductions.

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4. Renewable energy

Key data

(2017)

Total supply*: 17.1 Mtoe (9.7% of TPES) and 99.3 TWh (29.6% electricity generation).

IEA average: 9.9% of TPES and 24.6% of electricity generation

Bioenergy and waste:** 12.4 Mtoe (7.1% of TPES) and 36.0 TWh (10.7% of electricity generation)

Solar: 1.0 Mtoe (0.6% of TPES) and 11.5 TWh (3.4% of electricity generation)

Wind: 4.3 Mtoe (2.4% of TPES) and 49.6 TWh (14.9% of electricity generation)

Hydro: 0.5 Mtoe (0.3% of TPES) and 5.9 TWh (1.8% of electricity generation)

*Not including non-renewable waste.

**Includes 1.2 Mtoe (4.2 TWh) of non-renewable municipal and industrial waste.

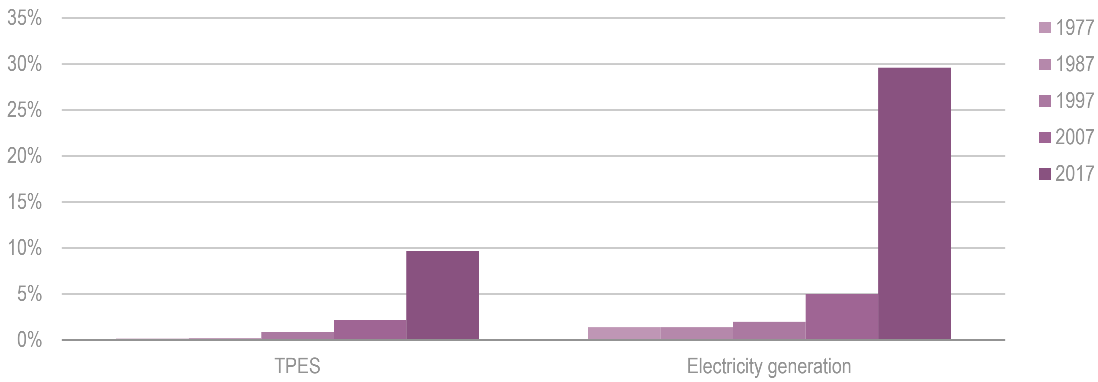
Overview

Over the past decade, the United Kingdom has achieved a remarkable growth in renewable energy, supported by different policy schemes. The United Kingdom is a market leader in offshore wind with an installed capacity of around 7.9 gigawatts (GW). The contracts for difference (CFD) auctions, which provide 15 year contracts to new renewable generation at a guaranteed strike price have resulted in strong cost reductions. In the 2017 CFD auction, the clearing price for offshore wind halved compared to the first auction in 2015 and secured 3.3 GW (UK Government, 2017a, 2017b). All these factors led to the development of a competitive renewable energy industry in the United Kingdom (see below Box 4.2). In November 2018, the total renewable electricity capacity in Great Britain (GB) from wind, solar, and biomass (42 GW) overtook the capacity of coal and gas generation (40.6 GW). Besides the outstanding growth in renewable electricity to reach 30% in 2017 from 5.5% in 2007, renewables progress in the heating and transport sectors has been more challenging to achieve under its EU 2020 target of 15% renewables in total energy consumption with 30% of electricity, 12% of heat, and 10% of transport. The United Kingdom aims to increase its renewable energy supply further, especially in heating and transport, under the Clean Growth Strategy (UK Government, 2017b). The innovative Renewable Heat Incentive (RHI) and the Renewable Transport Fuel Obligation (RTFO) have provided mixed results. A review of these policies for the horizon 2030/50 is recommended to foster the modernisation of the heating and transportation infrastructure to low-carbon technologies and fuels, as well as research, development, and demonstration (RD&D) projects.

Supply and demand

Renewable energy supply has increased significantly in the United Kingdom over the past decade. The share of renewable energy in the total primary energy supply (TPES) has grown from 2% in 2007 to 10% in 2017 and its share in electricity generation increased from 5% to 30% (Figure 4.1).

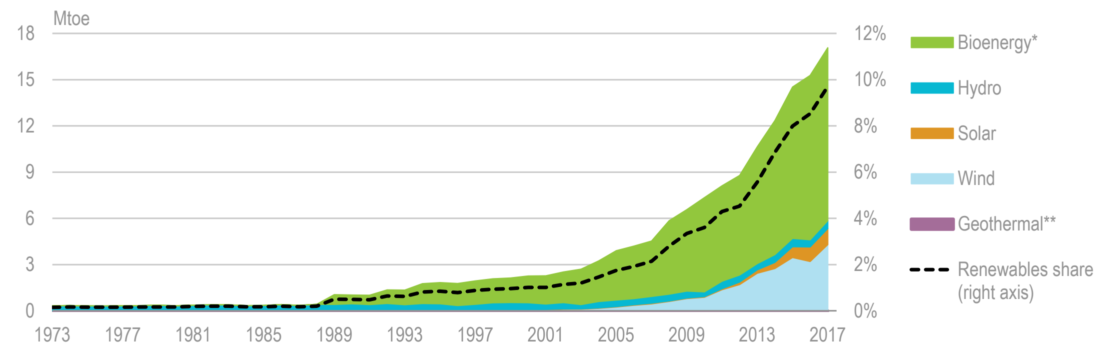
Figure 4.1 Share of renewable energy in TPES and electricity generation, 1977-2017



In the past decade, the United Kingdom has sharply increased the share of renewable energy in its primary energy supply and electricity generation.

Source: IEA (2019), *World Energy Balances 2019 First edition (database)*, www.iea.org/statistics/.

Figure 4.2 Renewable energy and waste in TPES, 1990-2017



Bioenergy and waste is the largest RES in the primary energy supply.

* Bioenergy includes primary solid biofuels, liquid biofuels, biogases and renewable municipal waste.

** Negligible.

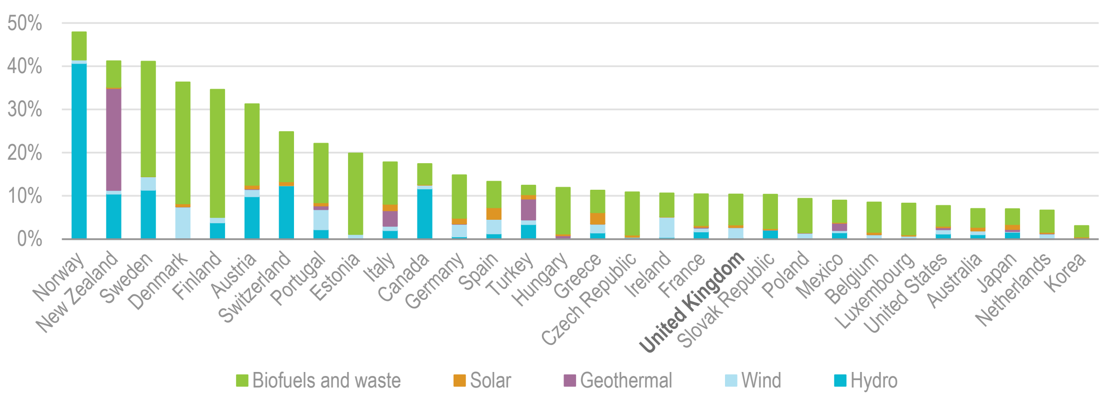
Source: IEA (2019), *World Energy Balances 2019 First edition (database)*, www.iea.org/statistics/.

Renewable energy in the TPES

In 2017, the supply of renewable energy in the United Kingdom was 17.1 million tonnes of oil-equivalent (Mtoe), 9.7% of the TPES. The share of renewable energy in the TPES has increased since the 1990s, mostly thanks to the rapid increase of bioenergy and waste supply; the growth has been particularly remarkable since 2009 (Figure 4.2).

Nevertheless, the United Kingdom has the eleventh lowest share of renewable energy in the TPES among the International Energy Agency (IEA) member countries (Figure 4.3). Bioenergy and waste was the largest source of renewable energy in TPES at 7.1% (including 1.2 Mtoe non-renewable waste). Bioenergy and waste includes primary solid biofuels (54%), biogas (22%), wastes (17%), and transport biofuels (7%) (Figure 4.4). Energy transformation accounts for nearly two-thirds of the biofuel and waste demand, followed by the residential and industry sectors. The second-largest renewable energy is wind, with 2.4% in the TPES in 2017.

Figure 4.3 Renewable energy and waste as a percentage of the TPES in IEA member countries, 2017

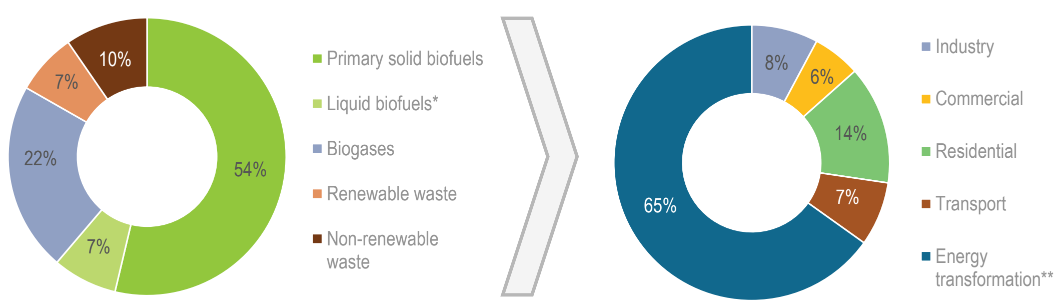


The United Kingdom has the eleventh lowest share of renewable energy in TPES among IEA member countries.

Note: Includes non-renewable waste.

Source: IEA (2019), *World Energy Balances 2019 First edition (database)*, www.iea.org/statistics/.

Figure 4.4 Bioenergy and waste supply by source and consuming sector, 2017



In 2017, primary solid biofuels accounted for over half of bioenergy and waste, and around two-thirds of bioenergy and waste were used in heat and power generation.

* Includes biodiesel and biogasoline, e.g. fuel ethanol.

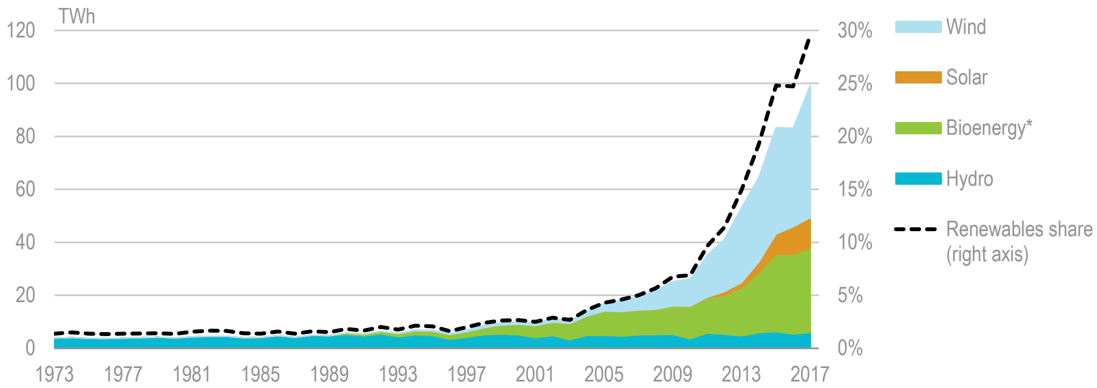
** Energy transformation is mainly electricity and heat generation from primary solid biofuels and wastes.

Source: IEA (2019), *World Energy Balances 2019 First edition (database)*, www.iea.org/statistics/.

Electricity from renewable energy

The share of renewable electricity has increased significantly. In 2018, the total installed capacity of variable renewable energy was 32.7 gigawatts (GW), of which 61% was wind and 39% solar photovoltaics (PV). In 2017, renewable energy generated 99 terrawatt hours (TWh), which accounted for 30% of the total electricity generation, up from 5% in 2007 (Figure 4.5). This places the United Kingdom at the median share of renewables in electricity generation among IEA countries (Figure 4.6).

Figure 4.5 Renewable energy and waste in electricity generation, 1990-2017

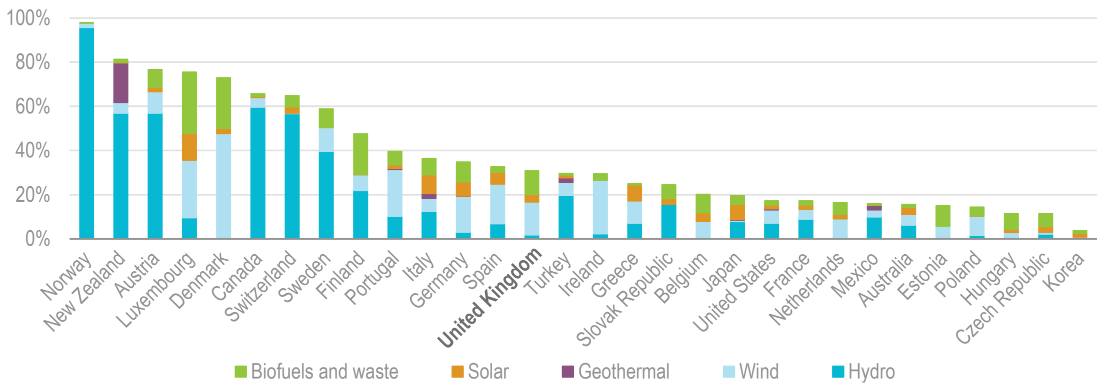


Renewable energies have shown considerable growth, particularly wind and bioenergy and waste, and accounted for 31% of the total electricity generation in 2017.

* Includes primary solid biofuels, liquid biofuels, biogases and renewable municipal waste.

Source: IEA (2019), *World Energy Balances 2019 First edition (database)*, www.iea.org/statistics/.

Figure 4.6 Renewable energy as a percentage of electricity generation in IEA member countries, 2017



The United Kingdom's share of renewable energy in electricity generation is around the median in the IEA.

Note: Includes non-renewable waste.

Source: IEA (2019), *World Energy Balances 2019 First edition (database)*, www.iea.org/statistics/.

Wind is the largest source of renewable electricity with 14.9% of the total electricity generation in 2017 and wind generation is expected to increase strongly until 2020 at an average annual growth rate of around 13%. The total wind power generation has increased from 5.3 TWh in 2007 to 50.0 TWh in 2017.

In 2018, the United Kingdom was the largest market for offshore wind energy in the world with an installed capacity of around 7.9 GW offshore, besides 12.2 GW of onshore wind capacity. Solar PV installations increased rapidly over the past seven years, with 99% of the United Kingdom's capacity being deployed since May 2010, driven by financial support for utility, commercial, and small-scale solar PV installations.

Heat from renewable energy

The United Kingdom has a low share of renewable heat, with 7.7% of heat consumption met by renewables in 2017 (UK Government, 2018i, Table 6.7). Most of the heat in buildings is supplied by individual gas (75%) or oil (8%) boilers (CCC, 2016). This reflects the housing stock (much of which is composed of low-density single-family dwellings), extensive gas networks, and low gas prices.

District heating networks are very limited and supply only about 2% of UK heat demand, primarily from natural gas boilers and small co-generation plants. Some small district heating schemes have recently deployed biomass boilers, e.g. the 29 megawatts (MW) Blackburn Meadows biomass-fuelled co-generation[1] plant.

In 2011 the government launched the RHI to bridge the gap between the cost of renewable and fossil fuel heating technologies. As of the end of August 2018, the United Kingdom had over 18 800 non-residential accredited renewable heat installations accredited on the scheme with a total capacity of 4 210 megawatt thermal (MW_{th}), which have been paid for generating 26 404 gigawatt hours (GWh) of heat since November 2011 (UK Government, 2018a). Over 63 500 residential installations accredited on the scheme have been paid for generating 2 942 GWh of heat since April 2014. Biomass boilers dominate, and heat pumps (in particular, air-source heat pumps [ASHPs]) also have a significant share in the residential sector (see "Policies and measures" below for more details).

Institutions

The **Department for Business, Energy and Industrial Strategy (BEIS)** is responsible, among other issues, for renewable energy policy. It oversees the effectiveness of the various mechanisms: the renewables obligation (RO), feed-in tariffs (FITs), CFDs, and the RHI. BEIS was created in July 2016 as a result of a merger between the Department of Energy and Climate Change and the Department for Business, Innovation and Skills.

The **Department for Transport** is responsible for the promotion of renewable energy use in transport through policies and measures such as the RTFO and the Greenhouse Gas Reporting Mechanism. The **Office for Low Emission Vehicles**, which promotes the uptake of ultra-low emission vehicles, is based in the department and is jointly run with BEIS.

The **Department for Environment, Food and Rural Affairs (Defra)** is responsible for policy and regulations on environmental, food, and rural issues, which include air quality, waste, water, and domestic adaptation strategies. Defra works with BEIS to ensure that

[1] *Co-generation* refers to the combined production of heat and power.

specific government policies on low-carbon energy and decarbonisation measures are sustainable and aligned with Defra's environmental objectives.

The **Low Carbon Contracts Company (LCCC)** is the government counterparty for CFDs. It manages CFDs with low-carbon generators throughout their lifetime, forecasts and settles CFD payments, and manages the Supplier Obligation Levy that funds CFD payments. LCCC is a private company under the ownership of BEIS.

National Grid (NG) is the system operator whose responsibilities include the system integration of variable renewable energy sources (RES), in coordination with 14 distribution network operators who are at the forefront of integrating a rising share of solar PV and batteries through innovative approaches.

The **Office of Gas and Electricity Markets (Ofgem)** is the National Regulatory Authority and administers various schemes, which include the RO, FITs, and guarantees of origin. It also oversees appeals for CFD allocation and capacity market rules, and grants licenses to operate new offshore transmission assets. Ofgem is governed by the Gas and Electricity Markets Authority and funded by annual licence fees paid by licenced companies.

Policies and measures

Targets and objectives

The EU Renewable Energy Directive (RED, 2009/28/EC) supported a renewable energy target of 20% to 2020 and provided for the United Kingdom to achieve 15% of the domestic final energy consumption from renewables in electricity generation, heating, and transport. Although there is a binding 10% subtarget of transport fuels from renewable sources, there are no binding subtargets for heat or electricity.

In its first National Renewable Energy Action Plan, the United Kingdom indicated that it would aim at 30% of electricity, 12% in heat and 10% in transport (UK Government, 2010).

The European Commission stated in March 2018 that the RED would no longer apply to the United Kingdom as of the withdrawal date from the European Union (Brexit), subject to the transitional arrangement of the withdrawal agreement (see EC, 2018). UK participation in the second RED, which sets targets for 2030, is still not clear at the time of writing and depends on the future UK-EU relationship.

The Clean Growth Strategy adopted in October 2017 (UK Government, 2017b) sets out how the government will achieve its legally binding emissions caps (so called "carbon budgets"), which includes measures to increase the use of renewable energy in electricity, heating, and transport. The Clean Growth Strategy foresees UK Government spending commitments for renewables to match an expansion of renewable generation to meet 50% of UK electricity demand by 2032.

Electricity from renewable energy sources

The United Kingdom has three major support schemes for electricity generation based on RES: a RO that has existed since 2002, FITs introduced in 2010, and CFD introduced in 2013. The CFD scheme is the main mechanism for supporting new large-scale renewable energy generation.

The United Kingdom is making strong progress in improving the flexibility of the electricity system, which will help to integrate increased shares of variable generation (which stood at 18% in 2017), without increasing the risks to system security while keeping costs to a minimum, as highlighted by the Committee on Climate Change (CCC, 2018a and 2018b). System integration of renewables-based generation is discussed in Chapter on Electricity.

Renewables Obligation

The RO, introduced in 2002, required UK electricity suppliers to have Renewables Obligation Certificates (ROCs) for each megawatt hour of electricity supplied. Ofgem issues ROCs to generators who can sell those ROCs to suppliers or traders. The value of a ROC is negotiated between the generator and supplier or trader, and there are also certificate trading exchanges. Suppliers that cannot demonstrate to Ofgem their compliance with the obligation have to make a payment per ROC into a buy-out fund. After Ofgem's administration costs have been deducted, the money from the buy-out fund is recycled on a pro-rata basis to suppliers who present ROCs. This encourages suppliers to choose ROCs over the buy-out fund. The cost of the RO to suppliers is passed on to consumers through their energy bills.

From the start of the scheme in 2002 until its end of 2016/17, Ofgem accredited 25 156 generating stations with a total capacity of 29.2 GW. In the 2016/17 obligation period, 86.2 million ROCs were issued based on 65.2 TWh of electricity generated by accredited stations, which was equivalent to 22.2% of the total UK electricity supply. Under the scheme, 28.3 million tonnes of carbon dioxide-equivalent emissions were avoided through renewable electricity generation (Ofgem, 2018). The RO is being replaced by the CFD. The RO closed to new capacity on 31 March 2017, but some projects can still qualify and be accredited via certain grace period conditions up to 2019. Accredited capacity will receive support for 20 years or until the final closure of the scheme on 31 March 2037, whichever is the earlier.

Feed-in tariffs

The FITs support scheme was introduced on 1 April 2010 to encourage the deployment of small-scale, low-carbon electricity generation, particularly by organisations, businesses, communities, and individuals. The technologies supported under FITs are: solar PV, onshore wind, hydropower, anaerobic digestion with a capacity up to 5 MW, and micro co-generation installations with a capacity below 2 kilowatts (see also Box 4.1).

Under the FIT scheme, generators receive 1) a generation tariff, i.e. a payment for every kilowatt hour generated, dependent on the technology and capacity of the installation, and on the commissioning date and 2) an "export tariff" – an additional payment for every kilowatt hour exported to the local electricity network. As an additional benefit, generators can reduce their energy bills when they use electricity "onsite". Electricity suppliers pay the FITs to generators and then pass these costs on to consumers through electricity bills. Since the introduction in 2010, the FIT scheme has supported over 800 000 installations with a total capacity of 6 GW; 99% of the installations or 80% of capacity are solar (UK Government, 2018b).

The levels of FITs for new installations are revised regularly to provide rates of return that encourage investment but prevent overcompensation. To control the costs of the FIT scheme and reduce the burden on end users, the scheme was reviewed in 2011/12 and 2015. After the 2015 review of the FIT scheme, the government reduced the level of support, fixed the budget available until March 2019, and confirmed that the generation tariff would close from the end of March 2019. In a consultation document published in July 2018, BEIS proposed closing the export tariff (smart export guarantee) alongside the generation tariff so that the scheme would close to new applications after 31 March 2019 (BEIS, 2018c). At the same time, BEIS launched a call for evidence on a potential replacement support scheme for small-scale low-carbon generation as of April 2019 (BEIS, 2018d).

Contracts for difference

The CFDs, introduced by the Electricity Market Reform of 2013, are now the main mechanism to support new large-scale low-carbon generation projects (renewables and nuclear; Chapter 8 gives a detailed analysis).

A CFD is a private law contract between a low-carbon electricity generator and the government-owned LCCC. The winning generators are guaranteed a certain electricity price (called a strike price) throughout a long-term contract. If the wholesale electricity price is below the agreed strike price, the generator will receive a top-up payment to make up the difference. If the wholesale price is above the contract price, the generator pays the surplus back. The CFDs improve the predictability of the income, and thus reduce the cost of capital for new renewable energy projects, which have high up-front capital costs but low operational costs. CFD payments are raised through a levy on all GB electricity suppliers, who pass these costs on to consumers. The scheme has delivered substantial new investments and helped achieve significant reductions in the costs of some renewable technologies, particularly offshore wind.

The first CFD auction round included two separate “pots” for established technologies (such as onshore wind and solar PV, pot 1) and less-established technologies (offshore wind, biomass co-generation, and advanced conversion technologies, pot 2) with the results published in February 2015. The second auction (September 2017) excluded onshore wind and solar PV and only included pot 2 less-well-established technologies. Two offshore wind projects were awarded CFD deals at British pounds (GBP) 57.50 per megawatt hour (GBP/MWh) (EUR 64.10/MWh) – a 50% cost reduction from contracts awarded in 2015.

The Clean Growth Strategy confirms public spending of up to GBP 557 million for further CFD auctions. The next such auction will be carried out in May 2019 (pot 2 auction) and the government will hold further biennial tenders through the 2020s with a target between 1 GW and 2 GW of offshore wind per year. The government has worked with industry to develop a sector deal for offshore wind, which was presented in March 2019. Based on the commitment from the government in 2018 to run regular Contracts for Difference auctions with a total funding of up to GBP 557 million, which would build up to 30 GW of offshore wind capacity, subject to costs coming down (UK Government, 2019).

In June 2018, after a public consultation, BEIS published proposed changes to the CFD scheme (UK Government, 2018e). Given the results of the consultation, the government decided to differentiate wind projects on remote islands – remote island wind – from other onshore wind projects to enable them to compete for a CFD in pot 2. The government also decided to amend the definition of "waste" and the CFDs eligibility criteria for dedicated biomass with co-generation and energy from waste with co-generation. All the new dedicated biomass with co-generation plants and energy from waste with co-generation plants (both under 25 megawatt and larger) that apply for new CFD contracts must have a minimum of 70% overall efficiency (net calorific value), achieve a primary energy saving of 10% (gross calorific value), and a 10% heat efficiency (gross calorific value).

Guarantees of origin

The United Kingdom has developed, in accordance with Article 15(2) of the EU Renewable Energy Directive (2009/28/EC), the Renewable Energy Guarantees of Origin (REGO) scheme, which provides transparency to consumers about the proportion of electricity that suppliers source from renewable generation.

Ofgem issues one REGO certificate per megawatt hour of eligible renewable output to generators of renewable electricity. The primary use of REGOs in Great Britain and Northern Ireland is for fuel mix disclosure – a requirement on licensed electricity suppliers to disclose to potential and existing customers the mix of fuels (coal, gas, nuclear, renewable, and other) used to generate the electricity supplied.

All EU member countries must recognise the guarantees of origin issued by other EU member countries. The European Commission stated in March 2018 that the United Kingdom's guarantees of origin will no longer be recognised by the EU-27 member countries as of the withdrawal date, "subject to any transitional arrangement that may be contained in a possible withdrawal agreement" (EC, 2018). In a 'no deal' scenario, the government has legislated to ensure that Renewable Energy Guarantees of Origin issued in EU countries will continue to be recognised. This will allow electricity suppliers to continue to use EU Renewable Energy Guarantees of Origin and will ensure that existing supply contracts are not compromised, insofar as these contracts depend upon Renewable Energy Guarantees of Origin. This position will be kept under review.

Planning and consent

The Planning Act 2008 set out the application process for nationally significant infrastructure projects (NSIPs), which include electricity generation stations above 50 MW onshore or 100 MW offshore; and electricity lines at or above 132 kilovolts. To implement the Planning Act 2008, six National Policy Statements (NPSs) on the energy infrastructure were introduced, which included one for the renewable energy infrastructure. The NPSs set out the need for an energy infrastructure and provide guidance on how decision makers should consider applications for development consent. For NSIPs, applications are submitted to and examined by the Examining Authority from the Planning Inspectorate, which follows a prescribed procedure in which each stage addresses rights, responsibilities, and a time frame for all parties to obtain development consent from the Secretary of State. Local planning authorities (LPAs) were responsible for renewable and low-carbon energy projects with an installed capacity of 50 MW or less, and should ensure that their development plans are in line with the NPSs.

The Conservative Party Manifesto of 2015 aimed to give 'the local people the final say' in wind farm applications and strengthened the local authorities. Since 2016, the planning of onshore wind has been given to the LPAs. Wind energy development is today a matter for the LPAs and is devolved to the administrations in England, Wales, Scotland, and

Northern Ireland. The Energy Act 2016 together with the Infrastructure Planning (Onshore Wind Generating Stations) Order 2016 made LPAs the primary decision makers for onshore wind applications below and above 50 MW in England and Wales.

LPAs take planning decisions in accordance with the policies set out in the NPPF. LPAs in England can grant planning permission for onshore wind sites under two conditions: 1) the development site is in an area identified as suitable for wind energy development in a local or neighbourhood plan and 2) a consultation demonstrated that the planning impacts identified by the affected local communities are fully addressed and therefore the proposal has their backing. However, if an LPA does not grant consent, the applicant can turn to the Secretary of State who retains the responsibility for applications to vary the existing onshore wind farm consents above 50 MW.

At the same time, the Energy Act 2016 placed greater requirements on the planning process for onshore wind energy, including environmental concerns, which has reduced the number and speed of projects to be developed.

In August 2010, the government adopted the "connect and manage" grid access regime (which was implemented in February 2011) to speed up grid connections and allow NG to grant grid connections early on before the completion of major network reinforcements and reduce the time it takes to connect new generation.

Microgeneration is often deemed to be "permitted development" and is granted automatic planning permission by the Town and Country Planning (General Permitted Development) Order 1995, as amended. Such permission is usually granted subject to limitations and conditions which are designed to minimise the impact. This applies to both residential and non-residential generation. Solar PV is limited to a maximum capacity of 1 MW to qualify.

Box 4.1 Renewable energy for communities

Community-led wind projects has been supported through the FIT[2]. The United Kingdom introduced FIT pre-accreditation, which included an extra six months' validity period for community energy projects. Additionally, the Rural Community Energy Fund, with a budget of GBP 15 million provides support to community groups in rural areas for the development and implementation of energy projects, which include wind.

The UK government's National Planning Policy Framework (NPPF), led by the Ministry of Housing, Communities and Local government, encourages local authorities and neighbourhood planning bodies to support community-led initiatives for renewable and low-carbon energy, and to facilitate permitting procedures for such projects. Moreover, the NPPF encourages authorities to identify opportunities in which new projects can draw their energy supply from decentralised, renewable, or low-carbon energy supply systems. For instance, the United Kingdom is encouraging the development of wind projects on the remote islands of Scotland, which will directly benefit local communities.

[2] In March 2019, the FIT closed and is to be replaced by the Smart Export Guarantee.

Heat from renewable energy

The government has put a strong focus on renewable heat policy under the EU RED and the ambitious long-term GHG emission targets under the 2008 Climate Change Act.

Part of this effort has been a more strategic approach, with the publication of a heat strategy in 2012 and an updated strategic document in 2013 (UK Government, 2013). Key aspects of this strategy focused on buildings and industrial heat decarbonisation and the role of heat networks. Subsequently, the government set up a Heat Networks Delivery Unit, made some funding available for district heating networks, and developed a set of industrial carbon reduction and energy efficiency roadmaps.

In the 2017 Clean Growth Strategy, the government set out plans to phase out, during the 2020s, the installation of high-carbon fossil fuel heating in new and existing homes currently not connected to the gas grid, and to invest in low-carbon heating by reforming the RHI, spending GBP 4.5 billion to support innovative low-carbon heat technologies in homes and businesses between 2016 and 2021.

Renewable Heat Incentive

The principal mechanism to support renewable heat in Great Britain is the RHI, which was established in 2011 for non-residential entities (businesses [including industry], public sector, and non-profit organisations) and in 2014 for residential users. A precursor programme, the Renewable Heat Premium Payment scheme, ran from 2011 to 2014. This provided around 16 000 grants to support investment in renewable heat technologies by households, social housing landlords, and community groups. A similar to the RHI scheme started in 2012 in Northern Ireland and closed to new applications in 2016. The GB scheme is expected to remain open until March 2021, subject to budget availability.

The RHI supports renewable heat technologies such as biomass, biomass co-generation, biomethane injection to the gas grid, biogas, heat pumps, solar thermal, and geothermal. Owners of eligible plants apply to Ofgem after commissioning the installation and receive quarterly payments for either seven years (residential) or 20 years (non-residential). Payments are based on the metered heat output or, in most domestic cases, on the estimated heat demand. RHI payments come from public (taxpayer) funds.

The deployment of renewable heat installations and the generation of renewable heat are monitored by Ofgem and BEIS and published on a monthly basis (UK Government, 2018a, for monthly updates see www.gov.uk/government/collections/renewable-heat-incentive-statistics.) As of mid-2018, there are over 18 000 non-domestic installations and over 63 000 domestic installations accredited to the RHI schemes (Table 4.1), compared to over 20 million gas boilers in the current housing stock (UK Government, 2018i).

Table 4.1 Key RHI statistics (data to end of August 2018)

	Non-residential scheme	Residential scheme
Number of applications	19 788	69 536
Number of accredited installations	18 821	63 559

	Non-residential scheme	Residential scheme
Number of installations in payment	18 215	65 661
Installed capacity (MW_{th}) of accredited installations	4 210	817
Heat generated and paid for (GWh)	26 404 (since November 2011)	2 942 (since April 2014)
Key technologies	Biomass boilers (71% of heat generated and paid for), biomethane (22%)	Biomass boilers (52% of heat generated), ASHPs (31%), GSHPs (16%), solar thermal (2%)
Key sectors	Agriculture (28%) Accommodation/B&B (30%)	Rural (80%)

Note: GSHP = ground source heat pump.

Source: UK Government (2018a), *RHI Deployment Data*, BIS, www.gov.uk/government/collections/renewable-heat-incentive-statistics accessed on 30 September 2018.

Box 4.2 Industrial aspects of renewable energy policy

The sustained support for renewable energy has reinforced supply chains across the renewables sector, particularly offshore wind. The United Kingdom is now among the world's largest markets for offshore wind, with 13 700 people employed in the sector (7 900 direct jobs and 5 800 indirect). This has led offshore wind suppliers into United Kingdom-based manufacturing, which creates jobs and brings investment into the economy. The Siemens blade facility in Hull is just one example of this success. Indeed, there has been strong progress in attracting investment and promoting rejuvenation in areas such as Hull, Grimsby, Barrow-in-Furness, Great Yarmouth, Campbeltown, and Lowestoft through the development of a UK supply chain.

Moreover, the government's ambition (outlined in its manifesto) to have a strong, industrialised UK supply chain is increasing its capacity to win export orders. An Offshore Wind Industry Council (OWIC) was set up to develop an ambitious business-led proposal for an offshore wind sector deal.

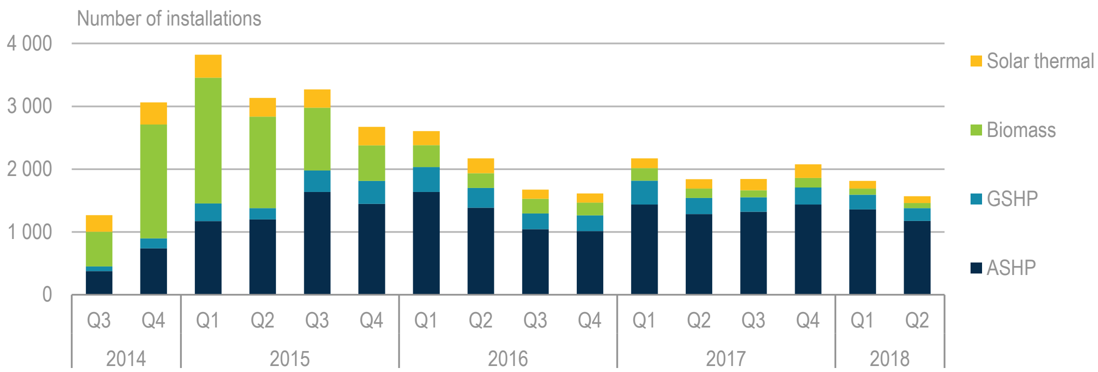
As a result of these initiatives, the domestic content of UK wind farms increased from 43% in 2015 to 48% in 2017. This means the offshore wind industry has almost hit its long-term target, set out by the OWIC, to source 50% of its work in Britain. The United Kingdom also has a strong track record in the supply of offshore wind development services, engineering design, and the supply of interarray cables and offshore substations. Approximately 75% of the value of operations and maintenance contracts for UK offshore wind farms are won by UK businesses.

In March 2019, the UK government concluded an Offshore Wind Sector Deal with the industry to boost economic growth and job opportunities in the UK. Based on the commitment from the government in 2018 to run regular Contracts for Difference auctions with a total funding of GBP 557 million, which would build up to 30 GW of offshore wind capacity, subject to costs coming down. Under the deal the industry is committed to invest GBP 250 million Offshore Wind Growth Partnership (OWGP) and the government expects the sector to continue cutting costs to lower their impact on bill payers while investing in and driving growth in the UK's manufacturing base with UK content raised to 60% by 2030 (UK Government, 2019a).

RHI spending has been consistently below budget and, furthermore, there was a slowdown of RHI accreditations after a reduction in the biomass tariffs (20% for the domestic tariff and 15% for small commercial installations) from April 2015. This resulted in a sharp decrease in the deployment of biomass boilers under the scheme, without a corresponding increase from other technologies. Non-residential installations saw a reduction of 23% (by capacity of accredited installations) from 2015 to 2016, and the number of residential installations fell even more dramatically. Subsequent to further tariff revisions from January 2017, deployment increased, especially for ASHPs whose tariffs were increased by 25%, but in 2018 the deployment dropped again, especially in the second quarter (Figure 4.7).

Overall, the results have been mixed. According to an assessment commissioned by the UK House of Commons' Public Accounts Committee and published in May 2018, "the RHI has failed to meet its objectives or provide value for money for the GBP 23 billion expected total cost to taxpayers" (Public Accounts Committee, 2018). The report highlights that some RHI-funded installations may contribute to air pollution and BEIS and Ofgem could do more to monitor this impact by working with local government across GB. According to the report, there are also cases of fraud and non-compliance with the RHI application requirements.

Figure 4.7 Domestic RHI-accredited installations by technology, Q3 2014 - Q2 2018



Notes: Excludes so-called legacy systems that were installed after the announcement of the plans to introduce the RHI and the actual launch of the domestic RHI.

Source: UK Government (2018a), *RHI Deployment Data*: *August 2018*, BEIS, accessed on 30 September 2018. www.gov.uk/government/collections/renewable-heat-incentive-statistics#monthly-deployment-data

The National Audit Office found the government had sufficiently adapted the scheme to new planning targets and controlled the scheme's costs (to avoid the budget control problems that occurred on a similar scheme in Northern Ireland) (NAO, 2018). BEIS also conducted research into the RHI outcomes in general terms. Ofgem estimates rather low overpayments as a result of non-compliance with the scheme's rules at 4.4% and 2.5% of the total scheme expenditure in 2016/17 (on the non-residential and residential RHI schemes, respectively).

Following the report, BEIS introduced legislative reforms to the RHI that tighten the scheme regulations to guard against non-compliance and manipulation of the scheme's rules (UK Government, 2018f). In addition, BEIS and Ofgem put in place a new strategy to reduce the amount of fraudulent activity, quantify non-compliance, and establish the root causes of fraud and error across all the environmental and social schemes that Ofgem delivers on behalf of the government. These measures improved BEIS' and

Ofgem's ability to identify and tackle RHI gaming and non-compliance, and both organisations will continue to monitor this area to ensure taxpayers' money is protected.

The RHI has its budget confirmed until April 2021. BEIS is developing its future policy framework to support low-carbon heating. It has commissioned an evaluation to understand consumer behaviours further, as well as the market and supply chain for renewable heating systems. This evaluation is expected to provide evidence on consumer-perceived access to renewable fuels as well as an understanding as to factors that influence consumer decisions to install renewable heating systems. A final report is expected in mid-2021, along with several interim reports.

A call for evidence on the future framework for heat in buildings was published in March 2018 (UK Government, 2018g). This sought views and evidence on actions the government could take during the 2020s to phase out high-carbon fossil fuel heating in off gas grid buildings, as a first step to developing a post-RHI policy.

Contrary to renewables-based electricity, which is financed by consumers through their energy bills, renewable heating is supported from the state budget (by taxpayers).

Table 4.2 shows the RHI budget and commitments made.

Table 4.2 RHI budget and committed spend (GBP million)

Year	2016/17	2017/18	2018/19	2019/20	2020/21
Planned budget	640	780	900	1010	1150
Committed spend					
Non-domestic RHI	441	612	720	779	812
Domestic RHI	92	106	117	122	125
Total	533	719	838	901	937

Source: BEIS (2018b), UK Submission to the IEA for the 2018 in-depth review. Data to end of September 2018.

Heat Networks Investment Project

In parallel to the RHI, the government committed funding for district heating networks, which supplied around 2% of the United Kingdom's heat in 2017. The GBP 320 million Heat Networks Investment Project (HNIP) capital investment programme is expected to support up to 200 projects by 2021 through grants and loans and other mechanisms. Funding can go to projects that use a minimum of 50% renewable or waste heat, or alternatively 75% co-generated heat. Potentially, the networks could therefore still be fully supplied by fossil fuels.

A first pilot round of funding of GBP 24 million ran from October 2016 to March 2017 and supported nine district heating projects – including five gas-fired co-generation plants, one gas boiler, one gas and biomass-fired co-generation plant, and one heat pump[3] – that will deliver heat to 5 000 homes and 50 non-domestic buildings. Applications were limited to local authorities and other public sector bodies during the pilot phase. It is expected that these nine networks will supply around 85 000 MWh of heat per year, which would result in savings of 216 324 tonnes of carbon dioxide (tCO_2) over the next 15 years. Following this pilot, the main funding round is expected to open at the end of 2018, with first year funding to be allocated by March 2019. The government plans to

[3] The Sheffield District Energy Network project (energy from waste) will not go ahead.

broaden the scope of eligible applicants, which could include the private sector, community groups, and not-for-profit groups.

In addition, there are further support measures available at the devolved level in Scotland (e.g. zero-carbon loans for renewable heat and a district heating loan fund).

Renewable energy in transport

The United Kingdom has two support schemes to incentivise the utilisation of renewable fuels in road transport: the RTFO and the Greenhouse Gas Emissions Regulations for transport fuels.

In 2017-2018, after public consultations, these two mechanisms were amended and the government published its 15-year renewable transport fuel strategy in September 2017 (UK Government, 2017e, 2017f).

Renewable Transport Fuel Obligation

Introduced in 2008, the RTFO requires suppliers of road transport fuel to source a growing percentage of the total volume of fuel from RES. The level of RTFO was 4.75% in 2017 and was set to rise to 7.25% in 2018, 8.5% in 2019 and 9.75% in 2020. The RTFO applies to suppliers of more than 450,000 litres (L) of fuel per year and operates as a certificate trading scheme.

Suppliers demonstrate compliance by redeeming certificates, which they either claim for supplying sustainable renewable fuel or purchase from other suppliers. Fuels awarded under the RTFO need to comply with sustainability criteria, including a minimum greenhouse gas emission savings threshold calculated over the life cycle of the fuels. In case insufficient amounts of affordable fuels are available on the market, obligated suppliers can also choose to pay "buy-out" money to the government (at 0.30 GBP per litre [GBP/L]) rather than redeem certificates.

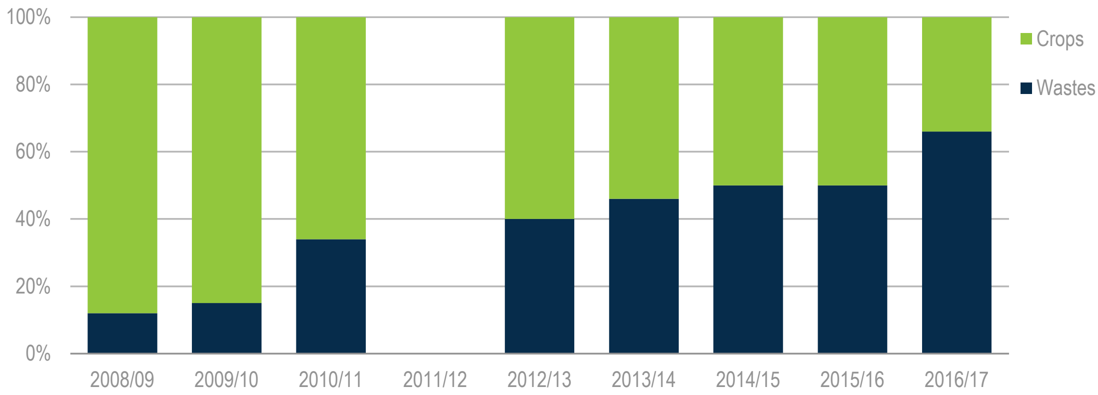
The RTFO levels set will also allow the United Kingdom to meet the 2020 target for 10% renewable energy in road transport set under the EU RED. In addition, minimum targets to 2032 were set, aligned with national carbon budgets, to provide a longer-term framework for renewables in transport. The government committed to continue increasing the level of RTFO beyond 2020 so that it will reach at least 12.4% in 2032. While the actual amounts of biofuels have not increased over the last years, when biofuel targets were kept stable, the fuels supported now achieve much higher GHG savings (around 70%).

A binding subtarget for "development fuels" was introduced, which will increase from 0.1% in 2019 to 2.8% in 2032. Development fuels are fuels considered to be of strategic importance which are produced from wastes and residues. They include aviation fuel (avtor and avgas), hydrogen, renewable synthetic natural gas and fuels that can be blended at rates of at least 25% and still meet the relevant fuel standard, i.e. EN228 for petrol and EN590 for diesel. For these, the buy-out price (see above) is also set a higher level, i.e. at 0.80 GBP/L (UK Government 2017g).

In the tenth year of RTFO operation (2017/18), 1 624 million L of renewable fuel were supplied, which is 3% of the total road and non-road mobile machinery fuel. Of this fuel 1 623 million L (99.96%) has been demonstrated to meet the sustainability requirements. Biodiesel comprises 49% of the total biofuels supply, bioethanol 46%, and biomethanol

4%. There was also a small volume of biopetrol, biomethane, off-road biodiesel, diesel with a bio-origin, and hydrotreated vegetable oil (UK Government, 2018h and 2019b).

Figure 4.8 The split between biofuel waste and crop in UK RTFO



Source: Williams (2018), *Renewable Energy Directive Implementation: UK perspective*.

UK biofuels policy focuses on promoting waste-derived biofuels, which generally have higher greenhouse savings over their life cycle compared to crop-derived biofuels. A double reward is provided for the use of waste, thanks to which the share of waste-based biofuels has grown over the past decade (Figure 4.8). Biofuels supported under the RTFO in 2017/18 achieved an aggregate greenhouse gas saving of 76% compared to fossil fuels (71% when indirect land use change impacts were taken into account). To further promote the transition to waste-derived biofuels, the government introduced a sliding scale for the maximum contribution from fuels made from agricultural crops used to meet the obligation: 4% in 2018 and declining from 2021 to reach 3% in 2026 and 2% in 2032.

The cost of supplying renewable fuels is placed on suppliers obligated under the RTFO. The total value of the RTFO for 2015/16 was GBP 451.7 million. This is calculated as the difference between the cost of renewable fuels supplied and the fossil fuels they have replaced. The forecast total value of the RTFO for 2016/17 is GBP 527 million[4].

Greenhouse gas emissions regulations (for transport fuel)

Changes to the Motor Fuel (Greenhouse Gas) Reporting Regulations (DFT, 2017b) introduced a 6% greenhouse gas (GHG) emissions reduction obligation on fuel suppliers, and a certificate trading scheme similar to that of the RTFO. Obligated suppliers of more than 450 000 L of fuel per year will have to reduce the GHG intensity of their fuels below the 2020 target level of 88.45 grammes of carbon dioxide equivalent per megajoule. Obligated suppliers will be able to claim certificates for fuels that are below the target level and to trade certificates with other suppliers to meet their obligation. As with the RTFO, suppliers unable to meet their obligation will be able to pay in lieu of certificates, at a cost of 74 GBP/tCO_2. Suppliers are expected to meet their obligations by measures that include to supply bioenergy, to supply other lower-carbon fossil fuels, such as road fuel gases, and to

[4] RTFO Annual Report, www.gov.uk/government/collections/renewable-transport-fuels-obligation-rtfo-orders#annual-reports.

reduce upstream emissions from producing transport fuels. The amended regulation is also expected to:

- Support the uptake of electric vehicles (EVs), by allowing electricity suppliers to claim credits for the electricity used to charge EVs.

- Support sustainable renewable aviation fuels and renewable fuels of non-biological origin – which include renewable hydrogen – to make them eligible for GHG credits and subject to the reporting requirements.

- Enhance oil supply chain transparency by requiring suppliers to report on the GHG emissions from their fuels, the source of the crude used to make their fuels, the country where the fuel was purchased, and the name of the processing facility at which the fuel was refined, with simplified reporting requirements for small and medium-sized enterprises.

- Reduce burdens on businesses, by aligning the RTFO and GHG reporting deadlines to a calendar year cycle (DFT, 2017b).

Assessment

Renewable energy supply in the United Kingdom has grown at an impressive rate over the past decade, primarily in the electricity sector. Beyond electricity, policy attention is placed on heat and transport, where considerable potential exists to increase the utilisation of renewable energy to drive the UK clean energy growth agenda. Continued growth in renewable energy will be needed to achieve the 2020 target of 15% (as required by the Renewable Energy Directive) from today's 10%, and to cut further GHG emissions (as set out in the Climate Change Act and the Clean Growth Strategy). The United Kingdom will need to review targets and policies for the heat and transport sectors if it wants to replicate the successful growth of renewable energy in electricity.

Electricity

The United Kingdom is on track to deliver around 35% of electricity generation from renewables by 2020, well in excess of that projected for 2020 in the National Renewable Energy Action Plan 2010 of 'around 30%' (DECC, 2010). Variable renewables (wind and solar PV) provided 18.3% of the total electricity generation in 2017 and are set to grow in the coming years. The increasing levels of variable renewable electricity create challenges for the electricity system that require both technical and market solutions (Chapter 8).

Growth of renewable energy in the electricity sector is a key achievement of UK energy policy thanks to support schemes, the carbon price floor, and other measures that target reducing coal-fired generation. The growth in renewable electricity has primarily been driven by three support schemes: the RO was introduced in 2002 and closed to new applications in 2017; FITs were used to encourage small-scale renewable electricity generation, introduced in 2010 and planned to be closed in 2019; and CFDs – introduced as part of the Electricity Market Reform of 2013 and for which two auctions were held (2015 and 2017). The CFDs have provided revenue certainty for developers, which led to significant investments – particularly in offshore wind where the United Kingdom is a world leader. The annual costs of the three support schemes is estimated amount to a total GBP 8.6 billion in 2021/22, all paid for by electricity consumers through additional charges levied on their bills by suppliers (see Chapter on General Energy Policy, Figure 2.9).

A number of actions have been taken to control costs and to ensure value for money for future projects approved under the schemes. The rates paid under the FIT support scheme are subject to review at least every three years. In addition, the strike prices for CFD contracts are now set as part of competitive auctions. As a result, low-cost renewable energy projects are awarded with contracts, which thereby improves the cost-effectiveness of the scheme over the previous system, in which strike prices were set by BEIS.

There was no pot for established renewables in the second allocation round in 2017, nor will there be one in the third. (No decisions have been taken on future CFD allocation rounds for established technologies.) This and the end of the RO leaves onshore wind or solar PV projects of over 5 MW in limbo. In addition, with the closure of the FIT from 2019, there will be no support for any solar projects, unless a new support framework is developed for small-scale installations.

Separate technology-specific ‘pots’ under CFDs are a good instrument to direct support towards technologies at a lower level of technical maturity, and thus encourage technology innovation. Even though such separate pots lead to higher strike prices and higher costs for electricity consumers in the short term, they are strategically important in the long term.

It has been announced that auctions will be run every two years after the auctions in May 2019, using the GBP 557 million that was announced as part of the 2016 Budget. Depending on the auction prices and eligibility criteria, BEIS intends to support the delivery of between 1 and 2 GW of new offshore wind every year in the 2020s, provided costs continue to fall. The offshore wind sector deal of March 2019 could facilitate up to 30 GW of generating capacity by 2030, subject to the cost coming down.

Transport

The transport sector is now the largest CO_2-emitting sector, as it accounts for 32% of energy-related CO_2 emissions in 2016. The United Kingdom has a target of 10% of energy consumption in the transport sector to come from renewable sources by 2020 under the EU RED. In 2016, a level of 4.5% was achieved. The 2017 amendments to the RTFO will also help the UK to achieve the 10% target under the EU RED.

The RTFO and the Greenhouse Gas Emissions Regulations for transport fuel are the principal policy measure that support renewable energy use in the transport sector.

In September 2017, an updated 15-year strategy for renewable fuels in road transport was published. It increased the obligation rate under the RTFO from the current level of 4.75% to 12.4% by 2032 and introduced an obligation on fuel suppliers to reduce GHG emissions by 6% to 2020. Commendably, the strategy provides long-term policy certainty to the fuel suppliers, which allows for forward planning and future increases in renewable energy in a cost-effective manner. In addition, the incorporation of a subtarget for “development fuels”, e.g. advanced biofuels from wastes and revenues, hydrogen, and biomethane, creates a valuable framework to promote the development and deployment of a further array of low-carbon fuels from non-food crop feedstocks.

Increasing renewable energy use in the transport sector can be achieved not only through blending or using drop-in[5] renewable fuels but also through transport sector electrification e.g. of rail or light passenger vehicles. This is due to the increasing share of renewables in UK electricity generation. Therefore, the government is to be commended for its efforts to promote the uptake of ultra-low emission vehicles through the work of the Office for Low Emission Vehicles. The growth in use of EVs is supported through a range of measures and the development of a nationwide public charging network. An intention to end the sale of new conventional petrol and diesel cars and vans by 2040 has been announced, which will provide a further incentive to the uptake of ultra-low emission vehicles.

Heat

In 2017, only 7.2% of energy in the heat sector came from renewable sources, so there is significant potential to further decarbonise heat demand.

The major instrument to support renewable heat is Great Britain's RHI scheme that has been in place since in 2011 for non-residential users (industry and other businesses, commercial, and public sector), followed by a residential scheme introduced in 2014. The RHI is innovative, and one of few subsidy mechanisms for renewable heat generation. Owing to a very thorough monitoring system for the deployment of the RHI, the United Kingdom now has one of the most comprehensive renewable heat deployment statistics available globally, which is very helpful for analysing lessons learned from this pioneering mechanism. The cost-effectiveness of the RHI – measured as the amount of taxpayer subsidy that is spent to achieve 1 MWh of renewable heating – has proved to be better than expected with 49 GBP/MWh, compared to the government's target of 51 GBP/MWh (Public Accounts Committee, 2018).

So far, the RHI has not proven as effective as initially expected in stimulating consumers to switch to renewable heat. In fact, there are many additional barriers that affect renewable heat uptake, e.g. building suitability, consumer preferences, installer expertise, etc. In addition, the United Kingdom's extensive natural gas network makes it difficult for renewable heat to compete, so the residential RHI development takes place mostly in off gas-grid areas. Moreover, the RHI reportedly has implementation challenges, such as non-compliance with the scheme requirements, as well as an unclear impact on air pollution (Public Accounts Committee, 2018).

A similar RHI scheme in Northern Ireland (open between 2012 and 2016) has been the subject of public inquiry because of a significant controversy as a result of issues that included inadequate budgetary controls – such as no upper limit on the amount of energy that could be paid for.

BEIS has revised downwards by almost two-thirds its expectations of how much renewable heat will be produced by RHI, and the expected reductions in carbon emissions by almost half (Public Accounts Committee, 2018). This means that RHI must be improved and other policies must be developed for the United Kingdom to meet its carbon targets.

[5] "Drop-in" fuels can be used unblended without fuelling infrastructure and vehicle modifications where vehicle manufacturer approvals are provided.

The recent changes to the RHI are a positive development, as they revised tariffs for new projects and improved the budget management mechanism. A consumer behaviour study commissioned by BEIS is expected to provide further analytical input for the development of new heat policies. The publication of the main features of the new HNIP scheme in 2018 is another encouraging development, even though the HNIP pilot projects so far have supported mainly heat networks based on gas-fired plants. Heat networks need further deployment support while making sure they are based on renewables and/or waste heat.

Aside from the RHI and HNIP programmes, the United Kingdom lacks several of the policies that have been effective in other countries: there is no national obligation to install renewable heat options in new-build properties, no carbon or energy taxes for domestic consumers, and tax rates on natural gas are very low compared to elsewhere, with VAT only payable at 5%. The lack of regulations on heat zoning or connection to heat networks (except for new developments in London) make the business case for these difficult. There are no major building renovation support schemes that link energy efficiency and renewable heat deployment (IEA, 2018). These factors will make it difficult for the United Kingdom to increase decarbonisation of the heating sector, which is much needed to meet the country's carbon budgets.

According to the CCC, "detailed plans should be published to phase out the installation of high-carbon fossil fuel heating in homes and businesses in the 2020s, ensuring there is no policy hiatus in 2021. Further action is needed to deliver cost-effective uptake of low-carbon heat" (CCC, 2018b). The CCC urges the government to focus on low-cost, "low-regret" opportunities, and to establish support frameworks for heat pumps and biomethane post-2021, as well as support for low-carbon technologies in heat networks, and to re-balance subsidies for heat pumps and other capital-intensive technologies towards a capital grant, in line with international best practice (ibid.).

The 2018 assessment commissioned by the UK Parliament also highlights the need for an effective heat strategy that would build on a better understanding of consumers' behaviour and would join up policy across various areas, which include heat networks, energy efficiency, heat decarbonisation research and development, product quality, and building regulations (Public Accounts Committee, 2018).

The Clean Growth Strategy sets out various potential pathways to 2050. These include possibilities to increase the use of renewable energy and reduce emissions in the heat sector. The options considered include the electrification of heat through the use of heat pumps, the use of hydrogen (produced with zero emissions) instead of natural gas, and the use of heat networks. All these options have merit, with other options potentially also being developed in future years. Heat networks are expected to play a vital role in the long-term decarbonisation of heating under each of the three illustrative pathways to 2050, and are projected to meet 17% of heat demand in homes (up from today's 2%) and up to 24% of heat demand in industrial and public sector buildings. Based on the evidence available, it is not feasible to determine which option or combination of options would provide the most cost-effective path to decarbonise the heat sector. Given the scale of emissions in the heat sector and the potential challenges associated with changing technologies in businesses and people's homes, further work will be required, which includes the need to trial potential solutions with a view to inform future policy development.

Recommendations

The UK government should:

- Ensure timely decisions on future CFD auctions for renewable electricity (established technologies) to provide certainty to project developers.
- Promote the use of electric and other low-emission vehicles and the development of an accessible, efficient, and effective national charging network to support the announced end to the sale of new conventional petrol and diesel cars and vans by 2040.
- Continue to promote the use of sustainable biofuels in transportation by 1) increasing support for the development of advanced biofuels from waste and residue feedstocks, and 2) improving the framework to roll-out fuel distribution for alternative fuels, e.g. biomethane and hydrogen.
- Design a scheme for renewable heat for when RHI closes in 2021, incorporating lessons learned from the implementations in both Great Britain and Northern Ireland.
- Support the RD&D of, and deployment support for, a range of potential options to increase renewable energy use and reduce emissions in all sectors, which include a sustainable biomass, marine technologies, electrification, the use of hydrogen and biomethane in the gas network, and the use of heat networks, with a view to informing future strategy and policy measures.

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5. Energy efficiency

Key data

(2017)

TFC: 127.3 Mtoe (oil 43.4%, natural gas 30.1%, electricity 20.3%, biofuels and waste 3.4%, coal 1.7%, heat 1.0%) -11% since 2007.

Consumption by sector: transport 32.6%, residential 29.0%, industry 23.8%, commercial 14.6%.

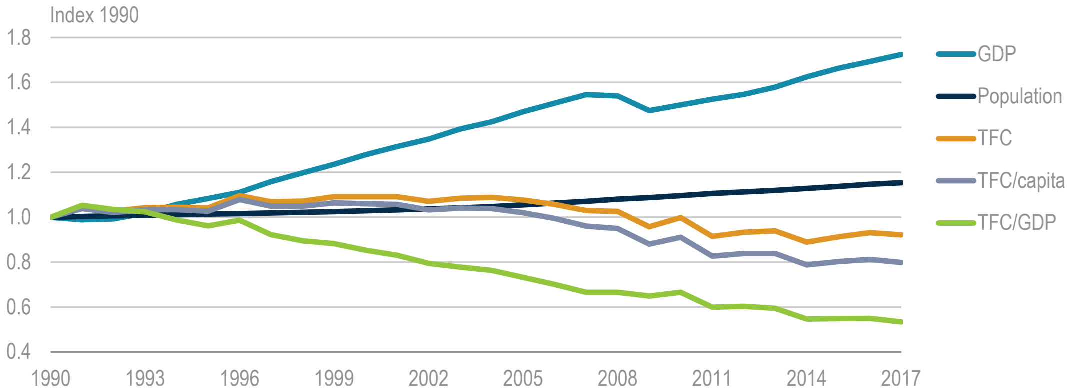
Energy consumption (TFC) per capita: 1.9 toe (IEA average: 2.9 toe), -17% since 2007.

Energy intensity (TFC/GDP PPP): 49.0 toe/USD million PPP (IEA average: 73.9), -20% since 2007.

Overview

Improving energy efficiency is central to meeting the United Kingdom's long-term goal of cutting greenhouse gas (GHG) emissions by at least 80% from 1990 to 2050. In the past decade, the United Kingdom has managed to decouple its total final consumption (TFC) of energy from its economic growth and increasing population (Figure 5.1), thanks to energy efficiency improvements and structural changes in the economy.

Figure 5.1 Energy consumption and drivers, 1990-2017



Despite a 72% increase in gross domestic product (GDP PPP) and 15% growth in population from 1990 to 2017, the TFC has declined by 8%, illustrating their decoupling.

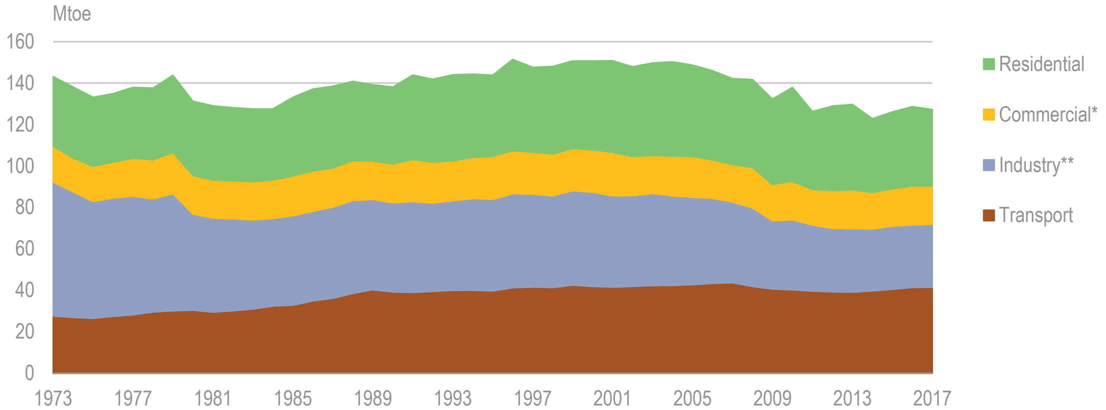
Note: GDP data are in US dollars (USD) 2010 prices and Purchase Power Parity (PPP).
Source: IEA (2019), *World Energy Balances 2019 First edition (database)*, www.iea.org/statistics/.

Total final energy consumption

In 2017, the United Kingdom's TFC was 127 million tonnes of oil equivalent (Mtoe), 11% lower than in 2007. The largest drop in TFC was in the industry sector, which fell by 22% between 2007 and 2017, whereas the residential sector decreased its consumption by 11% and the transport and commercial sectors remained relatively stable.

The transport sector is the largest energy-consuming sector (33% of the TFC in 2017), mainly road transport. The residential sector is the second largest (29%) with industry the third (24%), as illustrated in Figure 5.2.

Figure 5.2 TFC by sector, 1973-2017



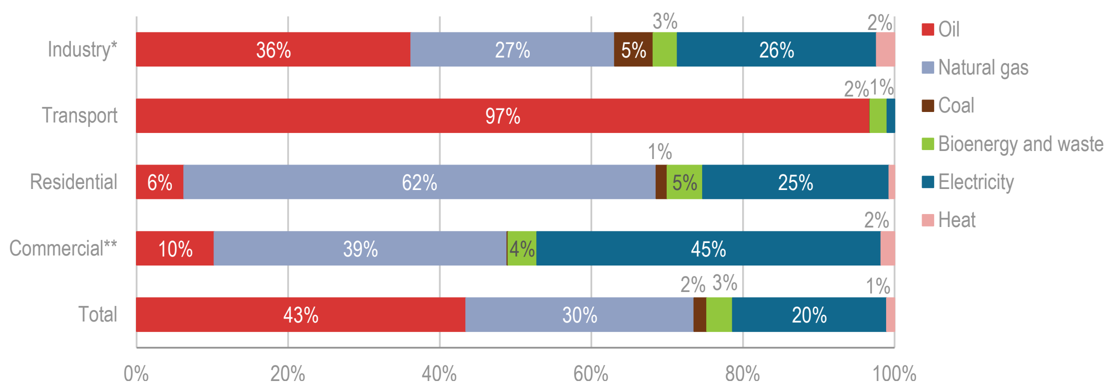
The transport sector is the largest energy consumer with 32% of the TFC and the total energy consumption slightly increased in recent years.

*Commercial includes commercial and public services, agriculture, and forestry.

**Industry includes non-energy consumption.

Source: IEA (2019), *World Energy Balances 2019 First edition (database)*, www.iea.org/statistics/.

Figure 5.3 TFC by source and sector, 2017



Oil is the largest energy carrier overall and dominates in the transport sector, whereas natural gas and electricity account for considerable shares in all the other sectors.

*Industry includes non-energy consumption.

**Commercial includes commercial and public services, agriculture, and forestry.

Source: IEA (2019), *World Energy Balances 2019 First edition (database)*, www.iea.org/statistics/.

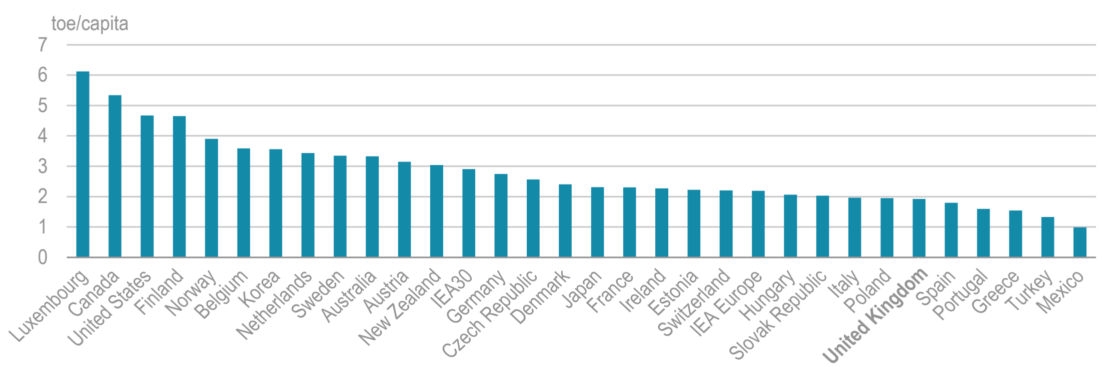
Oil is the largest energy source in the United Kingdom's final energy consumption, at 43% of TFC in 2016 (Figure 5.3). Most oil is consumed in transport, but it also has a large share in the industry sector. Natural gas is the second-largest source, at 30.8% of TFC. It accounts for the main part of residential energy consumption, and it has the second-largest shares in industry and commercial sectors. Electricity accounts for a considerable share in all the sectors except in transport and it is particularly important in the commercial sector. In recent years, biofuels have increased steadily in the residential and industry sectors.

Energy intensity

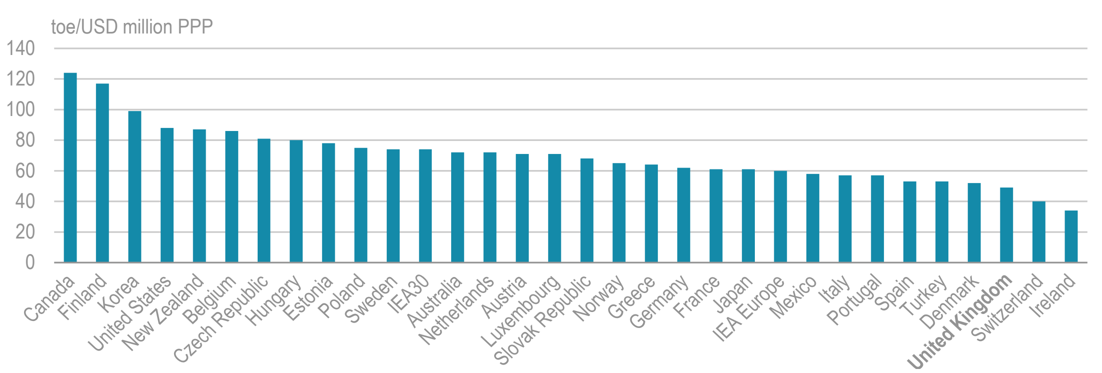
The United Kingdom has a relatively low energy intensity compared to other International Energy Agency (IEA) member countries, both by capita and by GDP (Figure 5.4). In 2017, the United Kingdom had the sixth-lowest TFC per capita, 18% below the IEA median. Furthermore, the United Kingdom had the third-lowest TFC per unit of GDP, 29% below the IEA median.

Figure 5.4 Energy intensity in IEA member countries, 2017

Energy consumption per capita (TFC/CAP)



Energy consumption per GDP (TFC/GDP)



In an IEA comparison, the United Kingdom has the sixth-lowest final energy consumption per capita and the third lowest consumption per GDP.

Notes: toe = tonnes of oil equivalent. Energy intensity in total final energy consumption, not including the energy transformation sector. GDP data are in USD billion 2010 prices and PPP.

Source: IEA (2019), *World Energy Balances 2019 First edition (database)*, www.iea.org/statistics/.

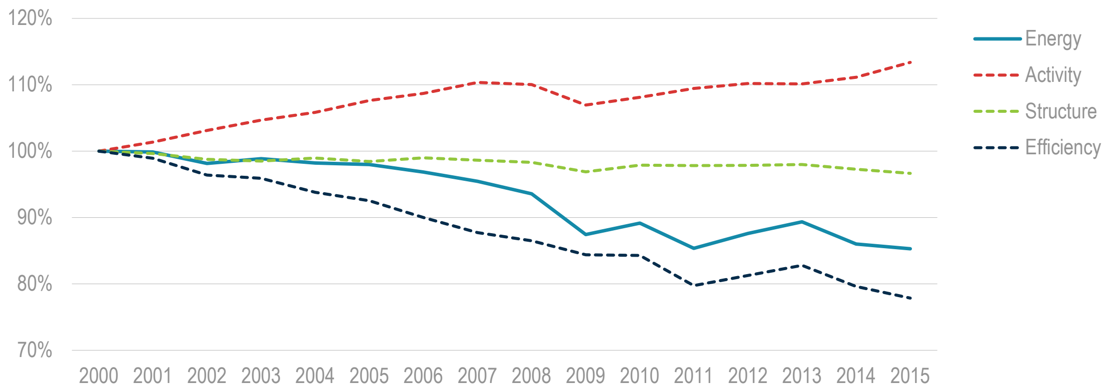
Energy intensity depends on the structure of the economy. Services have generally a low energy consumption compared to energy-intensive manufacturing industry. The United Kingdom's large service sector, e.g. in finance, thus contributes to the relatively low TFC per GDP.

However, energy intensity is also affected by the level of energy efficiency, and the United Kingdom has managed to reduce its TFC from an already relatively low level. From 2007 to 2017, TFC declined by 11%, but is slightly up since 2014 (Figure 5.1).

Overall energy efficiency progress

Another way to break down energy consumption is through a decomposition analysis. How a country's energy consumption develops depends on changes to the economic activity, the structure of the economy, and the efficiency of energy use. United Kingdom's decline in energy demand in recent years has mainly been a result of improved energy efficiency, which has compensated for an increased activity in the economy (Figure 5.5). Structural changes have also contributed to a lower energy demand, but to a smaller extent compared to the energy efficiency improvements.

Figure 5.5 Decomposition of energy efficiency, 2000-15



Since 2000, energy efficiency improvements have been the largest contributor to lower energy demand, and compensated for increased economic activity.

Source: IEA (2018), *Energy Efficiency Indicators 2018*, www.iea.org/statistics/.

Institutional framework

The **Department for Business, Energy and Industrial Strategy (BEIS)** leads on energy efficiency and heat, product safety, and ecodesign standards and labelling. BEIS also focuses on decarbonisation and removing barriers to energy efficiency, low-carbon investment, and access to finance. The Ministry of Housing, Communities & Local governments is responsible for the energy efficiency and safety programmes in housing, as well as the minimum energy performance requirements under Building Regulations for new and existing buildings, which includes homes and business premises.

The **Department for Transport (DFT)** is in charge of vehicle standards, transportation, and mobility policies. BEIS and DFT have jointly established the Office for Low Emission Vehicles.

Energy efficiency is devolved to Scotland, Wales, and Northern Ireland where the national governments set their own additional energy efficiency policies.[1] The implementation of energy efficiency policies relies also on local authorities. Local authorities are responsible for housing, transport, waste, and planning, which all have a significant impact on energy. BEIS supports and funds local programmes and partnerships. For example, BEIS has supported the Local Enterprise Partnerships in England to develop local energy strategies and is funding five regional energy hubs across England to increase local capacity.

Energy efficiency data and monitoring

The United Kingdom leads internationally in the collection and monitoring of end-use data, based on the National Energy Efficiency Data-Framework and includes gas and electricity consumption data, based on BEIS subnational energy consumption statistics, information on energy efficiency measures installed in homes, from the Homes Energy Efficiency Database, the Green Deal, the Energy Company Obligation (ECO) and the feed-in tariff schemes. It also includes data about property attributes and household characteristics, obtained from a range of sources. With the greater rollout of smart meters, distribution companies will share the data through a data company, which collects all the smart meter data.

Regulatory framework

The United Kingdom has a long history of energy efficiency policies, and many of them are also linked to the EU regulatory framework. With Brexit, the United Kingdom would no longer apply the EU directives on energy efficiency, minimum performance standards and vehicle fuel economy/emission standards. The overall 20% improvement target for 2020 under the EU Energy Efficiency Directive and the 32.5% efficiency goal for 2030 and the mechanisms to increase energy efficiency in products through EU minimum standards are key examples of EU-driven policies that have led to significant reductions in electricity demand in UK.

Energy Efficiency Directive

The 2012 Energy Efficiency Directive (EED) (2012/27/EU) established a set of measures to help the European Union reach its 2020 targets. For 2020, the European Union targets an overall 20% reduction of energy consumption from 2007 levels (in primary and final energy) compared to business-as-usual projections. Individual EU countries have set their own indicative national energy efficiency targets in an effort to contribute to the EU wide target. Under the EED, United Kingdom set itself a target of reducing final energy consumption by 18% to a level of 129.2 Mtoe in 2020, equivalent to a 20% reduction in primary energy consumption or 177.6 Mtoe.

Among other things, the 2012 EED required EU member countries to:

- Set energy efficiency targets, based on primary or final energy consumption, primary or final energy savings, or energy intensity.

[1] Energy efficiency is not fully devolved as set out in Table 2.1, related policies, for example, taxation remains a reserved policy.

- Require energy companies to save at least 1.5% of the annual energy sales to final consumers, or implement other measures that achieve the same savings, such as improving the efficiency of heating systems and thermal performance of buildings.
- Require large companies to regularly audit their energy consumption to identify ways to reduce it. National incentives should also support energy audits for small and medium-sized enterprises.
- Present national building renovation strategies and measures to improve the energy efficiency in public buildings.
- Ensure that central governments purchase only products, services, and buildings with a high energy efficiency performance.

The EED also asks EU member countries to report annually to the European Commission on its progress towards the EED. The United Kingdom’s 2017 National Energy Efficiency Action Plan (NEEAP) and Annual Report provide an overview of energy consumption trends and savings achieved across the UK economy through the United Kingdom’s main energy efficiency policies.

For the horizon to 2030, the European Union targets 32.5% energy savings compared to a reference case, with a clause for an upwards revision by 2023. The target is set under the EU Directive 2018/2002 on energy efficiency which was published in the Official Journal of the European Union on 21 December 2018. EU member countries will also be obliged to establish specific energy efficiency measures to the benefit of those affected by energy poverty.

Other EU directives

The Energy Performance of Buildings Directive (EPBD) (2010/31/EU) requires all new buildings to be nearly zero-energy from the end of 2020. New public buildings must be nearly zero energy from the end of 2018. In accordance with the directive, EU countries must draw up national plans to increase the number of nearly zero-energy buildings. A new version of the 2010 EPBD came into force in 2018 (2018/844/EU). It aims to accelerate the cost-effective renovation of buildings and decarbonise the national building stocks by 2050. For this, EU member countries will have to adopt stronger long-term renovation strategies.

Other important EU legislation comprises the Ecodesign Directive (2009/125/EC) and the Energy Labelling Regulation (EU 2017/1369). The Ecodesign Directive aims to improve the energy efficiency of energy-related products, which includes products and appliances in both the household and commercial sectors, by removing the least-efficient and worst-performing products from the market. This is achieved through product-specific EU Ecodesign regulations, which set minimum energy performance requirements for products and energy labels for products set under the Energy Labelling Regulation, which provides information through an A+++ (most efficient) to G (least efficient) scale that enables consumers to choose the most efficient products. New labels have also been agreed for some domestic products which will see A+++ - G categories replaced by A – G categories to allow consumers to distinguish more easily between energy efficiency classes. The EU minimum performance and labelling standards are agreed for some 30 product categories in addition to the cross-cutting EU labelling rules and measures on wasteful “standby and off mode”, covering household products, televisions, washing machines, fridges, and lighting, as well as space heaters, boilers, professional refrigeration, and ventilation units. These EU standards have a direct effect in the United Kingdom.

Under Article 4 of the EU End-use Efficiency and Energy Services Directive, the United Kingdom was required to meet an indicative national energy savings target for 2020 of 136.5 terawatt hours (TWh) or 9% of the 2001/05 average final energy consumption excluding energy consumption within the EU Emissions Trading System. BEIS concluded that the household sector accounted for 50% of the total expected savings by 2016, with private and public sector savings contributing 26% of the total savings and transport 25% (see Table 5.1 for total savings made).

Table 5.1 Overview of energy efficiency measures in the United Kingdom [TWh]

Energy efficiency improvement programmes, energy services, and other measures planned to achieve the energy efficiency target	Annual energy savings expected by the end of 2012	Annual energy savings expected by the end of 2016	Annual energy savings expected by the end of 2020
Household sector	61.9	81.7	102.3
Building regulations	33.1	46.3	55.7
Supplier obligations	26.9	28.5	26.7
Regulation of energy-using products	2.0	6.2	12.9
Smart meters/in-home displays	0.8	7	8
Private and public sectors	31.7	42.2	58.9
Building regulations	13.3	14.8	18.6
Business smart metering	0	1.1	3.8
Carbon trust programmes	10.6	5.0	1.7
Public sector loans (Salix Finance)	0.4	0.7	1.4
CCA and CCL	3.8	6.7	10.1
CRCEES	1.1	3.6	5.1
ESOS		3.2	3.1
Regulation of energy-using products	2.5	7.2	15.2
Transport	28.3	40.6	56.3
EU voluntary agreement to 2009	24.9	31.1	31.5
EU new car CO_2 target plus complementary measures: 130 gCO_2/km in 2015 and 95 gCO_2/km in 2020	0	4.4	14.9
EU new van CO_2 target: 147 gCO_2/km in 2020	0.0	0.2	2.3
HGV industry improvements and low rolling resistance tyres	0.0	0.4	2.1
Low carbon buses and SAFED bus driver training	0.1	0.2	0.4
Local sustainable transport fund	3.2	4.3	3.9
Rail electrification	0.0	0.0	1.2
Total energy and carbon savings[2]	**121.9**	**164.6**	**217.5**

Notes: SAFED = Safe and Fuel Efficient Driving. gCO_2/km = grammes of carbon dioxide per kilometre

Source: UK Government (2017a), *UK National Energy Efficiency Action Plan*, https://ec.europa.eu/energy/sites/ener/files/documents/uk_neeap_2017.pdf.

[2] This includes only quantified policies. Notable exceptions include savings from tax policy, such as the CCL, and enhanced capital allowances.

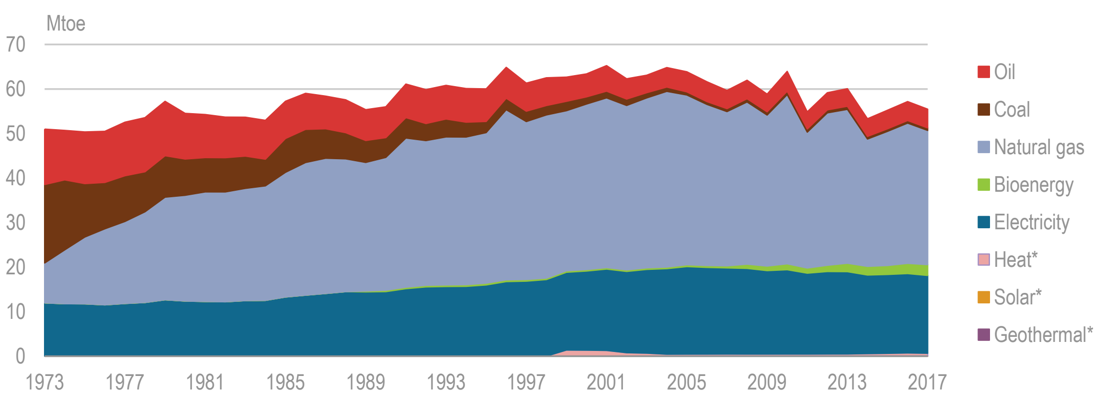
Energy consumption trends, efficiency, and policies

In 2017, the residential and commercial sectors (including small shares for agriculture, forestry, and fishing) together accounted for 44% of the TFC in the United Kingdom. Transport consumed the second largest share with 33% of the TFC. Industry, including the non-energy use of fuels, accounted for the remaining 24%.

Residential and commercial

Residential and commercial energy consumption consists mainly of energy use in buildings, largely for heating. The long-term trend in building energy consumption has been a shift from oil and coal consumption towards natural gas and electricity (Figure 5.6). In 2017, the residential and commercial sectors consumed 55.5 Mtoe, of which 54% was natural gas and 31% electricity. The rest was mainly oil (8%) and biofuels (4%), and small shares of coal, district heating, solar, and geothermal.

Figure 5.6 TFC in residential and commercial sectors by source, 1973-2017



Natural gas and electricity together accounted for 86% of the total energy consumption in the residential and commercial sectors in 2017.

* Negligible.

Note: The commercial sector includes commercial and public services, agriculture, forestry, and fishing.

Source: IEA (2019), *World Energy Balances 2019 First edition (database)*, www.iea.org/statistics/.

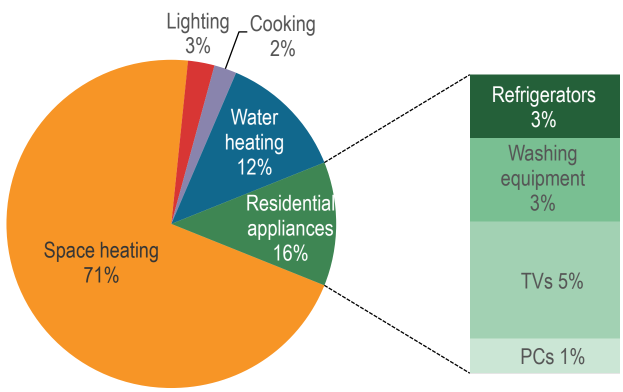
Improved energy efficiency in buildings has contributed to a reduction in the total energy consumption in the residential and commercial sectors. From 2007 to 2017, energy consumption declined by 7% (as shown in Figure 5.4). However, despite recent improvements, the United Kingdom is still among the highest energy consumption per floor area for residential space heating in the IEA. In 2015, buildings in the United Kingdom consumed on average 0.49 gigajoules per square metre (GJ/m^2), which was the fourth-highest level among IEA member countries and shows the potential for further improvements (IEA, 2018).

Space and water heating account for most of energy consumption in buildings. In the residential sector, nearly 80% of energy consumption is for heating, and the remaining mostly household appliances (Figure 5.7). The main source of heating in the United Kingdom is natural gas.

Thanks to the improved energy efficiency in buildings, residential space heating demand has reduced significantly (see details on building stock in Box 5.1 and Figure 5.8). Between 2000 and 2015, energy use for space heating of one square metre fell by 28% (after temperature corrections) thanks to a switch to high-efficiency condensing boilers.

Unlike heating, energy consumption for appliances has increased slightly in recent decade because efficiency improvements have been outpaced by the growth in energy consumption in personal computers (PCs) and other devices.

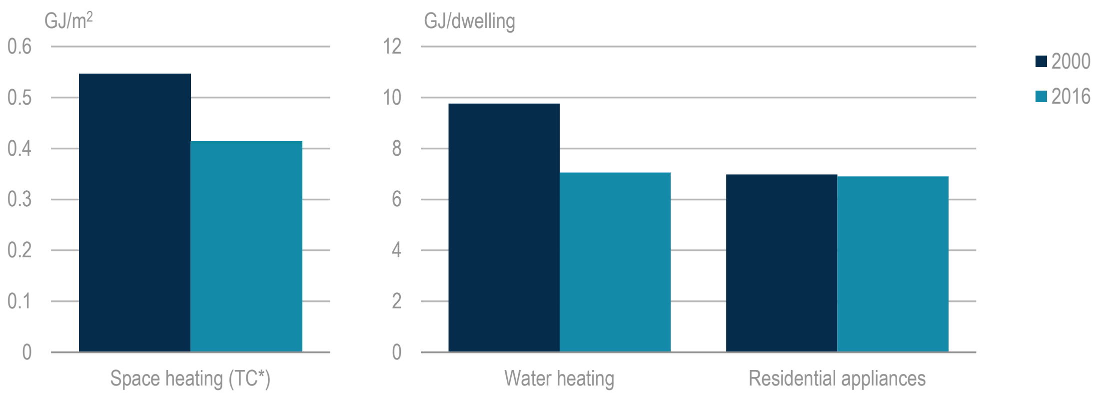
Figure 5.7 Breakdown of the TFC in the residential sector, 2016



Most of the energy consumption in residential buildings is for heating purposes, and space and water heating together account for over 80% of the total energy demand in the sector.

Source: IEA (2018), *Energy Efficiency Indicators 2018*, www.iea.org/statistics/.

Figure 5.8 Residential energy intensity, 2000 and 2016



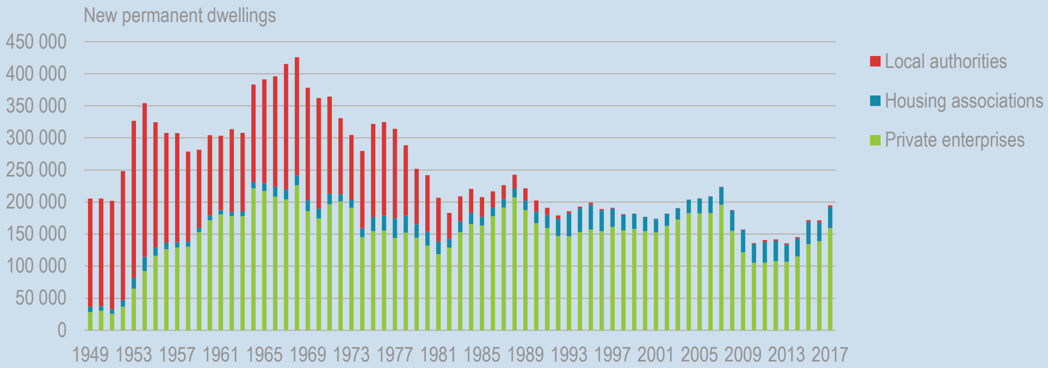
The United Kingdom has significantly improved energy intensity for space and water heating in residential buildings, but still has among the least-energy-efficient buildings in the IEA.

Source: IEA (2018), *Energy Efficiency Indicators 2018*, www.iea.org/statistics/.

Box 5.1 Housing stock in the United Kingdom

The United Kingdom has one of the oldest housing stocks in Europe with over one-third of homes built before 1945 and less than a quarter built since 1980. The commercial building stock is more modern with 40% of the stock built in the past 30 years (UK Government, 2017c and 2017d). The UK housing stock is growing by around 150-200 thousand new permanent dwellings per year (Figure 5.9). This corresponds to roughly 0.5% of the total housing stock in the United Kingdom. The number of new dwellings fell in 2008-10 during the financial crisis, but has picked up in recent years. However, the construction rate is significantly lower than in the 1950-70s, when local authorities investedd in housing. Most new dwellings are built by private enterprises and a smaller share by housing associations. In 2017, private enterprises accounted for 82% of the total 195 000 new dwellings.

Figure 5.9 New completed permanent dwellings in the United Kingdom by tenure, 1949-2017



Around 200 000 new dwellings are built in the United Kingdom every year, mostly by private companies.

Source: UK Government (2018a), Live Tables on Housing Supply: Net Additional Dwellings", www.gov.uk/government/statistical-data-sets/live-tables-on-house-building;

MHCLG (2017b), Dwelling Stock Estimates: 2017, England, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/710382/Dwelling_Stock_Estimates_2017_England.pdf.

Buildings

The United Kingdom has been implementing energy performance certificates (EPCs) for buildings that are bought, sold, or rented to provide certificates graded on a scale of A (most efficient) to G (least efficient).

The Energy Efficiency (Private Rented Property) (England and Wales) Regulations 2015 set new standards for energy efficiency in rented property. As of 1 April 2018, such property must be at minimum EPC band E before they can be let on a new tenancy. Part L (Conservation of fuel and power) of the Building Regulations sets minimum energy performance standards for new buildings and for works to existing buildings (i.e. extensions, conversions, and replacement windows and boilers).

Since 1996, the proportion of dwellings in the lowest energy efficiency bands F or G has decreased to 5% or 1 in 20 homes, most of them being rented property or social housing.

Over half of the social housing dwellings have standards below EPC band C (MHCLG, 2017a). Therefore, recent government efforts focus on upgrading the performance of houses for the fuel poor[3] and for rental property (EPC E as of April 2018) as well as social housing.

The Clean Growth Strategy (UK Government, 2017b) aims to upgrade the energy performance of buildings of all the fuel poor to EPC band C by 2030 and as many homes as possible by 2035, where practical, cost-effective, and affordable. The Committee on Climate Change (CCC) flagged in their assessment of the Clean Growth Strategy the need to improve significantly the energy efficiency standards for new buildings to avoid costly retrofitting (CCC, 2018). The buildings mission, announced through the Clean Growth Grand Challenge, aims to at least halve the energy use of new buildings by 2030 using new technologies and modern construction practices. This includes a building's use of energy for heating, cooling, and appliances.

An independent review of building regulations and fire safety, led by Dame Judith Hackitt, concluded that "what is being designed is not what is being built" and that a new system approach to buildings regulations design, implementation, and compliance was needed with a focus on the health and safety of multi-occupancy higher-risk residential buildings that are ten storeys or more in height (Hackitt, 2018). The government intends to consult on amending the building regulations to promote low-carbon and higher-energy efficiency heating, ventilation, and air conditioning.

The United Kingdom was the first country to introduce, in 1994, an obligation on suppliers to meet energy efficiency targets by upgrading insulation or appliances (through the Energy Efficiency Standards Performance and later the Energy Efficiency Commitment). Today, the ECO requires large energy suppliers to deliver energy efficiency improvements, such as insulation and heating system upgrades. ECO focuses on the poorest and most vulnerable households. Since ECO was introduced in 2013, it has installed over 2.4 million measures in over 1.8 million homes. Final costs are paid by the consumers with an estimated total cost of British pounds (GBP) 640 million per year. ECO is set to continue until 2022 (Clean Growth Strategy).

Several other energy efficiency schemes were funded through general taxation, which included the Green Deal Home Improvement Fund (2014-15), the Green Deal Communities Fund (2014), the Central Heating Fund (2015), and the Thermal Efficiency Innovation Fund (2017-18). A green deal loan scheme (pay as you save) did not get the level of take up that was hoped for and the government investment in it ended in 2015, although the statutory framework remains and new owners bought the Green Deal Finance Company in 2017.

Heat

In the United Kingdom, 85% of dwellings had gas central heating in 2016 (UK Government, 2017a). One-third of the boilers in these systems are less than three years old, but almost two-thirds of warm air systems and storage radiators are over 12 years

[3] The definition of fuel poor differs across the UK. In England, a household is deemed to be in fuel poverty if it has required heating costs that are above the national median, and meeting these costs places the household below the official poverty line (60% of median income). In 2015, around 11% of households were in fuel poverty in England.

old (UK Government, 2017a). Since 2005, the standards for gas boilers in the United Kingdom have been among the highest in the world.

More stringent standards for domestic heating came into force in April 2018 under the so-called policy (which amended the Domestic Building Services Compliance Guide). The standards apply in England only, whenever a new boiler is installed in an existing system. They require all gas boilers installed into existing systems to have an Energy-related Products (ErP) directive (ErP) (Eco-design)[4] efficiency of at least 92%, have time and temperature controls installed at the same time, and additional energy efficiency measures (weather compensation, load compensation, flue gas heat recovery, and smart controls) when replacing the boiler. This is estimated to improve the efficiency and control of around 1.2 million heating systems every year. The broader Boiler Plus policy does not apply to oil boilers; however, the policy did introduce a requirement for time and temperature controls to be installed alongside oil boilers in the rare cases where those controls are not yet in place.

As described in the Chapter 4, the Renewable Heat Incentive (RHI) supports renewable heat technologies, such as biomass, biomass combined heat and power, biomethane, biogas, heat pumps, solar thermal, and geothermal. Under the Clean Growth Strategy, the government aims to boost the development of heat networks to drive the long-term decarbonisation of heating. District heating represents only 2% of the total heat demand.

The UK gas distribution companies in the North of England (Northern Gas Networks and Cadent, together with Norway's Equinor) have studied the potential of converting natural gas into hydrogen (and CO_2, which could be stored offshore) to decarbonise heat with detailed plans for the switch to hydrogen in 2028 and a seven-year programme to convert 3.7 million homes and 40 000 businesses in cities such as Leeds, Newcastle, York, Manchester, and Liverpool (both using existing gas pipelines and building new ones).

The government aims to phase out the installation of high-carbon fossil fuel heating in new and existing buildings off the gas grid during the 2020s, initially with new buildings. As a first step towards this commitment, the government published the *Future Framework for Heat in Buildings: Call for Evidence* in March 2018 (UK Government, 2018b), with the objective to seek views on measures the government could take during the 2020s to phase out high-carbon fossil fuel heating in off gas grid buildings and recognised the importance of both heat decarbonisation and improving the energy efficiency of buildings.

Transport

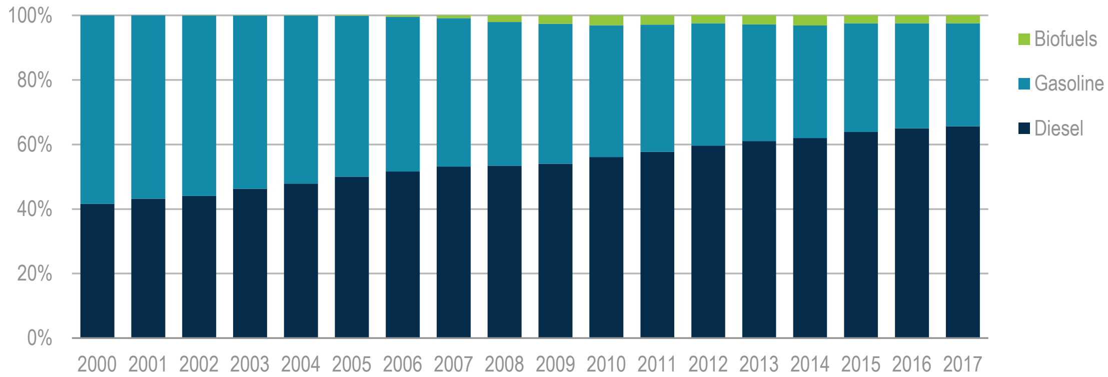
Transport accounts for around one-third of the TFC, and the share is increasing. In 2017, the transport sector consumed 41.5 Mtoe, up by 4% in the previous three years. Oil fuels accounted for 97% of total transport consumption in 2017, mainly diesel (65%) and gasoline (30%) and 2% from kerosene-type jet fuel in domestic aviation (Figure 5.10).

[4] The ErP is an energy efficiency rating system introduced by the European Union in September 2015 and replaced the United Kingdom's Seasonal Efficiency of Domestic Boilers UK rating system.
More information on the Boiler Plus policy is available at:
https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/718569/Boiler_Plus_Factsheet_v3.pdf

Biodiesel and biogasoline accounted for 1% each and electricity used in trains accounted for the remaining1% of transport energy demand (Figure 5.11).

Road transport made up 93% of the energy demand in transport in 2017 (IEA, 2019). The rest is consumed in rail, domestic navigation, and domestic aviation, with around 2% each (international navigation and aviation are not included in TFC). Of the total road transport, passenger vehicles, which include buses, account for around two-thirds of energy consumption and freight trucks for the remaining third (IEA, 2018).

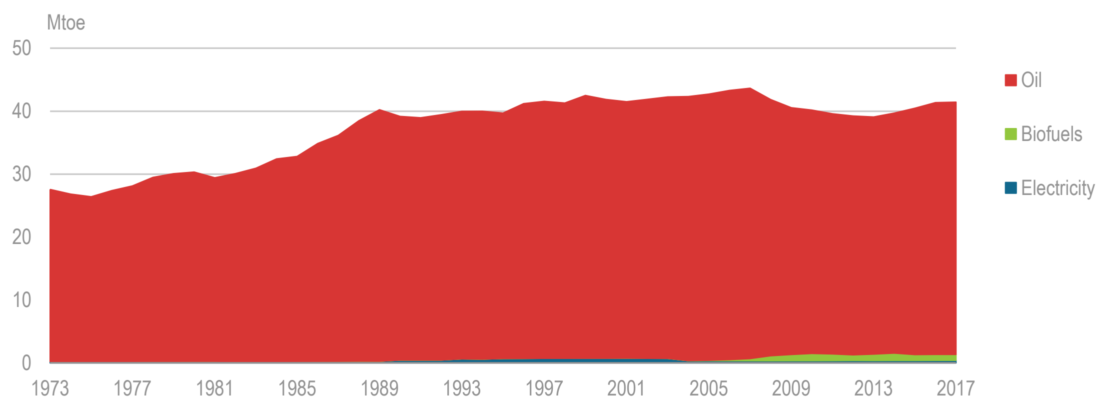
Figure 5.10 Energy consumption in road transport by fuel, 2000-17



The share of diesel in road transport increased from 42% in 2000 to 65% in 2016.

Source: IEA (2019), *World Energy Balances 2019 First edition (database)*, www.iea.org/statistics/.

Figure 5.11 TFC in transport by source, 1973-2017



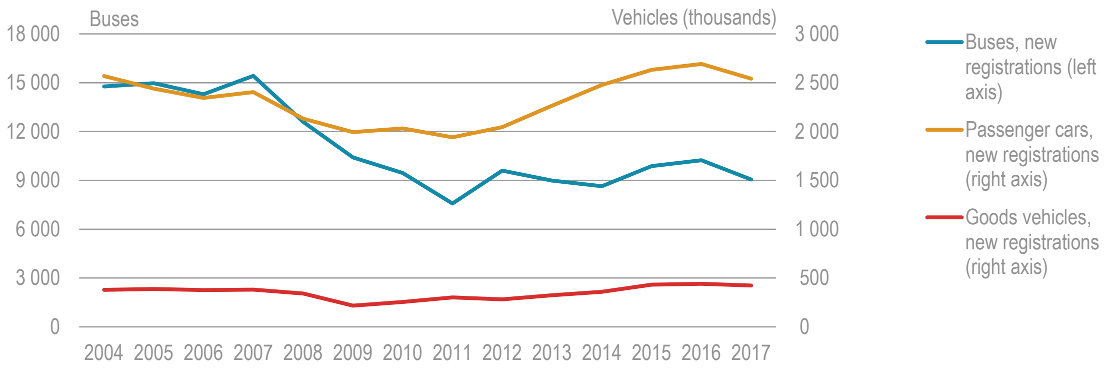
Transport energy demand is relatively stable at around 40 Mtoe, and nearly completely dependent on oil-based fuels.

Note: The transport sector demand excludes international aviation and navigation.
Source: IEA (2019), *World Energy Balances 2019 First edition (database)*, www.iea.org/statistics/.

Overall new car registrations have increased (Figure 5.12). The number of diesel cars has increased steadily since the 1980s, and in the past decade gasoline consumption has declined significantly in passenger cars and road transport as a whole (Figure 5.10). In 2017, diesel accounted for nearly half of the energy consumption in passenger cars and 65% of the total road transport energy use.

Biofuels have also increased in the past decade, thanks to the biofuels blending policy, but accounts for only around 2% of energy use in road transport. The shift from gasoline to diesel in passenger cars contributed to improving the energy efficiency of the vehicle fleet. Between 2000 and 2016, energy consumption per travelled personal kilometre in passenger transport was reduced by 15%. However, an increased reliance on diesel vehicles also has a negative effect in terms of more local air pollution. Energy efficiency efforts are mainly expected to come from the further decarbonisation of the vehicle fleet (see Chapter on Energy and Climate Change).

Figure 5.12 New registered buses and passenger cars, 2004-17



New registrations for both passenger cars and buses fell after the financial crisis of 2008, but buses have not recovered in the same way as new cars.

Source: European Commission (2018), *Statistical Pocketbook 2018*, DG Transport, https://ec.europa.eu/transport/facts-fundings/statistics/pocketbook-2018_en.

Industry

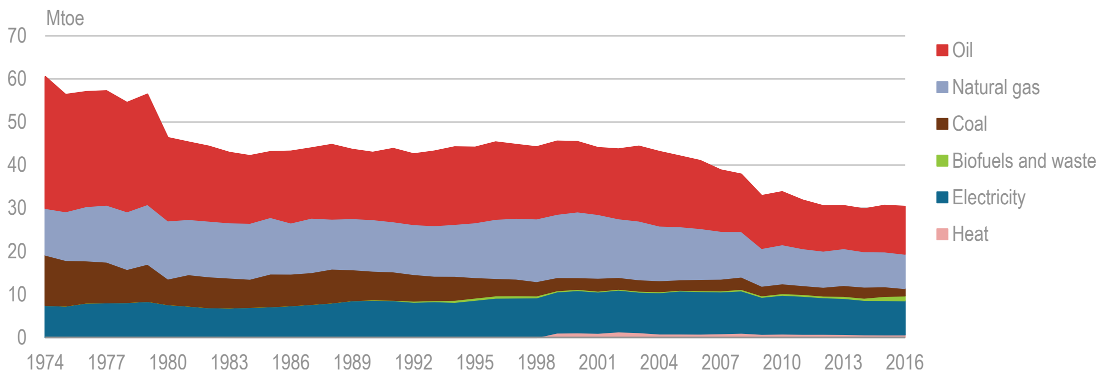
The industry sector has gone through the largest changes in the recent decade in terms of final energy consumption. From 2007 to 2017, industry energy consumption fell by 22%, but in recent years it has stabilised at around 30 Mtoe (Figure 5.13). In 2017, the total industry energy consumption was 30.3 Mtoe, of which 24% was the non-energy use of oil and gas in process industries.

Compared to other sectors, industrial energy consumption is more divergent in terms of fuels. In 2017, oil accounted for 36% of the industry energy demand. Two-thirds of the oil was used in non-energy purposes. Natural gas each accounted for 27% and electricity for 26% of the total energy consumption in industry, and the rest was coal (5%), bioenergy and waste (3%), and district heating (2%). Whereas all the other fuels have decreased in recent years, bioenergy and waste more than doubled between 2014 and 2017, in the attempt to decarbonise energy consumption in the sector.

The United Kingdom has a large chemical and petrochemical industry sector, which accounted for 28% of total energy consumption in industry in 2016 (Figure 5.14). Largest share of the chemical and petrochemical consumption was oil products (mainly liquefied petroleum gases, naphtha and ethane) used as feedstock in the processes. Other large energy consuming industries mostly use natural gas and electricity. Energy consumption has fallen across most industries in recent years. From 2006 to 2016, construction was the only industry sector to increase its energy consumption.

In 2017, industry accounted for 27% of the UK energy-related CO_2 emissions and, therefore, energy efficiency and decarbonisation are mutually supportive (see also Chapter on Energy and Climate Change).

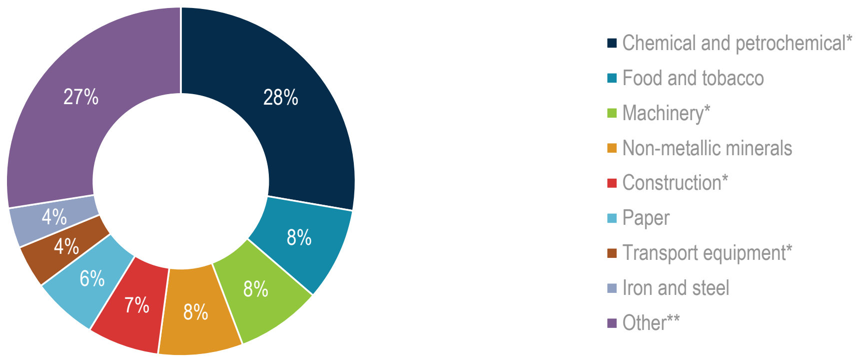
Figure 5.13 TFC in industry by source, 1974-2016



The industry sector's energy consumption has declined by 25% over the past decade, but has stabilised at around 30 Mtoe in recent years.

Notes: Includes non-energy consumption.
Source: IEA (2019), *World Energy Balances 2019 First edition (database)*, www.iea.org/statistics/.

Figure 5.14 Energy consumption in manufacturing industry sectors, 2017



The chemical and petrochemical industry stands out as the industry with the highest fuel consumption, most of which is oil products used as feedstock in the processes.

*Includes fuels for non-energy use.
**Other industries include non-ferrous metals, wood and wood products, mining and quarrying, textile and leather, and non-specified industry consumption.
Source: IEA (2019), *World Energy Balances 2019 First edition (database)*, www.iea.org/statistics/.

Policies

Energy efficiency improvements in industry are encouraged through several schemes, which include the Climate Change Agreement (CCA) scheme, the Carbon Reduction Commitment CRC Energy Efficiency Scheme (CRCEES), and the Energy Savings Opportunity Scheme (ESOS).

The CCA scheme, which is voluntary, has been in place since 2001 and allows energy-intensive participants in 53 sectors a reduced Climate Change Levy (CCL) in exchange for signing up to energy efficiency or carbon reduction targets. In 2015 and 2016, the number of industrial facilities that participated in the voluntary scheme fell slightly from 3 416 to 3 186. It was estimated at the start of the current scheme in 2013 that CCAs accounted for 13% of the total UK energy use, and 56% of the UK industrial energy use.

The CRCEES, based on the Carbon Reduction Commitment from April 2010, aims to improve energy efficiency and cut emissions for large public and private companies. There were 1 915 participants registered for 2016-17. The scheme features a range of drivers (information, reputational, and financial) that aim to encourage organisations to develop energy management strategies. The government has decided to close the CRCEES after the current phase (covering emissions to March 2019) ends, citing efforts to reduce red tape for industry and announcing that the reporting elements would be taken forward from April 2019 through a new streamlined energy and carbon framework extending to an estimated 11,900 participants. The UK central government departments and devolved administration also have to participate in the CRCEES.

The ESOS was launched in July 2014 and requires large companies (including electricity generators) to perform energy audits to meet the requirements of Article 8 in the EU EED. There are no exemptions from ESOS based on participation in the CCA scheme. The government estimates that ESOS covers around 50% of non-domestic electricity use and 60% of non-domestic gas use.

The Industrial Energy Efficiency Accelerator (IEEA) supports, with a total budget of GBP 9.2 million funding, innovation pilots in industry to lower the cost of near-market energy-efficient technologies for a range of industrial sectors through demonstration projects. IEEA is delivered by the Carbon Trust.

The CCAs and ESOS provide United Kingdom companies with an incentive to improve their energy management and performance. In the case of the ESOS, this incentive extends to the implementation of an energy management system certified to the ISO 50001 global standard. If at least 90% of a company's energy use is covered by an ISO 50001 certification, it is seen to have complied with the obligations of the ESOS. There were 3 078 UK ISO 50001 certifications in 2017, which was 13% of the global total and made the United Kingdom second only to Germany in terms of number of certifications globally. After the introduction of the ESOS, ISO 50001 certifications in the United Kingdom nearly quadrupled from 376 in 2014 to 1 464 in 2015, with this number nearly doubling again in 2016. Although growth slowed in 2017 (only a 9% increase), the incentive provided by the ESOS for ISO 50001 certification does appear to have had some impact.

The Clean Growth Strategy commits to improving business energy efficiency at least by 20% by 2030 through a package of measures that includes: improved energy efficiency regulations for new and existing commercial buildings, raising minimum energy performance standards for rented property, introducing an industrial energy efficiency scheme, joint industrial energy efficiency and decarbonisation plans in seven areas, international leadership on carbon capture, usage, and storage (CCUS), while deploying CCUS at scale in the United Kingdom, phasing out fossil fuel heating in new and existing businesses that are not connected to the gas grid and encouraging the decarbonisation of industrial heat.

Industrial decarbonisation and energy efficiency action plans

Alongside the Clean Growth Strategy, BEIS announced seven action plans for energy-intensive sectors (cement, ceramics, chemicals, food and drink, glass, oil refining, and pulp and paper), developed by government and industry together in the coming years to identify voluntary commitments (see Table 5.2). The plans build on the Industrial Decarbonisation and Energy Efficiency Roadmaps to 2050 (UK Government, 2015), which set out a series of potential pathways for emissions reductions that could be achieved in different decarbonisation scenarios. The action plans extend beyond energy-intensive manufacturing sectors to capture less-intensive sectors, such as food and beverage manufacturing. These sectors have been identified by the IEA as a potential source of future energy savings as a result of measures to improve the efficiency of low-temperature process heating through the deployment of electric heat pumps and to improve electric motor-driven systems through strengthened standards and increased adoption of energy management systems, such as ISO 50001. UK companies subject to the ESOS can obtain an exemption from the audit requirement if they obtain ISO 50001 certification, which provides some level of incentive for adoption.

Table 5.2 Seven industrial decarbonisation and energy efficiency action plans

Sector	Pathway	Base year emissions ($MtCO_2e$)	Relative emission reduction in 2050	Absolute emission reduction in 2050 ($MtCO_2e$)	Technology groups
Cement	BAU	7.5	12%	0.9	Others: energy efficiency
	Max Tech – with or without carbon capture		33-62%	2.5-4.7	CCS, fuel switching to biomass, others, and cementitious substitution
Ceramics	BAU	1.3	27%	0.3	Energy efficiency, others, material efficiency, fuel switching, biomass
	Max Tech		60%	0.8	Electrification of heat, CCS, energy efficiency, biomass, others, material efficiency, fuel switching
Chemicals	BAU	18.4	31%	5.8	Biomass, energy efficiency, CCS, fuel switching, clustering, others
	Max Tech – with and without biomass		79-88%	14.6-16.1	CCS, biomass, others, energy efficiency, clustering, fuel switching
Food and drink	BAU	9.5	40%	3.8	Energy efficiency, biomass, electrification of heat, material efficiency, CCS, other, fuel switching
	Max Tech – with and without electrification of heat		66-75%	6.2-7.2	Electrification of heat, energy efficiency, biomass, other, material efficiency, CCS, fuel switching
Glass	BAU	2.2	36%	0.8	Energy efficiency, material efficiency, other, fuel switching

Sector	Pathway	Base year emissions ($MtCO_2e$)	Relative emission reduction in 2050	Absolute emission reduction in 2050 ($MtCO_2e$)	Technology groups
	Max Tech – with and without carbon capture				CCS, electrification of heat, fuel switching, material efficiency, energy efficiency, other
Iron and steel	BAU	23.1	15%	3.4	Energy efficiency, material efficiency, fuel switching
	Max Tech		60%	13.9	CCS, energy efficiency, clustering, material efficiency, fuel switching
Oil refining	BAU	16.3	44%	7.2	Energy efficiency, fuel switching
	Max Tech		60%	10.4	Energy efficiency, CCS, fuel switching
Pulp and paper	BAU	3.3	32%	1.0	Energy efficiency, electrification of heat
	Max Tech – clustering and electrification		98%	3.2	Energy efficiency, clustering, electrification of heat
	Max Tech - biomass		98%	3.2	Biomass, energy efficiency, electrification of heat

Notes: CCS = carbon capture and storage. BAU = business as usual. $MtCO_2e$ = million tonnes of carbon dioxide-equivalent. Max Tech – maximal technical performance.

Source: UK Government (2017e), *Industrial Decarbonisation and Energy Efficiency Action Plans, Summary Document*, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/651276/decarbonisation-action-plans-summary.pdf.

Assessment

Improving energy efficiency is central to meeting the carbon budgets and the long-term goal of cutting GHG emissions by at least 80% from 1990 to 2050. The 2017 UK Clean Growth Strategy outlines significant policy proposals in energy efficiency over the longer term through the lens of emissions reductions.

The wide range of UK energy efficiency policies and programmes and their spread across government highlights the value of a coordinated and well-articulated framework on energy efficiency policies and programmes to draw together the many responsible areas.

The United Kingdom should ensure a strategic approach to energy efficiency policy and delivery (funding programmes), coordinate effectively across all sectors, increase the visibility of government policies and actions, and maximise the impact of individual measures. The strategy notes that building an energy efficiency market requires much more third-party finance than seen to date.

Many UK energy efficiency regulatory policies are based on or are a part of EU requirements. In the context of Brexit, the government in its Clean Growth Strategy underlined that it "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."

Appliances

Minimum environmental performance standards (MEPS) and labelling for around 30 energy-using product categories in the United Kingdom are currently covered under EU legislation. The commitment, as mentioned in the Clean Growth Strategy, to continue to meet or go beyond the current standards is important and will enable the United Kingdom to cost-effectively reduce energy bills and carbon emissions.

The development of a forward plan for the continued upgrading and expansion of these standards into the future will be an important body of work so as to provide clear signals to the market and not lose momentum in this space.

Buildings and heat

The challenge of improving the energy efficiency in existing buildings is a large one and one in which the United Kingdom has made significant strides. The building stock is growing at a rate well below 1% per year and, based on previous demolition rates, 97-99% of the existing housing stock will still be standing in 2050. Encouraging energy efficiency improvements in buildings is a complicated policy challenge in most countries. The CCC noted a recent upturn in building emissions in the United Kingdom.

The ECO has funded substantial work on domestic insulation, in particular over the past decade, but slowing in recent years, and is set to continue with a commitment to upgrade a further million homes between 2015 and 2020 and with a commitment to extend support for home energy efficiency out to 2028. The renovation task is large and the announced continuation of the ECO is unlikely to deliver more than a small proportion of this.

The government has recognised this challenge and aims to upgrade all fuel-poor homes to EPC band C by 2030, as far as reasonably practicable, and declared an aspiration for as many homes as possible to be EPC band C by 2035 where practical, cost-effective, and affordable. A key new initiative that has great potential is the introduction in 2018 of a requirement for a minimum energy performance level of EPC band E for new leases of private rented sector properties in the residential and commercial properties.

Also announced is an ambition to develop a long-term trajectory to improve the energy performance standards of private rented sector homes, with the aim to upgrade as many as possible to EPC band C by 2030 where practical, cost-effective, and affordable. A long-term trajectory is also due to be consulted on in summer 2019 for private rented non-domestic buildings. These are very welcome developments, particularly after the relatively poor uptake of the programme based on the Green Deal in recent years, but will require significant investment and resources over those already been announced to ensure delivery of the desired outcomes.

Experts concluded that the Green Deal requirements were too stringent for the type of renovation and spending of the funds. The National Audit Office found that the Green Deal did not provide value for money and that the ECO leads to a rise in the final prices for consumers (NAO, 2016), as it is paid for through energy bills (although it leads to net savings over time). The National Infrastructure Commission (2017) called upon the government to upgrade the building stock, both residential and commercial, as the rate of efficiency improvement in the UK housing stock had slowed.

The CCC in its assessment of the Clean Growth Strategy has flagged these commitments as needing firmer implementation plans. Clear action plans are needed to improve the energy efficiency of poorly performing building stock, both residential and commercial, through necessary upgrades to the thermal shell of buildings and upgrades to major energy-using systems, such as heating, hot water, ventilation, and lighting. Given the scale of the task, it is likely this will require a full suite of financial, regulatory, and promotional policy interventions. These could include green financing, tax concessions, subsidy through ECO, regulation through minimum standards for rental properties, mandatory building energy certificates, building code requirements for major renovations, and standards for building components, such as boilers, the promotion of energy efficiency renovation, which includes support information and the demonstration of effective energy-efficient renovations to the public, business, and building professionals.

The government increased the energy efficiency requirements for new buildings significantly in recent years, but backed away from its earlier commitments to set in place zero carbon standards in 2016 for homes and for commercial buildings in 2019. The government announced the intention through the Buildings Mission (UK Government, 2018c) to reduce by half the energy use of new buildings by 2030. In the Clean Growth Strategy there is an undertaking to consult on strengthening the energy performance standards for new and existing homes under Building Regulations, which includes future-proofing new homes for low-carbon heating systems. It is important that these be carried through and that a clear trajectory be established for future changes for both residential and commercial buildings. The government aims to put forward new regulations after the buildings safety review.

The CCC flagged in their assessment of the Clean Growth Strategy the need to significantly improve energy efficiency standards for new buildings, to avoid costly retrofitting. It will be important to also consider the role of onsite renewables and battery technology, electric vehicles (EVs) charging, and the likely need to mandate these if a zero-carbon ambition is to be achieved.

The government further improved standards on 1.2 million boilers per year in England and required installations of control devices to help people save energy. This is a welcome efficiency initiative given the predominance of gas and, to a lesser extent, oil boiler heating in the United Kingdom. The improvement in the energy efficiency performance of other key energy-using systems and building products should also be considered under an approach that focuses on the entire built environment.

The opportunity to improve the ability of the EPC to reflect the actual energy performance using new sources of data, which include meter data and building information, and to improve the scope and frequency of EPC through expanded trigger points should be pursued.

Transport

A major new commitment is the phasing out of the sale of new petrol and diesel cars and vans by 2040. The Road to Zero Strategy (Government, 2018d) was presented in July 2018 and sets ambitious goals for the roll-out of ultra-low emissions vehicles, for at least

50% – and as many as 70% – of new car sales by 2030 and a broader strategy to boost the flexibility and smartness of the power system.

Energy efficiency is mainly promoted by the need to reduce GHG emissions in the sector, although it is also promoted indirectly through transport fuel taxes, which are high by international comparison. The United Kingdom is planning further emissions reductions by enhancing the efficiency of all vehicles, reducing the carbon intensity of fuels, promoting ultra-low emission vehicles, and investing in a low-carbon infrastructure.

It will be important for the United Kingdom to continue to improve the minimum standards and labelling for vehicle fuel efficiency to at least the aspiration represented by the current EU standards, which include the imminent extension to heavy-duty road vehicles. The proposed change to EU standards in 2021 should be reflected in the United Kingdom.

There are also a range of initiatives internationally in aviation and maritime energy efficiency, to which the United Kingdom is a party, and it is expected these will be continued. For the rail system there is a commitment to reduce the reliance on diesel engines, which includes trials of new technology and hybrid engines, and to encourage the shift from road to rail transport where cost-effective. The increased use of public transport, the take up of EVs in public transport, and the greater use of cycling and walking as a means of urban commuting are announced policies. These are welcome initiatives.

Industry and business

The Clean Growth Strategy commits to improving business energy efficiency at least by 20% by 2030. Heavy industry and manufacturing is a declining proportion of the economy as the United Kingdom moves to a more services-based economy, and this is reflected in the long-term decline of industry emissions.

The Clean Growth Strategy commits to establish a new industrial energy efficiency scheme to help large companies install measures to cut their energy use and bills, with further details to come. The government is also reviewing the current ESOS for large energy users. Consideration could be given to introducing a level of requirement so the identified savings may have a greater scale of realisation. Promoting energy efficiency and emissions reduction in businesses and industry can be supported through effective incentives, tax treatment, financing, and support programmes. As the CCC observed, further clarity is needed on how this will be achieved.

The Clean Growth Strategy commits the United Kingdom to publish joint industrial decarbonisation and energy efficiency action plans with seven of the most energy-intensive industrial sectors. This represents a significant opportunity if appropriately resourced. The Industrial Decarbonisation and Energy Efficiency Roadmaps to 2050 (UK Government, 2015) and action plans for heat intensive industrial sectors will need to be carried through with industry.

Public sector

The government has an established leadership role in energy efficiency, both in adopting higher standards for its own facilities and operations and in using its procurement power to influence the market and support emerging technologies, such as EVs.

In the public sector, the United Kingdom should continue to lead by example with energy efficiency and emissions targets for public sector activity and facilities, which include innovative resourcing and monitoring, Display Energy Certificates, and the exercise of government procurement power in purchasing energy-efficient vehicle fleets (including EVs), leases, and products.

Recommendations

The UK government should:

- Buildings and appliances
  - Commit to clear actions to improve the energy efficiency of poorly performing existing building stock, both in residential and commercial sectors.
  - Improve energy efficiency requirements for new buildings by implementing the Grand Challenge and adapting the building codes. Set out a trajectory to affirm the long-term trajectory of nearly zero-energy performance in all new residential and non-residential buildings.
  - Continue to upgrade minimum standards and the labelling of appliances and common energy-using products, and establish a plan for extension of these to other product types.
- Transport
  - Continue to improve minimum standards and labelling for vehicle fuel efficiency for light and heavy-duty vehicles.
  - Continue to support the adoption of energy efficiency and emissions reduction measures for aviation, shipping, and rail transport, which includes the announced reduction in rail diesel engines.
- Business and industry
  - Promote energy efficiency and emissions reduction in business and industry through effective incentives and programmes after the end of the CRCEES.
  - Continue requirements for large energy users to examine energy savings opportunities and consider requiring identified cost-effective improvements to be acted upon.
  - Carry through, in partnership with industry, on actions in the Industrial Decarbonisation and Energy Efficiency Roadmaps to 2050 and associated action plans for heat-intensive industrial sectors.
- Public sector
  - Continue to lead by example with the procurement for public sector activity and facilities based on energy efficiency and carbon target policies.

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6. Nuclear

Key data

(2017)

Number of reactors: 15 reactors

Installed capacity (2016): 8.9 GW (15 reactors at 8 sites)

Electricity generation: 70.3 TWh, +11.6% since 2007

Share of nuclear: 10.4% of TPES, 15.3% of domestic energy production, 21.0% of electricity generation

Overview

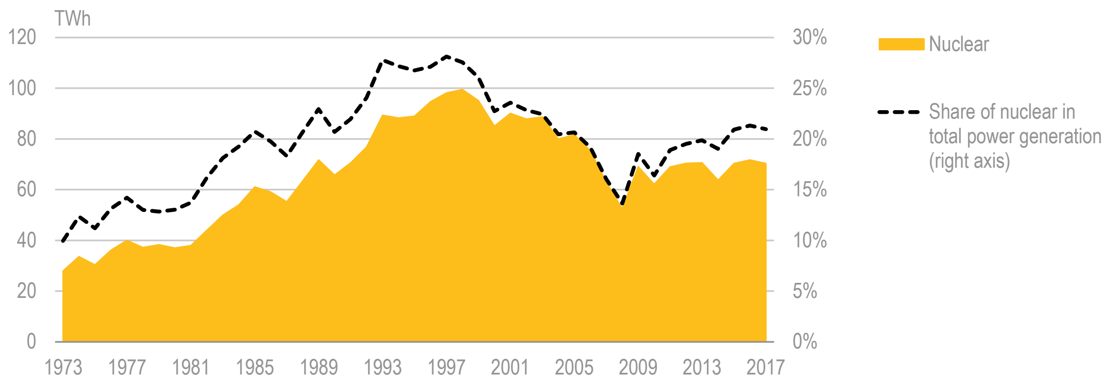
As a high-technology, low-carbon option for electricity generation, nuclear energy plays a significant role in both key aspects of the Clean Growth Strategy (UK Government, 2017a) of the government, to reduce greenhouse gas (GHG) emissions and enhance industrial productivity. The United Kingdom's Nuclear Sector Deal (UK Government, 2018a) states rebuilding a national nuclear supply chain as an explicit objective of the current government. The UK energy sector also operates under a legally binding target to reduce GHG emissions from 1990 levels by at least 80% in 2050. The fifth carbon budget set in 2016 thus requires a reduction of 57% to be reached over the period 2028-32.

As part of the United Kingdom's low carbon strategy, the 70 terawatt hours (TWh) of nuclear energy produced in 2017 accounted for 21% of the total electricity generation. This ranks the United Kingdom's share of nuclear power as the 11th highest among the Organisation for Economic and Co-operative Development (OECD) member countries. The share of nuclear power production increased steadily until the late 1990s. At its peak in 1998, nuclear power production had reached 99 TWh, which represented 27% of the total electricity generation. Subsequently, production declined to a low point of 50 TWh in 2008. Since then the trend reversed somewhat following the takeover of British Energy by the French utility Électricité de France (EDF) that same year. Today, all UK reactors are operated by the latter's UK subsidiary EDF Energy.

However, the current share of nuclear power in the energy mix is far from being assured. The United Kingdom has 15 nuclear reactors at eight different sites with a total capacity of 8.9 gigawatts (GW). Of these, 14 are advanced gas-cooled reactors (AGRs), of which eight reactors with a combined capacity of 4.2 GW are expected to be shut down in 2023 and 2024. The other six are expected to be shut down by 2030. Only the pressurised water reactor (PWR) at Sizewell B with a capacity of 1.2 GW is expected to run to at least until 2035, when it will have reached a 40-year lifetime. The shutdown of the first batch of AGRs coincides with the announced phase out of coal-fired capacity by 2025 and will, in the absence of new investment in power generation, significantly reduce the available amount of dispatchable capacity towards the middle of the next decade. On current planning, two new PWRs of the UK European Pressurised Reactor (EPR) design with a combined capacity of 3.2 GW will be commissioned at Hinkley Point C (HPC), with the first unit to be commissioned before the end of 2025, but this cannot be anticipated with certainty.

The "capacity crunch" around 2025 poses the question of possible lifetime extensions or long-term operations (LTOs) for the existing plants. EDF Energy has indicated not to seek lengthy LTOs for its AGRs as a general policy, although it is possible that requests for extensions for a year or two for individual AGRs will be submitted to the nuclear safety regulator. In conformity with standard industry practice, lifetime extensions for at least 20 more years of operations are, however, likely to be sought for the PWR at Sizewell B.

Figure 6.1 Nuclear power generation and its share in power generation, 1973-2017



Nuclear power peaked in 1998, at 28% of the total electricity generation, after which it declined, but it has recovered to above 20% of electricity generation in recent years.

Source: IEA (2019), *World Energy Balances 2019 First edition (database)*, www.iea.org/statistics/.

New nuclear construction and power market reform

Historically, the United Kingdom has been in the vanguard of the development of civil nuclear power. The world's first commercial nuclear power plant (NPP) started operations in 1956 at Calder Hall in West Cumbria. The 2012 *IEA Review of the Energy Policies of the United Kingdom* also commended the government for its careful, systematic preparation of a national programme for nuclear new build. Nuclear energy also enjoys overall public support (IEA, 2012). In 2018, only 22% of the British population were opposed to nuclear energy, while 35% supported it and 40% expressed a neutral stance. Among OECD countries, the United Kingdom remains a leader in new nuclear development. Nevertheless, the dynamism in favour of strengthening the role of nuclear energy to ensure a low-carbon electricity supply is less discernible than during the previous in-depth review (IEA, 2012). In the intervening six years, in particular, nuclear new build preparations have not progressed quite as decisively as originally envisioned.

To regain some momentum, in June 2018 the government set out its Nuclear Sector Deal (UK Government, 2018) to deliver “affordable, reliable and always available nuclear power”, which focuses on new financing models for the construction of new NPPs expected to deliver up to 30% lower costs by 2030, cost savings of up to 20% in decommissioning, a more competitive supply chain, and the development of a specialised workforce and increased diversity (40% female). The government sees the development of domestic nuclear power both as an opportunity to develop the nuclear technologies and skills to compete globally and as a source of social and economic benefits at the local and regional level. Concerning positive spillovers at the local level, local enterprise partnerships and industry will pursue a strategy to create clusters of nuclear expertise. The Nuclear Sector Deal is part of the UK Industrial Strategy (UK Government, 2017b), which includes substantially increased funding for research and development (R&D and, inter alia, subsidies for electric vehicle development.

In 2016, the government signed a contract for difference (CFD) with EDF Energy that started construction of two new EPRs at HPC. Developers have proposed four further projects at Sizewell (EPR), Bradwell (HPR100), Wylfa (ABWR), and Oldbury (ABWR). However, the projects at Wylfa and Oldbury have been suspended because of a commercial decision by Hitachi following negotiations with the UK government, which saw the government offer a package of support including a strike price of GBP 75 per megawatt hour, a one-third equity stake and all debt financing. A sixth project at Moorside in Cumbria was abandoned in November 2018, as its original sponsor, Toshiba of Japan, was pulling out of nuclear construction altogether due to well-known financial difficulties in its Westinghouse subsidiary and failed to find a buyer for the project. The Moorside project planned to build three AP1000 reactors. Reactors based on this design successfully began commercial operation in China during 2018. It is also one of the few reactor designs that have already undergone a generic design assessment in the United Kingdom, a first important step in the regulatory approval process.

If all four of the remaining nuclear projects are realised, which hinges partly on the forecasts of future electricity demand, this would add a further 12 GW of nuclear capacity. Future electricity demand depends partly on the extent to which a vision of the general electrification of the UK energy sector driven by concerns over air quality and climate change will come to bear. Projections by the National Grid in their most optimistic scenario on the electrification of cars and vans predict that without smart charging there could be up to 18 GW of additional peak demand by 2050.

It is generally recognised that, due to its high fixed capital costs, lengthy lead times during construction, and long lifetimes, NPPs face unique financing challenges in deregulated markets with volatile prices set at marginal costs. For HPC, the government thus concluded a CFD that offers EDF Energy and its Chinese partner China General Nuclear Power Group (CGN) a guaranteed price of British pounds (GBP) 92.50 per megawatt hour (GPB/MWh) in 2012 money for 35 years (reducing to 87.50 GBP/MWh if the construction of a further two EPRs at Sizewell goes ahead). Nuclear as a capital-intensive technology benefits strongly from a CFD that offers a stable price to coffer the cost of capacity as long as output is sufficiently stable. In addition, nuclear plants that receive CFDs are therefore only allowed to participate in the UK capacity remuneration mechanism.

The CFD contract was challenged by Austria and Luxembourg on the basis of the argument that it constitutes illegal state aid. However, the General Court of the European Union first dismissed the challenge in October 2014 and confirmed the dismissal in July

2018 on the grounds that the distorting impacts on competition of the aid were limited and that overall the positive effects were larger than the negative ones.

Additional nuclear construction projects are currently in the planning stage and accompanied by a lively discussion about future financing models and a number of industrial reconfigurations. Questions have been raised as to whether the strike price of the CFD for HPC was sufficiently competitive and whether CFDs are, indeed, the most appropriate instrument to promote nuclear new build. On the one hand, consumer groups, non-governmental organisations, and the National Audit Office have thus criticised the high level of the strike price of the HPC CFD compared to wholesale market prices. On the other hand, nuclear developers Hitachi at Wylfa and EDF Energy at Sizewell have made it known that they hesitate to take on the totality of the construction risk in future projects based on the conclusion of a CFD alone. Ideas that are being advanced include low interest loans from the government for up to 50% of a project, direct public investment in a nuclear project, or the treatment of NPPs as regulated assets. The practice to include costs for ongoing projects already in construction in the calculation of a regulated tariff would take a regulated asset base (RAB) approach. This financing model has been used for regulated utilities in sectors such as electricity transmission, water, or transport. It could reduce the risks for capital providers and thus reduce the cost of capital. Estimates indicate that cost savings could be as high as 20 GBP/MWh.

Table 6.1 Nuclear new build projects in the United Kingdom

NEA NPP construction	Contractor	Capacity	Construction start date	Generation date
HPC	NNBG (EDF/CGN)	Two 1.5 GW EPR reactors	2016	Scheduled 2025
Sizewell C	NNBG (EDF/CGN)	Two 1.6 GW EPR reactors	Provisionally 2018-19	Possibly 2028
Bradwell B	CGN	Two 1.2 GW Hualong One reactors	No start date	No start date
Wylfa Newydd	Horizon (Hitachi Ltd)	Two 1.35 ABWR reactors	No start date	Scheduled for mid-2020s
Oldbury	Horizon (Hitachi Ltd)	Two 1.35 GW ABWR reactors	No start date	No start date

Notes: NEA = Nuclear Energy Agency. NNBG = Nuclear New Build Generation Company.

Source: Updated and adapted from National Audit Office (NAO).

The particularity of nuclear energy is that it possesses a number of attributes difficult to price in a market environment. The reliable provision of dispatchable low-carbon power with few system costs, a feature that distinguishes nuclear energy from variable sources, can be made comparable to the megawatt hour costs of other low-carbon sources. The potential contribution of nuclear energy to carbon emission reductions will increase in the future. Until today, 75% of the United Kingdom's impressive reductions in carbon emissions in the electricity sector have been achieved through a switch from coal-fired to gas-fired generation. With the phase out of coal, the choice will be increasingly between nuclear power and gas as a dispatchable complement to the variability of wind and solar PV output in addition to the flexibility provided by storage and demand response.

Beyond electricity provision, carbon emission reductions, and low system costs, there are also the beneficial contributions of nuclear energy to the provision of physical inertia and, in the case of PWRs or advanced boiling water reactor (ABWR)s, frequency control and load modulation can, to some extent, be financially quantified. Yet, its contribution to the diversification of the electricity supply, technological spillovers, the preservation of skills, and the local economic development are of a more qualitative nature.

However, for these reasons, as well as due to the heterogeneous nature of individual nuclear new build projects, it is unlikely that nuclear projects will ever compete head-on with other renewables resources, such as wind and solar photovoltaics in unified "equivalent firm power" capacity auctions as proposed in the 2017 *Cost of Energy Review* requested by the government from Professor Dieter Helm (Helm, 2017). Even adjusting and derating different forms of electricity would create myriads of methodological challenges in a fast-evolving environment that are unlikely to be overcome to allow comparing like with like.

UK membership in Euratom and Brexit

The United Kingdom announced that it will be leaving the Euratom treaty as part of Brexit. As in other areas of energy policy affected by Brexit, there still exists considerable uncertainty as experts both in the United Kingdom and in the European Union explore options for future relations under different scenarios. The government's Brexit White Paper of July 2018 (UK Government, 2018b), however, stated that in the area of civil nuclear trade, the United Kingdom will seek a close association with Euratom. The United Kingdom and the European Union have also now jointly published a political declaration on the future relationship (UK Government, 2018c), which, among other things, sets out the parties' desire to agree a wide-ranging Nuclear Cooperation Agreement (NCA) that covers the continued co-operation on safeguards, safety, civil nuclear trade, research, and monitoring and improving security of supply for medical radioisotopes.

A Notice to Stakeholders by the European Commission of March 2018 spells out the implications of the United Kingdom leaving the Euratom acquis without a deal and becoming a third country (EC, 2018). After a hard Brexit the United Kingdom would no longer be able to participate in the common European supply arrangements for reactor fuels conducted by the European Supply Agency. EU countries would also require specific licences for exports to the United Kingdom.

In August 2018, the United Kingdom published guidance for operators on civil nuclear regulation that sets out the steps that businesses in the United Kingdom may need to take in a "no deal" scenario (UK Government, 2019), which includes import licence arrangements, authorisations for trans-frontier shipments of radioactive waste, and notifications for radioactive source shipments.

In the Withdrawal Agreement (UK Government, 2018d) there are six articles that deal in some detail with separation issues around civil nuclear trade. For example, one article deals with the equipment that Euratom inspectors currently use in the United Kingdom for their safeguards work. It specifies that Euratom equipment located at Sellafield and other UK sites will be inventoried and ownership will transfer to the United Kingdom, with the European Union being reimbursed at the book value of this equipment at the end of 2020.

The Withdrawal Agreement also provided for a general transition period (or "implementation period") between the European Union and the United Kingdom for the period between 29 March 2019, the date the United Kingdom was due to leave the European Union, and 31 December 2020. This could be, in principle, a period during which a NCA or, alternatively, specific arrangements pertaining to the export and import of nuclear materials be negotiated, and the political declaration commits both parties to trying to achieve this.

In the meantime, a domestic Nuclear Safeguards Act 2018 ('2018 Act') that provides for the continuation of nuclear safeguards after the United Kingdom's withdrawal from Euratom was passed by the UK Parliament on 6 June 2018 and enacted on 26 June 2018. The 2018 Act enables the United Kingdom to establish a domestic nuclear safeguards regime, to be operated by the national regulator (the Office for Nuclear Regulation), that will enable the United Kingdom to discharge its international safeguards and nuclear non-proliferation obligations. The regulatory regime was approved by the UK Parliament in February 2019. The 2018 Act also ensures that the United Kingdom is able to give effect to its obligations under new nuclear safeguards agreements with the International Atomic Energy Agency (IAEA) and under other international agreements that relate to nuclear safeguards. As part of the United Kingdom's withdrawal from Euratom, the United Kingdom has also signed new bilateral NCAs with Australia (August 2018), Canada (November 2018), and the United States (May 2018) and confirmed the operability of an existing NCA with Japan (February 2019) to continue civil nuclear trade when the Euratom arrangements no longer apply to the United Kingdom. The United Kingdom also remains a member of the IAEA conventions on Nuclear Safety, the Safety of Spent Fuel Management, and the Safety of Radioactive Waste Management. The United Kingdom's new bilateral nuclear safeguards agreements with the IAEA, signed in June 2018, were ratified by the UK Parliament in December 2018 together with the three new bilateral NCAs.

Waste management and decommissioning

The United Kingdom has comprehensive policies in place for the decommissioning of nuclear installations and the disposal of nuclear waste. Decommissioning funding is based on three distinct pillars. The decommissioning of legacy nuclear sites is overseen by the Nuclear Decommissioning Authority (NDA), which has an annual expenditure of about GBP 3 billion. It is responsible for the decommissioning and clean-up of 17 sites, which include the Magnox fleet of nuclear power stations, research centres, fuel enrichment and fabrication facilities, and the vast Sellafield nuclear research and fuel reprocessing site. Funding for the decommissioning of current reactors, which EDF Energy acquired from British Energy in 2009, is ensured through the Nuclear Liabilities Fund. New reactor projects are required to have a separately funded decommissioning programme approved by the government to ensure that operators are able to meet the costs of decommissioning and waste management. In the case of the HPC project, decommissioning costs will be accounted for from a share of electricity sales in the order of GBP 2/MWh. In approving and then supervising the funded decommissioning programme, the government is advised by the independent Nuclear Liabilities Financing Assurance Board.

The United Kingdom is also continuing preparations for a Geological Disposal Facility (GDF) for what is referred to as "higher-activity waste (HAW)", which is expected to be operational in the 2040s with estimated costs in the order of GBP 12 billion[1].

The UK Government has policy responsibility for radioactive waste management in England. The Welsh Government has the responsibility in Wales; the Scottish Government in Scotland and the Northern Ireland Executive in Northern Ireland.

The policy framework for the long-term management of higher-activity radioactive waste and how to engage with communities to identify a suitable site for a GDF in England is set out in '*Working with Communities: Implementing Geological Disposal*' which was published by the UK Government in December 2018 (UK Government, 2018e).

An equivalent document for Wales was published in January 2019: *Geological disposal of radioactive waste: working with potential host communities*[2].

Northern Ireland is not participating further in this stage of the process to identify a site for a GDF and there are no plans to site a GDF in Northern Ireland. Any future policy decisions in relation to geological disposal in Northern Ireland would be a matter for the Northern Ireland Executive and would be subject to community agreement as well as planning and environment consents.

Scotland is not participating in the process to identify a suitable location for a GDF. The Scottish Government has a distinct policy for HAW, published in 2011. This policy is that long-term management of HAW should be in near-surface facilities. Facilities should be located as near to the site where the waste is produced as possible. In 2016, the Scottish Government published an Implementation Strategy[3], expanding on the framework provided by its 2011 policy, to allow waste management decisions to be taken to ensure the policy is implemented in a safe, environmentally-acceptable and cost-effective manner.

The National Policy Statement for Geological Disposal Infrastructure (UK Government, 2018f) is the document that will outline the criteria that will be considered by the Planning Inspectorate and the Secretary of State when a decision is made whether to give development consent to a proposed GDF development or not. The consultation on a draft of this document took place from January to April 2018. The draft National Policy Statement then underwent Parliamentary scrutiny in 2018, with a select committee report in July 2018 and a debate in the House of Lords in September 2018. The National Policy Statement for Geological Disposal Infrastructure is expected to be published by the UK Government in 2019. It will apply to England only, as planning consent for all radioactive waste projects are devolved to the respective national administrations

There is no absolute target date for starting operations, although the NDA currently bases its plans on the assumption that the first disposal of nuclear waste at the GDF could take place in the 2040s. The siting process in England began at the end of

[1] The UK government's definition of HAW includes high- and intermediate-level waste as well as the small proportion of low-level waste not suitable for the existing disposal facilities.
[2] https://gweddill.gov.wales/docs/desh/publications/190130-geological-disposal-of-higher-activity-radioactive-waste-working-with-communities-en.pdf
[3] https://www.gov.scot/publications/higher-activity-waste-implementation-strategy/

December 2018 and in Wales in January 2019. Detailed site investigations may take up to 15 years and it will take about ten years to construct the first vaults within a facility. Interim storage facilities will be used until the GDF is fully operational.

Research and development

In the area of nuclear R&D, the United Kingdom maintains a Nuclear Innovation Programme but is reducing its funding from the original GBP 250 million to GBP 180 million over the next five years. The United Kingdom committed GBP 86 million for a National Fusion Technology Platform at Culham under the Nuclear Sector Deal (UK Government, 2018a), and plans to invest GBP 20m into plans for a next generation fusion reactor. The Nuclear Sector Deal includes a commitment to co-operate with the Welsh government on developing a thermal hydraulics facility in North Wales.

The information gathering stage of the small modular reactor (SMR) competition announced in 2016 was concluded at the end of 2017, when the United Kingdom announced three further initiatives: up to GBP 44 million of funding for research on advanced modular reactors, which include Generation 4 reactors and small fusion reactors; up to GBP 12 million of funding for the nuclear safety regulators, the Office of Nuclear Regulation, and the Environment Agency to build-up the appropriate regulatory capacity; and the establishment of an Expert Finance Working Group on Small Reactors to provide independent recommendations on the commercial feasibility of SMRs. The Group was set up in February 2018 and presented its final report, the *Market Framework for Financing Small Nuclear* (UK Government, 2018g), in August 2018. Its key recommendations are to establish a manufacturing supply chain initiative, similar to that for offshore wind, streamline regulatory approval, maintain suitable sites, and focus on the reduction of capital costs, especially for a first-of-a-kind model through a combination of public financing, loan guarantees, CFDs, power purchase agreement (PPA)s, or RAB financing.

The UK's withdrawal from the Euratom Treaty has the potential to affect the UK's relationship with EU nuclear research collaborations conducted under the umbrella of the Euratom Research & Training Programme (Euratom R&T). Under the terms of the Withdrawal Agreement the UK will continue to participate fully in Euratom R&T until the end of 2020. This will coincide with the start of the new 2021-25 R&T programme, to which, subject to negotiations, the UK aims to seek association as part of its future Science and Innovation relationship with the EU (the Euratom R&T programme runs on a five-year cycle with a two-year extension to bring it in line with the EU's overarching Multiannual Financial Framework). Under a no deal outcome the UK would still retain limited access to research activities as a third-country. BEIS set out the arrangements in a 2018 note *(Nuclear Research if there's no Brexit Deal*) and in April 2019 (UK Government, 2019b).

The UK Atomic Energy Authority (UKAEA) hosts the Joint European Torus (JET) at the Culham Centre for Fusion Energy, which is at the heart of the European fusion research programme. UKAEA have a contract with the EU Commission to operate JET on behalf of Euratom. Under the terms of this contract the EU provides 87.5% of the JET operating costs, with the UK providing the remaining 12.5%. On 27 March 2019 the European Commission and the UK signed a new contract extension for the JET facility. This contract extension will ensure this can continue to operate until at least the end of 2020 regardless of Brexit. Beyond 2020, the future of JET as a collaborative European facility will depend on the outcome of UK-EU negotiations. The UK's participation in the International Thermonuclear Experimental Reactor (ITER) fusion mega project may be affected by EU exit, although the UK has been clear that it expects any future association to include continued participation in the EU's umbrella project for ITER.

Assessment

The United Kingdom remains a leader in the civil use of nuclear energy. Its institutional infrastructure is sound and all the important issues of nuclear power development, which include regulation, financing, construction, supply chain, fuel supply, skills, and decommissioning are systematically addressed. A UK export strategy for nuclear power components and skills that was always part of this framework does not look unreasonable. In addition, the United Kingdom is one of European countries in which the first concrete has been poured as part of the construction of a new NPP.

However, there is no longer a momentum in the United Kingdom today to fill a potential supply gap with a fleet of new Generation 3 PWR and ABWR reactors (following the phase-out and retirement of coal plants, closed Magnox reactors, and ageing AGRs). One of the reasons is the Brexit process that drains policy-making resources from other sectors. Nuclear energy, with the large size of its installations, the need for special safeguards, and the difficult-to-quantify benefits, is likely to be more affected by this Brexit process than other energy carriers. At the same time, the government is aware of this and has launched a number of initiatives in the nuclear field, most importantly with the publication of its Nuclear Sector Strategy of June 2018 that set out a coherent case for new nuclear development.

Ultimately, however, the overall dynamics of the UK nuclear sector will depend on continuing and expanding nuclear new build. Inevitably, the ambitious target of the UK industry of 16 GW of new nuclear capacity by 2030 that was initially announced, establishes the backdrop against which success or failure will be assessed. The new build project at HPC by a French-Chinese consortium with 3.2 GW is a sizeable step, but will not be sufficient on its own to carry the momentum of UK nuclear development forward. At least one additional project needs to be agreed in the coming two years to maintain momentum. Otherwise, the creation of an internationally competitive UK supply chain for nuclear new build will be difficult to sustain in an industry that is subject to very strong increasing returns to scale at all levels.

A decisive element in this context is the need to articulate better the contribution that is expected of nuclear energy to the UK low-carbon electricity supply. Do current projections of the evolution of the UK electricity market suggest that nuclear energy will be able to run in an economically efficient baseload mode or will it be primarily used as a low-carbon backup for the generation from variable or intermittent renewable resources? The answer will have a bearing on the cost and financing of nuclear electricity, on its optimal share, as well as, to some extent, on the appropriate technology to be chosen.

Overall, nuclear energy in the United Kingdom benefits from a strong policy framework and good public support. However, current arrangements do not yet ensure the economic viability of the projects for new NPPs beyond HPC. This means that UK nuclear power is approaching, rather quickly, a bifurcation that will decide whether the original ambitions for its development can, by and large, be maintained or whether the share of nuclear power in UK electricity supply will decrease dramatically after 2025. If UK policy makers are convinced that nuclear energy should remain an important part of the electricity mix, they will need to set out the overall system's contribution of nuclear power in terms of carbon emissions, reliability, flexibility, grid services, and diversification, to create a broad consensus that the economic incentives required do, indeed, constitute good value for money.

Recommendations

The UK government should:

- Ensure that the role of nuclear power is well understood for delivering the United Kingdom's decarbonisation requirements under the carbon budgets over the period 2028-32, in line with the Nuclear Sector Deal.
- Continue to articulate the broader contribution of nuclear power to fuel diversification and the security of electricity supply, drawing on a transparent evidence base that demonstrates the costs and benefits, with a view to designing appropriate financing mechanisms for economically viable new NPPs.
- Continue its efforts to ensure that exiting the European Union and the Euratom treaty will not impact nuclear trade or the supply chain of the UK nuclear sector.
- Concentrate its nuclear research efforts on a smaller number of ventures, such as the follow-up to the SMR competition for a maximum return on invested research funds.

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7. Energy technology research, development and demonstration

Key data

(2017 provisional figures)

Government energy RD&D spending: GBP 536 million

Share of GDP: 0.26% per 1,000 GDP units (IEA median*: 0.30%, IEA average*: 0.35%)

RD&D per capita: GBP 6.8

Exchange rates: GBP 1 = USD 1.28 = EUR 1.14

* Median and average of 19 IEA member countries for which 2017 data are available by the time of publishing.

Overview

The United Kingdom has a strong energy research, development, and demonstration (RD&D) framework with a major focus on clean energy growth and innovation, based on the United Kingdom's Industrial Strategy (UK Government, 2017a), the Clean Growth Strategy (UK Government, 2017b).

Under the umbrella of the new Energy Innovation Board (EIB), RD&D policies, programmes, and funding are well coordinated across the government and its agencies.

New missions are under consideration for the Clean Growth Grand Challenge of the Industrial Strategy which prioritise areas in which the United Kingdom faces the most acute decarbonisation challenges, such as reducing industrial emissions in particular industrial clusters.

For instance, the government released in November 2018 the new carbon capture, usage, and storage (CCUS) Action Plan (UK Government, 2018), which sets out the steps the government and industry should take in partnership to enable the development of the first CCUS facility in the UK, commissioning from the mid-2020s, to achieve the government's ambition of having the option to deploy CCUS at scale during the 2030s, subject to costs coming down sufficiently.

A new International Research and Innovation Strategy and specific International Energy Strategy are currently being developed to update priorities and funding programmes.

In line with Mission Innovation, in the Autumn Statement 2015 (UK Government, 2015) the government set out its goal to double relevant clean energy RD&D funding to reach GBP 400 million per year in 2020-21.

Energy research and development strategy and priorities

The UK energy technology research and innovation policy is oriented towards the development of clean growth industries of the future as an integral part of the UK Industrial Strategy, the UK Clean Growth Strategy, and the UK Aid Strategy.

In the context of the Industrial Strategy, the government has set Grand Challenges of Clean Growth and the Future of Mobility (as well as Artificial Intelligence and Ageing Society). The Grand Challenge of Clean Growth focuses on maximising the advantages for UK industry from the global shift to clean growth – through leading the world in the development, manufacture, and use of future low-carbon technologies, systems, and services that cost less than high-carbon alternatives, in particular:

- Develop smart systems for cheap and clean energy across power, heating, and transport.
- Transform construction techniques to improve efficiency dramatically.
- Make the United Kingdom's energy-intensive industries competitive in the clean economy.
- Put the United Kingdom at the forefront of the global move to high-efficiency agriculture.
- Make the United Kingdom the setter of global standards for finance that supports clean growth.

The Clean Growth Strategy is underpinned by the Energy Innovation Programme. The government has ambitious goals on decarbonisation and has increased the investment in its clean energy technologies in line with the Industrial Strategy of 2017. The government plans to invest more than British pounds (GBP) 2.5 billion in RD&D for clean growth technology between 2015 and 2021 (Table 7.1).

Institutions

The central government's **Department for Business, Energy and Industrial Strategy (BEIS)** leads on energy innovation policy priorities. BEIS has a central role in the coordination of energy-related innovation across the government and agencies.

BEIS is also responsible for the sponsorship of **UK Research and Innovation (UKRI),** which was created out of the merger of Innovate UK and the Research Councils in April 2018. The UKRI is a public body sponsored by BEIS and it has its own internal governance framework with the purpose to facilitate research and innovation activity across the United Kingdom. UKRI typically focuses on excellent science and academic collaboration, whereas BEIS Energy Innovation focuses on industrial collaborations.

BEIS and the **Department for Transport (DFT)** have established a package of funding targeted at the roll-out of low-emission vehicles in the joint Office for Low Emission Vehicles (OLEV).

The **Department for Environment, Food and Rural Affairs (Defra)** also funds low-carbon innovation in agriculture and waste.

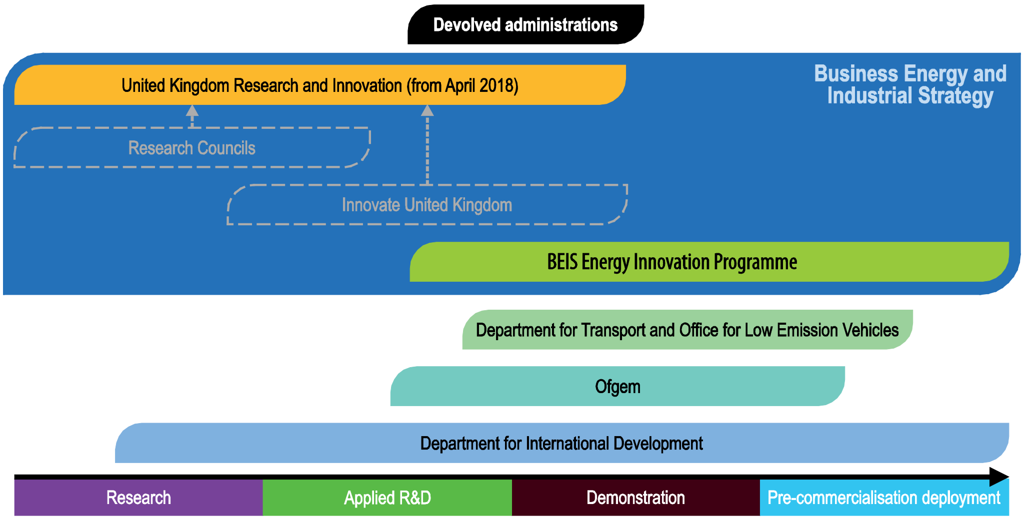
As the national regulatory authority, the **Office of Gas and Electricity Markets (Ofgem)** incentivises innovation under the new RIIO (revenue = incentives + innovation + outputs) network regulation, with up to GBP 720 million of regulated expenditure available to gas and electric companies to support smarter, more flexible, efficient, and resilient networks.

The **Energy Innovation Board (EIB)** was established in November 2016 to replace the work of the Low Carbon Innovation Coordination Group (LCICG). The EIB plays a strategic role in aligning domestic and international clean technology investments across the government. The EIB is chaired by the government Chief Scientific Advisor. The EIB is attended by senior civil servants across BEIS, UKRI, Department for Communities and Local government, Department for International Development (DFID), DFT, and Ofgem, with Her Majesty's Treasury (HMT) as observers. The EIB is internal to the government, but is seeking external members with industry insights to provide external challenge.

The **Department for International Development (DFID)** defines the United Kingdom's Overseas Development Aid (ODA) funding. The United Kingdom's EIB has an International Working Group (subgroup to the EIB) tasked with developing cross-government co-operation opportunities and knowledge sharing related to international research and innovation collaboration.

Figure 7.1 provides an overview of the landscape of energy RD&D in the United Kingdom.

Figure 7.1 The United Kingdom's institutional structure for public RD&D



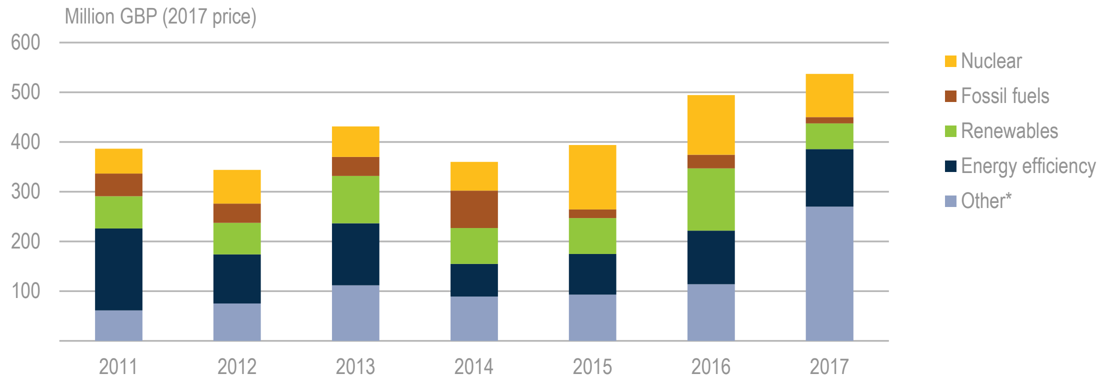
Source: IEA, 2019. All rights reserved.

Funding on energy

Public spending

In 2017, the government's provisional estimates of spending was GBP 536 million on energy-related RD&D. Energy efficiency made up 21%, followed by nuclear energy (16%), and renewables (2%), but a large part is allocated to other technologies. The total amount of energy-related RD&D spending has steadily increased since 2014 (Figure 7.2). By international comparison, the United Kingdom has a relatively low energy RD&D budget as a percentage of GDP (Figure 7.3). In 2017, the UK spending on energy RD&D was below the median among the IEA member countries, at 0.26% of GDP.

Figure 7.2 Government energy RD&D spending by category, 2011-17



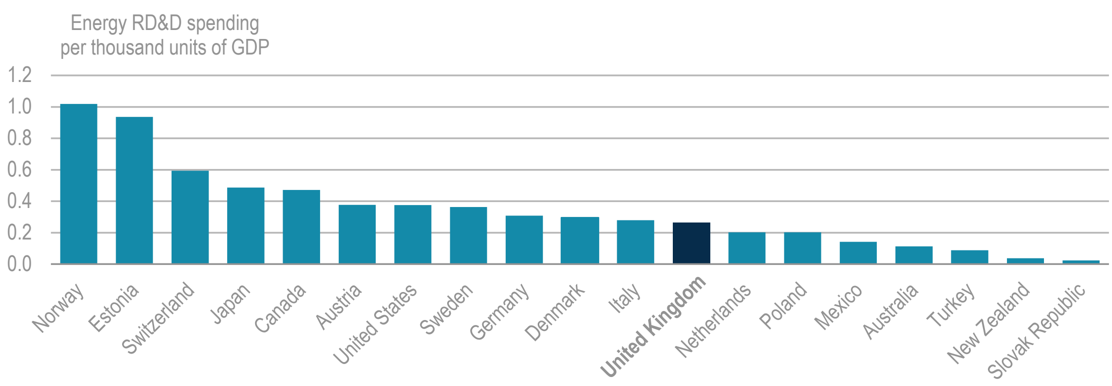
The United Kingdom's energy RD&D covers a broad spectrum of activities and nuclear research has the highest share of total spending.

* Other includes hydrogen and fuel cells, other power and storage technologies, and cross-cutting research.

Note: 2017 figures are estimated.

Source: IEA (2018), *Energy Technology RD&D Budgets 2018*, www.iea.org/statistics/.

Figure 7.3 Public energy RD&D spending as a ratio of GDP in IEA countries, 2017



The United Kingdom's spending on energy RD&D as a ratio of GDP was slightly below the median among IEA countries in 2017.

Note: Data are not available for Belgium, Czech Republic, Finland, France, Greece, Hungary, Ireland, Korea, Luxembourg, Portugal, and Spain at the time of publishing.

Source: IEA (2018), *Energy Technology RD&D Budgets 2018*, www.iea.org/statistics/.

Under the Clean Growth Strategy, the government is committed to invest in low-carbon innovation a total budget of GBP 2.5 billion over the period 2015-21 (Table 7.1) to support RD&D in low-carbon transport (33%), power (25%), smart systems (10%), homes (7%), agriculture land use and waste (4%), industry (6%), and cross-sector projects (15%).

Energy RD&D programmes

Several programmes and funds are available to the energy sector, including:

- BEIS's Energy Innovation Programme supporting the commercialisation of innovative clean energy technologies and processes (GBP 505 million).
- UKRI energy research and development funding, including support for the Energy Systems Catapult and the Offshore Renewable Energy Catapult (GBP 1.2 billion).
- The Faraday Challenge funding for the design, development, and manufacture of electric batteries (GBP 246 million).
- Up to GBP 620 million from a range of departments, including BEIS, DFT, DFID, and Defra and additional Industrial Strategy Challenge Fund support.
- Ofgem makes up to GBP 720 million of regulated expenditure available to gas and electric companies in Great Britain to support smarter, more flexible, efficient, and resilient networks.

Table 7.1 The United Kingdom's investments (GBP million) in clean growth technology 2015-21

Sector	Basic and applied research	Technology development	Technology demonstration	Total
Smart systems (including energy storage)	175	43	47	265
Power sector (including renewables)	209	276	154	638
Homes (including heat and energy efficiency)	100	31	53	184
Transport (including EVs and batteries)	296	413	132	841
Business and Industry (including industrial fuels and CCUS)	57	47	58	162
Natural resources (including land use and waste)	69	30	0	99
Cross-sectoral clean technology innovation (including for entrepreneurs)	234	62	91	387
Total	1 140	902	534	2 576

Sources: Based on the information provided in the UK government's Clean Growth Strategy.

The BEIS Energy Innovation Programme (GBP 505 million) is allocated to smart systems (GBP 70 million), the built environment – energy efficiency and heating (GBP 90 million), industrial decarbonisation and CCUS (GBP 100 million), nuclear innovation and fission (GBP 180 million, renewables innovation (GBP 15 million), and support for energy entrepreneurs and green financing (GBP 50 million).

The United Kingdom has created the Offshore Renewable Innovation Hub (with a budget of up to GBP 1.3 million), led by the Offshore Renewable Energy Catapult and Knowledge Transfer Network, to bring the offshore wind industry together to solve common innovation challenges. The United Kingdom is working with other countries to develop shared solutions to reduce the cost of renewable energy technologies, which includes through the European Research Area Networks (ERA-NETs), with a focus on demonstration projects for bioenergy (GBP 700 000) and offshore wind (GBP 8 million).

Similarly, the UK Smart Systems Innovation programme focuses on reducing the cost of energy storage technologies (including electricity storage, thermal storage, and power-to-gas technologies) with a total budget of GBP 9 million. This includes feasibility studies to implement the government's 'Upgrading our Energy System: Smart Systems and Flexibility Plan', a potential first-of-a-kind large-scale future energy storage demonstrator (up to GBP 600 million), innovative energy demand-side response (DSR) technologies in UK businesses or public sector organisations to reduce their energy use in peak times and provide flexibility to the energy system (GBP 7.6 million), and innovative domestic applications of DSR technologies and business models (up to GBP 7.75 million from 2018-21). Up to GBP 8.8 million is available to develop innovative approaches to energy management using smart meter data, tailored to the needs of smaller non-domestic sites.

Low-carbon transport spending includes an allocation of GBP 30 million, with funding from the BEIS Energy Innovation Programme (GBP 18 million) and OLEV (GBP 12 million) for an electric vehicle (EV)-to-grid programme to invest in demonstrators and feasibility studies. Further Department for Transport funding is available for low carbon fuels: on the Advanced Biofuels Demonstration Competition (ABDC), designed to support the construction of demonstration scale advanced biofuels plants (GBP 16 m), on the Future Fuels for Flight and Freight Competition (F4C), intended to encourage private investment and support the construction of advanced biofuels plants for aviation and heavy goods vehicles sectors (TRL 7-8, GBP 22 m). DfT's low carbon fuels team collaborates with universities through the Supergen Bioenergy Hub (SBH), focusing at TRL 2-3. SBH and DfT have awarded GBP 200 000 in research into CCUS solutions for transport.

Built Environment Innovation provides GBP 9.8 million for the second phase of work led by the Energy Systems Catapult in the Smart Systems and Heat programme, which supports the development of local energy plans and low-carbon heating projects across the United Kingdom. The programme supports RD&D into potential uses of hydrogen gas for heating (up to GBP 25 million) and the development of technologies that reduce the carbon emissions associated with providing heat and hot water to UK buildings (GBP 10 million), alongside investment in technologies and approaches to improve the energy efficiency of existing UK buildings (GBP 10 million).

The United Kingdom maintains a strong focus on Nuclear Innovation and invested GBP 20 million over 2016-18 to support innovation in the civil nuclear sector and training and capacity building of UK regulators to support the development of advanced technologies (GBP 7 million).

As part of its focus on Industrial Innovation*,* the BEIS Energy Programme is investing GBP 9.2 million in an Industrial Energy Efficiency Accelerator to seek industry-specific solutions that are close to commercialisation by leveraging private sector investment and strengthening UK supply chains to reduce the energy costs for UK industry. The United Kingdom also promotes the design and construction of CCUS demonstration projects (GBP 20 million), early investment in fuel switching processes and technologies (GBP 20 million), bulk low-carbon hydrogen supply (GBP 20 million), and innovation to reduce the cost of CCUS (GBP 15 million).

The BEIS Energy Entrepreneurs Fund promotes ideas from the public and private sector, notably from small and medium-sized enterprises, and supports the demonstration of state-of-the-art energy technologies (up to GBP 13 million for phase 5 and up to GBP 11 million for phase 6). In addition, the Fund provides GBP 20 million of new investment to support clean technology early-stage funding.

Box 7.1 Carbon capture, usage, and storage

The United Kingdom's Clean Growth Strategy places a strong emphasis on CCUS innovation, international collaboration, and domestic deployment subject to cost reductions. As noted by the Climate Change Commission, CCUS will be critical in meeting the United Kingdom's carbon budgets.

Over the past years, the United Kingdom invested over GBP 130 million in research and development (R&D) and innovation support to develop CCUS, supporting the development of technologies that include NET Power's Allam cycle, Carbon Clean Solutions, and C-Capture. On top of this, the United Kingdom is investing GBP 100 million in industrial energy and CCUS innovation to 2021.

The United Kingdom also has a dedicated GBP 70 million international CCUS programme, which has been running since 2012, which provides technical assistance for CCUS in emerging economies and developing countries, such as Mexico, South Africa, China, and Indonesia.

The United Kingdom leads the Carbon Capture Innovation Challenge under Mission Innovation together with Saudi Arabia and Mexico and is developing a closer collaborative working with countries such as Norway, the United States, Canada, and Australia, which includes joint work on innovation and carbon dioxide transport and storage solutions and working multilaterally through the Carbon Sequestration Leadership Forum and North Sea Basin Task Force.

On 28 November 2018, the government published a CCUS Action Plan (UK Government, 2018) that set out its view on the next steps that industry and government need to take to enable the development of the first CCUS facility in the UK, commissioning from the mid-2020s, to achieve the government's ambition to have the option to deploy CCUS at scale during the 2030s, subject to costs coming down sufficiently. The CCUS Action Plan can help support the Industrial Clusters Mission, which the government announced at COP24 in December 2018. The Industrial Clusters Mission is designed to establish the world's first net zero industrial cluster by 2040, and CCUS will have a key role. The Mission is supported by GBP 170 million from an Industrial Strategy Challenge Fund to support the deployment of low carbon technologies and enabling infrastructure in one or more clusters.

Private funding and green finance

The government actively encourages private sector participation in energy technology RD&D as well as Entrepreneurship Training and Rural Development Initiatives programmes. The United Kingdom's Office of National Statistics publishes estimates of total private sector R&D, but not broken down by energy R&D.

The UK has been leading on green finance. The government and the City of London's Green Finance Initiative was established in 2016 and supported the LENDERS project through Innovate United Kingdom (which aims to improve the estimations of energy costs for homeowners when calculating mortgage affordability). BEIS and HMT are co-hosting a Green Finance Taskforce with leaders of the financial sector to accelerate the growth of green finance and help deliver the investment required to meet the United Kingdom's carbon reduction targets. The government also promotes the recommendations of the Task Force on Climate-related Financial Disclosures to integrate the risks and opportunities posed by climate change into mainstream financial disclosures.

Monitoring and evaluation

The BEIS Energy Innovation Portfolio has developed a suite of portfolio key performance indicator (KPI) metrics to quantitatively measure the overall performance of the portfolio and assess spending. KPIs collect evidence at the project level to measure key outputs, outcomes, and impacts relevant to the strategic aims of the portfolio.

Energy Innovation Needs Assessments (EINA) look at evidence for the innovation needs of a range of clean energy technologies and the systems and processes in which they are utilised. They will help steer the prioritisation of UK funding with the objectives:

- To create a methodology for conducting assessments of future innovation needs in a way that will produce comparable outputs across different technologies.
- To facilitate efforts across government to identify strategic energy innovation areas for investment.
- To analyse the role of technologies in the energy system.
- To quantify the scale of the opportunity to United Kingdom in the regions of:
    - Reducing technology costs.
    - Expanding economic growth.
- To help understand the uncertainty associated with the above estimates.

Once the methodology is tested and deemed successful, technology roadmaps for horizon 2050 will be developed in 2019.

International collaboration

The UK plays a leading role in international research efforts to strengthen collaboration with other countries (Chapter on General Energy Policy). The UK mainly focuses on the research of renewable energy, smart grid, nuclear, CCUS, and other technologies. It has also become a key contributor to leading the Super-Efficient Equipment and Appliance Deployment Initiative of the Clean Energy Ministerial, which identifies strategic alternatives to setting up test labs to better target and manage resources that support energy efficiency policies.

The UK actively participates in numerous international R&D platforms, where the exchange of knowledge plays a key role: Mission Innovation, IEA Technology Collaboration Programmes (TCPs), the Clean Energy Ministerial (CEM), the European

Union's Strategic Energy Technology (SET) Plan, ERA-NETs, and Horizon-2020, among others.

Besides boosting clean energy RD&D funding, the United Kingdom wants to strengthen private sector engagement and investment in energy innovation, build new or strengthened international networks and partnerships in energy innovation, and increase awareness of the transformational potential of energy innovation, the progress being made, and the remaining gaps and opportunities.

International energy innovation funding

The International Energy Innovation activity can be split into four main areas:

- UK government funding for R&D collaboration with developed countries
- UK government funding for R&D collaboration with, in, or targeting developing countries (usually classified as overseas development assistance)
- European funding for UK organisations
- UK membership of multilateral organisations and fora.

Box 7.2 International leadership on innovation

The United Kingdom has been a member of Mission Innovation (MI) since its launch in November 2015 in Paris. The UK took over as Head of the MI Secretariat from the United States on 1 October 2017; then vice-chair of the Mission Innovation Steering Committee and chair since May 2019, and is a member of all the Innovation Challenges. The United Kingdom led the development of the Innovation Challenges to deepen collaboration and information sharing between members. The United Kingdom is a member of all eight Innovation Challenges and co-leads the Affordable Heating and Cooling in Buildings Innovation Challenge with the United Arab Emirates and European Union, and the CCUS Innovation Challenge with Saudi Arabia and Mexico.

As part of Mission Innovation, the United Kingdom is working with both the Breakthrough Energy Coalition and the World Economic Forum (WEF). At the One Planet Summit in Paris (December 2017), Breakthrough Energy founder Bill Gates announced public-private collaborations with five Mission Innovation members: Canada, European Commission, France, Mexico, and the United Kingdom. The United Kingdom is building on the WEF's System Initiative on Shaping the Future of Energy to explore whether the outcomes of that project are relevant to the UK context. This includes a joint workshop held with business leaders and policy makers in May 2018.

The Energy Innovation Board has been developing an International Strategic Framework. Innovation features in the government's international funding for development programmes.

Since 2013, BEIS, UKRI, and DFID (since 2016) have provided funding to enable the Energy Catalyst programme to invest almost GBP 100 million in grant funding across more than 750 organisations and 250 projects, via five rounds of open competition. Since DFID joined in round 4, the programme has included international overseas development assistance alongside the original UK focus. Round 6 is currently under consideration.

The BEIS portion of the International Climate Fund, jointly administered with DFID and Defra, includes a commitment to invest GBP 40 million on Energy Innovation projects. Officials are currently designing this in close consultation with other departments.

UK government funding for R&D collaboration with developed countries

The United Kingdom is launching R&D collaborations with developed countries, which include the United States, Canada, and South Korea. UKRI (both Research Councils and Innovate UK) have run several competitions with these countries. As part of future collaborations, BEIS and UKRI will discuss the possibility of co-funding calls. The draft International Research and Innovation Strategy has recognised the issue of a relative lack of funding for collaboration with developed countries within the broader international research context – and is proposing a new non-ODA fund to support such collaboration.

UK government funding for R&D collaboration with, in, or targeting developing countries (usually classified as ODA)

As part of the United Kingdom's ODA funding, the government focuses substantial funding on RD&D in developing countries, part of a wider set of ODA activities that span the full spectrum from R&D to technical assistance and supporting innovation in market design and regulatory frameworks. UK ODA funding for international energy innovation is delivered through many programmes and organisations, namely: BEIS (the Newton Fund, Global Challenge Research Fund, and International Climate Fund), UKRI (the Newton Fund and Global Challenge Research Fund), and DFID.

European funding for UK organisations

EU funding for energy innovation is largely delivered through two programmes: Horizon 2020 (the European Union's main R&D programme) and Euratom, as well as the European Regional Development Fund. The United Kingdom is a very active contributor to the ongoing work of the European Union's Strategic Energy Technology (SET) Plan and provides the chair for two of its governance bodies (the SET Plan Bureau and its Joint Actions Working Group). The United Kingdom participates in ten (out of 15) temporary working groups for the implementation of the integrated SET Plan, and co-leads the one on nuclear safety. In addition, the United Kingdom six participates in six ERA-NETs launched under Horizon 2020 (CCUS, Bioenergy, Wind, Smart grids, Ocean energy, and Solar energy). Regarding Horizon 2020, the United Kingdom is involved in almost half of all successful Horizon 2020 Energy project proposals, which enables UK organisations to benefit from the results of these projects and the networks created.

Assessment

The government wants to place the country at the forefront of the industries of the future and has ambitious goals on decarbonisation. These two goals are combined in the Clean Growth Strategy as part of the Industrial Strategy of the United Kingdom, in which research and innovation play a central role. The IEA compliments the United Kingdom for its international role in research and innovation. The United Kingdom has a strong position and a long history of international collaboration in this field. It plays a leading role in international initiatives such as, for example, Mission Innovation. The Global Innovation Index 2016 ranked the United Kingdom as the third most innovative country in the world. The Catapult programmes, which are now under the umbrella of UKRI, have been a success story in the UK since their launch some five years ago and are contributing to this.

The government expects to invest GBP 2.5 billion between 2015 and 2021 in energy RD&D. It aims at a strategy for a distinct set of energy technology priorities that reflect its resource base, technological competences, and commercial interests. The strategy covers all innovation phases: basic and applied research, technology development, and technology demonstration. It also addresses a broad field of topics. These are reflected in the RD&D funding allocations. The International Energy Agency (IEA) recommends a strong connection between the innovation portfolio and the overall energy and climate policy goals to give better support to achieving these goals. The approach of the UK's TINAs and EINAs focuses on specific innovation areas within the energy portfolio aiming to identify options for support offering the highest impact.

Compared to other IEA countries, the United Kingdom is in the lower range of public spending on energy research and innovation per unit of gross domestic product (GDP). The current allocation of GBP 2.5 billion for energy RD&D seems slightly higher than historic budgets. It is unclear how much private parties are spending on R&D for energy and climate change. The government budget for research and innovation should reflect the challenges the United Kingdom takes on to 2050. The IEA advises the government to consider ways to increase the support for research and innovation efforts, both public and private, commensurate with the UK's decarbonisation ambitions to 2050 and to match efforts of other IEA member countries.

The IEA welcomes Ofgem's RIIO model and the support to innovation outputs. Ofgem's budget of GBP 720 million coming from regulated tariffs to support smaller, more flexible, efficient and resilient networks is much larger than the budget BEIS has for all energy RD&D and should be reviewed in terms of outcomes and cost-effectiveness. In the light of the heated debates about energy bills for consumers, Professor Dieter Helm in his cost of energy review questioned Ofgem's model to finance innovation through the distributors and consumer bills. As network operators are going to become increasingly system operators, their incentive will change and it is therefore timely to review this innovation funding.

Many countries are currently engaged in discussions on how to make their innovation approach more effective, in a way that maximises its contribution to the grand energy and climate challenges. A view that is gaining support is the approach of missions-oriented policy. The main difference to traditional innovation policy is that a missions-oriented policy does not focus on a technology, but on a goal. This comprehensive approach calls for an all-inclusive attitude of all the stakeholders, including government, to direct efforts to the energy transition. It also asks for attention to the need to consider other aspects besides technology development, such as behavioural issues, infrastructure, new business models, human capital, and the necessary market design. Without addressing these non-technological topics, technological innovations may not be implemented. The IEA encourages the government to adapt its research and innovation policy and incorporate a mission-oriented approach.

The IEA welcomes the installation of the EIB, which is intended to play a strategic role in coordinating energy research and innovation through all the innovation phases and across different institutions. The IEA notes that the EIB is mainly composed of internal, government parties and therefore suggests considering how to involve knowledge institutes and business in discussions of the EIB.

Innovations can have a large impact on society and technological development can go much faster than anticipated (e.g. cost reductions in offshore wind). This is why it is important to assess periodically the innovation portfolio and keep space to adapt it to new developments. Monitoring and evaluation are important instruments to make this happen. The IEA commends the United Kingdom for its systematic approach to monitoring and evaluation. The government has put a lot of effort into developing a suite of portfolio KPI performance metrics to measure the performance of the portfolio and provide accountability of the expenditure. The IEA calls on the government to continue this approach.

The United Kingdom plays an important role in international collaboration on research and innovation on climate and energy. This is well demonstrated by UK leadership in many areas.

In late 2016, the United Kingdom took a key position under Mission Innovation and has been leading the Mission Innovation Secretariat since 2017 and as Chair since May 2019. The commendable efforts by the United Kingdom have not only strengthened international energy innovation analysis under MI, but also supported co-operation through the IEA's Committee on Energy Research and Technology (CERT) and the IEA's Technology Collaboration Programmes (TCPs). The UK's participation in 19 TCPs remains strong (However, it is lower than it was at the end of 2012 when the United Kingdom was part of 23 TCPs). The United Kingdom is very active in the EU's Strategic Energy Technology (SET) Plan (having provided the chair of two of its governing bodies). The UK participates in ten SET Plan temporary working groups out of 15 and six EU energy related ERA-NETs). The UK is also active in the CEM (six initiatives and two campaigns) and in bilateral collaboration with different countries. The IEA calls on the United Kingdom to continue to participate actively and maintain a leading role in international research and innovation. The planned International Research and Innovation Strategy and specific International Energy Strategy will be able to shape these activities and align them with international opportunities.

Recommendations

The UK government should:

- ☐ Adapt its energy research and innovation policy to incorporate a missions-oriented approach.
- ☐ Focus on innovation areas within the energy portfolio to gain a higher impact from missions-oriented projects.
- ☐ Take opportunities to ensure that the large expected uplift in UK R&D spending flows through to the energy sector, to reflect the ambitions the United Kingdom has towards decarbonisation up to 2050 and to match the efforts of other IEA member countries.

- Continue the UK's leading role in international research and innovation, notably for Mission Innovation.

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8. Electricity

Key data

(2017)

Electricity generation: 335.5 TWh (natural gas 40.8%, nuclear 21.0%, wind 14.9%, biofuels and waste 10.7%, coal 6.9%, solar 3.4% hydro 1.8%, oil 0.5%) -14.6% since 2007

Electricity net imports: 14.8 TWh (imports 18.2 TWh, exports 3.4 TWh)

Installed capacity: 103.5 GW

Peak demand (2016): 61 GW

Electricity consumption: 307.9 TWh (residential 34.2%, commercial 31.8%, industry 30.1%, energy sector 2.3%, transport 1.6%)

Overview

In 2017, electricity accounted for 20% of the total final consumption (TFC) of energy in the United Kingdom, the third-largest final energy source after oil and natural gas. Electricity demand has declined in the past decade, similar to the overall trend for TFC.

In 2017, natural gas was the first fuel and accounted for 41% of electricity generation (Figure 8.1). Nuclear was the second largest power source. In recent years, electricity from renewable energy sources (RES), mainly wind, biofuels and solar, increased to reach 30% in 2017, above the UK's 2020 target, whereas the contributions of oil and coal in electricity supply have sharply fallen. In 2018, the installed RES capacity for the first time overtook fossil fuel capacity. By 2030, the United Kingdom expects more than 50% of its electricity generation to come from variable wind and solar, which will require the mobilisation of all flexibility sources, including from demand response, storage, flexible generation capacity, and as interconnectors. Great Britain is interconnected with France, Ireland, and the Netherlands and higher wholesale prices have increased imports from the European continent. Given the planned interconnector investments, the United Kingdom is to import about 20% of today's generation by 2025.

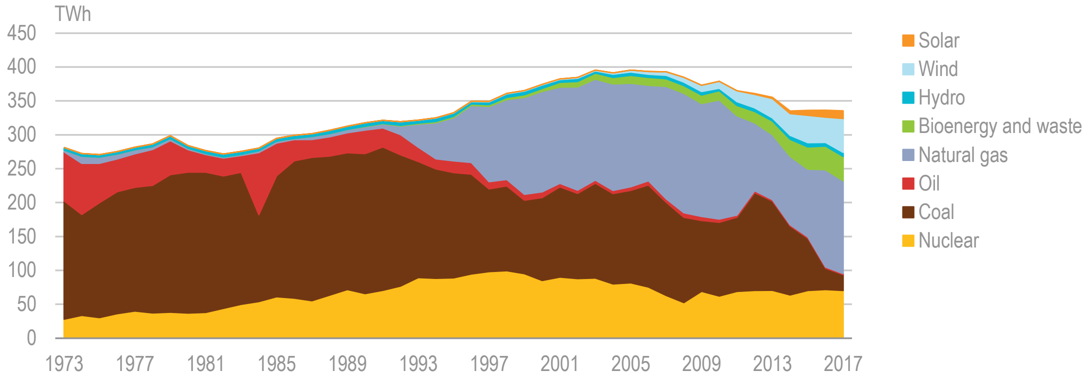
The Electricity Market Reform of 2012 radically changed the wholesale market design. Based on the lessons learned, the government has refined the design over time. Amid increasing electricity prices, the government is taking action in the retail market and introduced a temporary retail price cap to protect vulnerable customers. Price caps are likely to distort the market. An exit strategy is needed, based on a solid and regular assessment of the retail and wholesale market performance.

Supply and demand

Electricity supply and generation

Since peaking at 395 terawatt hours (TWh) in 2003, the UK's electricity generation has declined. In 2017, the total generation was 335 TWh, 15% less than that in 2007 (Figure 8.1). The largest reduction was in coal-fired power generation, which declined by 83% from 2007.

Figure 8.1 Electricity generation by source, 1973-2017

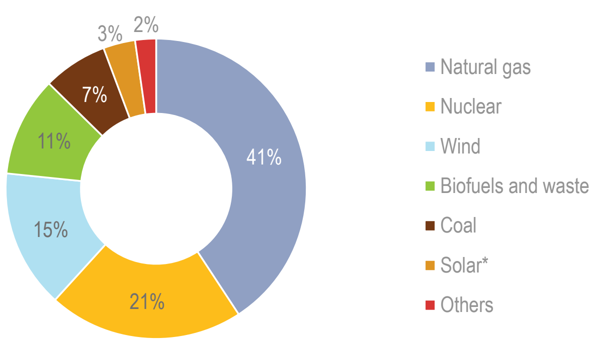


The shares of natural gas, nuclear, and renewable energies have increased, whereas the contribution of coal has sharply declined in recent years.

Source: IEA (2019), *World Energy Balances 2019 First edition (database)*, www.iea.org/statistics/.

Natural gas and renewables are replacing the shares of oil and coal. In 2017, natural gas accounted for 41% of the total generation, up from 20% in 2007 (Figure 8.2). Nuclear accounted for 21% of the electricity mix and delivers a stable base load to the grid. Several of the nuclear reactors are getting old, and the government is planning for new nuclear power plants to replace them (Chapter on Nuclear Energy).

Figure 8.2 Electricity supply by source, 2017

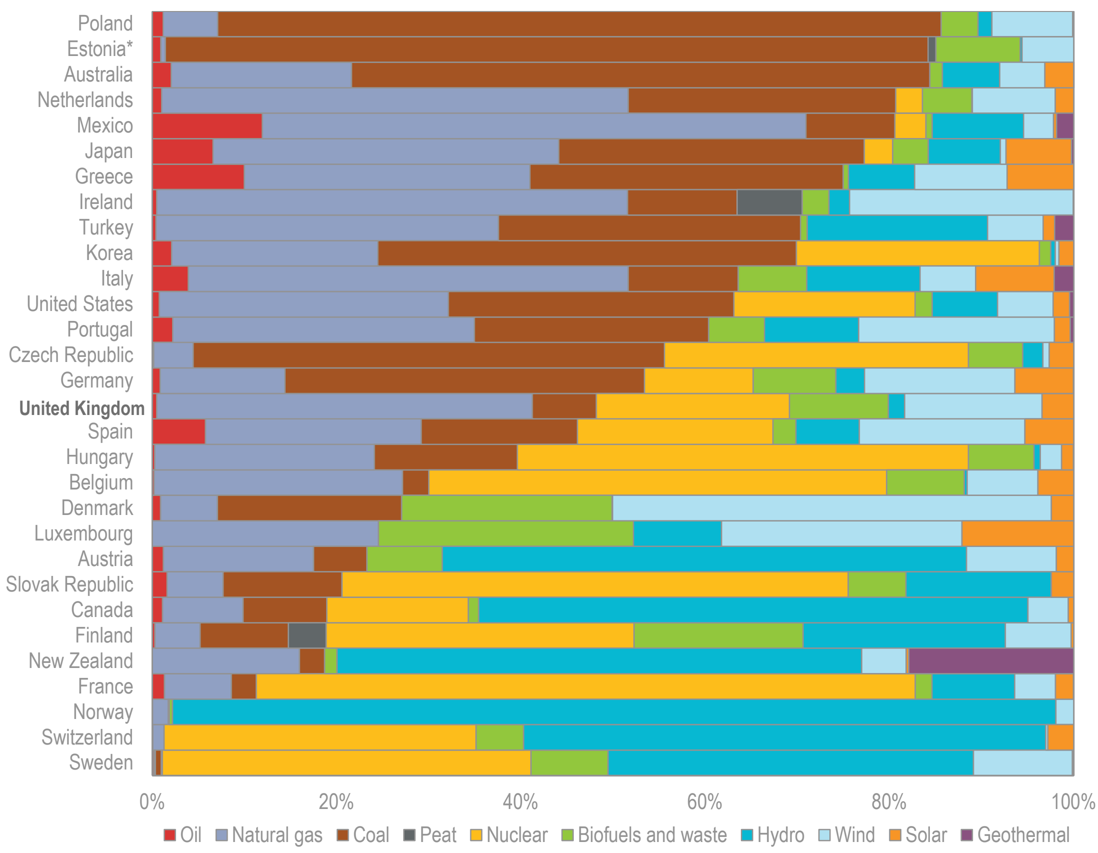


Natural gas dominates the United Kingdom's electricity supply, followed by nuclear power and an increasing share of renewable energy sources, which are replacing coal power.

* Others includes small shares of hydro and oil.
Source: IEA (2019), *World Energy Balances 2019 First edition (database)*, www.iea.org/statistics/.

In the past decade, RES have increased rapidly, particularly wind and biofuels, to account for 30% in 2017, fully in line with its national electricity from RES target under the EC Renewable Energy Directive (2009/28/EC). Together with nuclear power, the share of low-carbon power generation is over 50%, which places the United Kingdom around the median among International Energy Agency (IEA) member countries (Figure 8.3). The share of natural gas in the UK's power supply is the fifth highest, after Mexico, Ireland, the Netherlands, and Italy.

Figure 8.3 Electricity generation by source in IEA countries, 2017



The United Kingdom has around the median share of fossil fuels in electricity generation among IEA countries, with the fifth-highest share of natural gas.

*Estonia's coal represents oil shale.

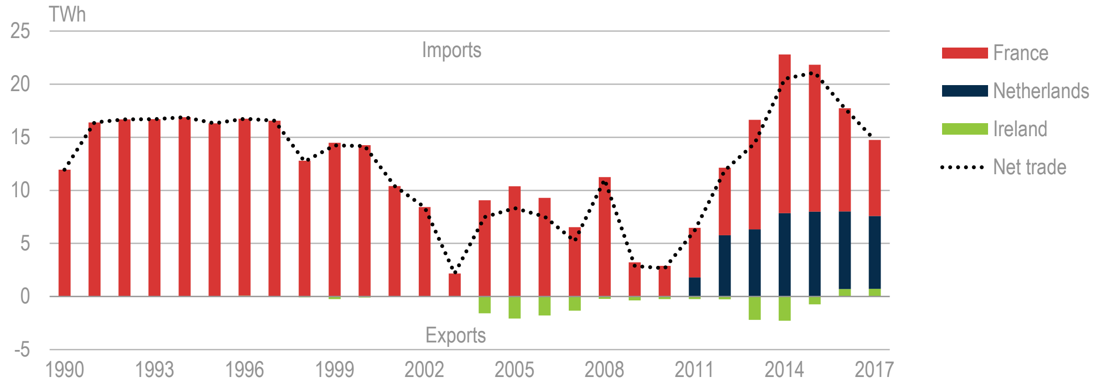
Source: IEA (2019), *World Energy Balances 2019 First edition (database)*, www.iea.org/statistics/.

Electricity imports

The United Kingdom is interconnected with France, Belgium, Ireland, and the Netherlands through five interconnectors with a total capacity of 5 000 megawatts (MW). In recent years, electricity imports have become more important. In 2017, the United Kingdom imported 18.2 TWh and exported 3.4 TWh. Nearly all the trade is with France and the Netherlands, in total 14.0 TWh net imports (Figure 8.4). UK wholesale prices have been on the average higher than those on the European continent, and thereby attract an increasing power trade to the United Kingdom. Many new interconnections have been proposed thanks to high day-ahead price differentials, which would raise the low interconnection levels (see Network adequacy below).

Seasonal variation in the production and consumption of electricity is crucially important for the security of supply.

Figure 8.4 Electricity imports and exports by country, 1990-2017

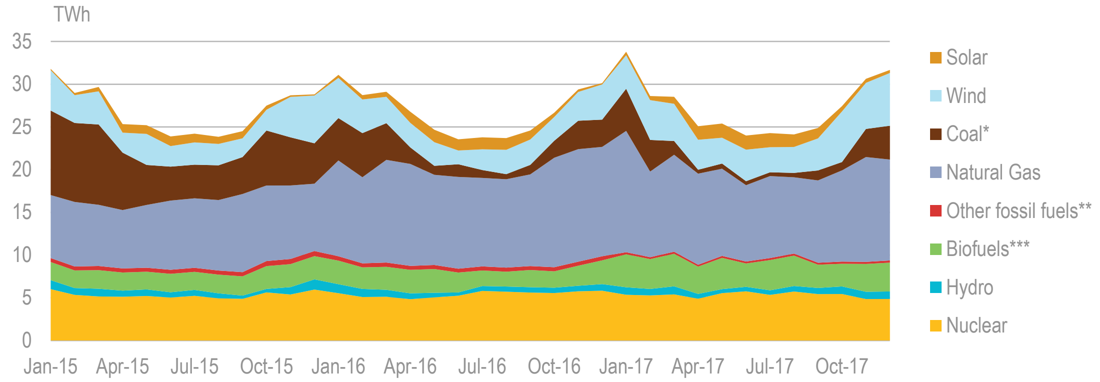


The level of interconnection between the United Kingdom and neighbouring markets is relatively low, but electricity trade has increased and new interconnectors are proposed.

Note: Data are provisional for 2017. Data on import/export country are not available for 2017.
Source: IEA (2018a), *Electricity Information, 2018*, www.iea.org/statistics/.

Electricity production and consumption peak in the winter, with a higher demand for heating (Figure 8.5). The monthly electricity production profile shows that power generation from nuclear energy and biomass and waste is stable over the year, whereas coal and natural gas power are used as flexibles sources to cover the variations in demand. Solar and wind power are variable sources.

Figure 8.5 Monthly electricity generation by source, 2015-17



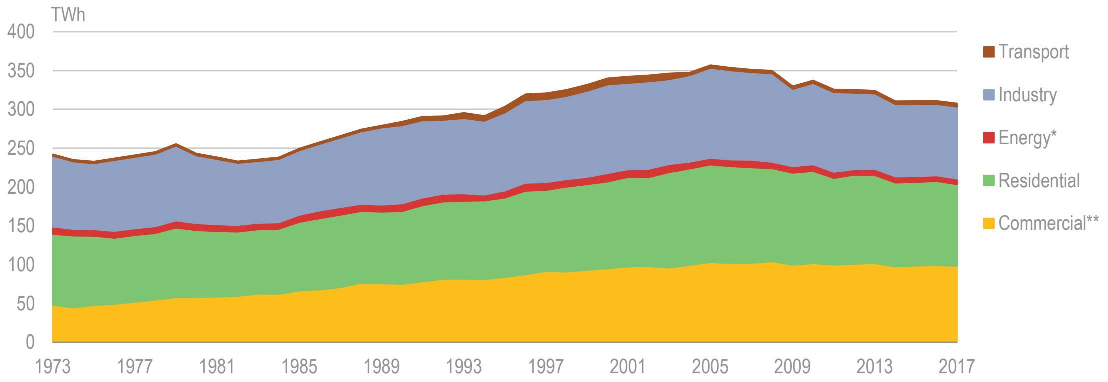
The monthly electricity generation of nuclear and biofuels is stable over the year, whereas coal and natural gas power are used to cover seasonal demand variations.

* Coal includes peat and manufacturing gases.
** Other fossil fuels includes oil products and fossil waste.
*** Biofuels includes renewable waste.
Source: IEA (2018a), *Electricity Information 2018*, www.iea.org/statistics/.

Electricity consumption

Electricity demand growth has flattened out. In 2017, the United Kingdom consumed 307.9 TWh of electricity, 12% below the level in 2007 (Figure 8.6). The sectoral proportion of consumption is fairly balanced with residential, commercial, and industry sectors each accounting for around one-third of the total consumption. One driver of the decline was the decrease in industrial consumption, down 18% from 113 TWh in 2007 to 93 TWh in 2017. Amid higher prices and more energy-efficient appliances, the residential sector's consumption declined by 14% over the past decade, whereas the commercial sector's consumption declined by 4%.

Figure 8.6 Electricity consumption (TFC) by consuming sector, 1973-2017



The total electricity consumption has decreased since 2005, mostly due to a decline by nearly 20% in the industry sector and higher energy efficiency in the residential sector.

* Energy includes petroleum refineries, coke ovens, and other energy sector consumption.

** Commercial includes commercial and public services, agriculture, and forestry.

Source: IEA (2019), *World Energy Balances 2019 First edition (database)*, www.iea.org/statistics/.

Institutional and regulatory framework

The **Department for Business, Energy and Industrial Strategy (BEIS)** retains broad responsibility for policies on energy, climate and electricity market design. Owned by BEIS, the Low Carbon Contracts Company (LCCC) signs and manages contracts for difference (CFDs) for low-carbon generation, forecasts CFD payments and sets Supplier Obligations.

The **Office of Gas and Electricity Markets (Ofgem)** is the national regulatory authority responsible for licensing energy companies, designing the rules for gas and electricity markets, and regulating gas and electricity network monopolies. Ofgem regulates regional transmission and distribution companies (see below) through price controls that limit how much can be charged to system users. Ofgem statutory principle objective is to protect the interests of consumers by promoting sustainability, competition, and security of supply in the energy market. Although it is independent of the government, it is accountable to the parliament. Ofgem is funded based on revenues from license holders.

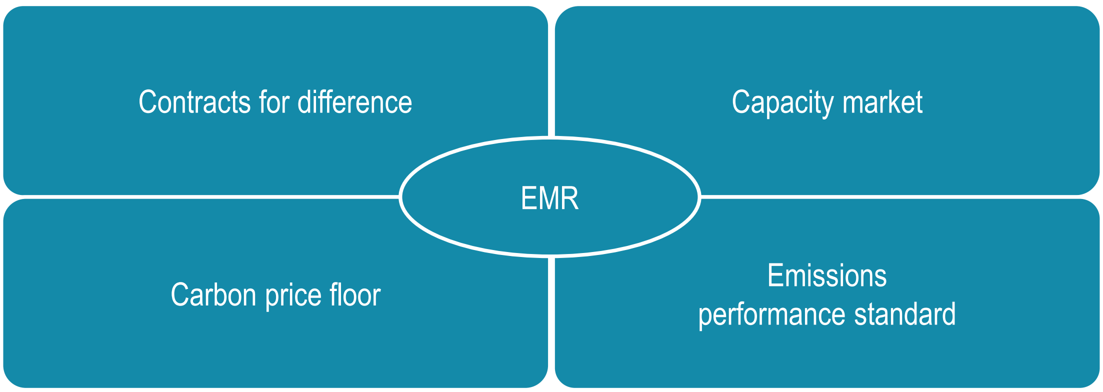
The **Competition and Markets Authority (CMA)** is the UK's primary competition and consumer authority, which took over many of the functions of the Competition

Commission and the Office of Fair Trading. It is an independent non-ministerial government department with responsibility for carrying out investigations into mergers, markets, and the regulated industries and for enforcing competition law, which includes in relation to energy.

The UK electricity market policy framework is set out in the Energy Act 2013 and the Electricity Act 1989 (as amended in April 2017), which also transpose EU directives, and EU networks codes and EU Electricity Regulations apply directly.

Based on the 2011 White Paper (UK Government, 2011), the UK Electricity Market Reform (EMR) introduced a carbon price floor (CPF), CFDs, an emissions performance standard (EPS), and the capacity market (CM) (Figure 8.7). The EMR framework is set out in the Energy Act 2013 and is examined in the following sections.

Figure 8.7 Electricity Market Reform



Source: IEA, 2019. All rights reserved.

Wholesale market design

The UK power market is the electricity market of Great Britain. Northern Ireland, part of the United Kingdom, operates a joint wholesale electricity market with the Republic of Ireland, the so-called single electricity market (SEM), in place since 2007.

Northern Ireland

The system operator for Northern Ireland is SONI and the Northern Ireland Electricity Networks owns the transmission and distribution network. The independent Utility Regulator (UR) is responsible for regulating the electricity (and water) utilities and promoting consumer interests. Northern Ireland has independent power producers that own three fossil fuel generation plants: AES Corporation owns Ballylumford (~1 000 MW) and Kilroot (~650 MW), and the Coolkeeragh (~450 MW) plant is owned by ENSBNI (a subsidiary of the Republic of Ireland's Electricity Supply Board. In 2018, 1 523 MW of renewable generation was connected to the grid in Northern Ireland, with the majority from onshore wind.

The SEM is facilitated by the single electricity market operator (SEMO), a joint venture between EirGrid plc (the transmission system operator [TSO] in the Republic of Ireland) and SONI. SEMO is licensed and regulated co-operatively by the Commission for Regulation of Utilities in Ireland and the UR. The SEM was reformed as the integrated single electricity market (I-SEM) in May 2018 aimed at improvements to the efficiencies of interconnector flows, investment, affordability, and trading through the introduction of continuous trading in the intraday, day-ahead, forwards, and balancing timeframes.

Great Britain wholesale electricity market

The Great Britain (GB) wholesale electricity market is based on "self-dispatch", in which suppliers and generators contract to buy and sell power and have to pay balancing costs if they under or over deliver. Besides the energy market, Great Britain also has a capacity market. Under the British Electricity Trading and Transmission Arrangements, Great Britain is now a SEM with a single price zone, despite congestion between Scotland and England and Wales. (This brings about high costs of countertrading and renders the integration of wind power a challenge.)

Generation and supply are unbundled from transmission and distribution and from the system operation. The National Electricity Transmission System (NETS) is owned and maintained by different regional transmission companies. Scottish Power is the transmission owner for Central and Southern Scotland. Scottish Hydro Electric Transmission owns the transmission network of North Scotland. National Grid Electricity Transmission (National Grid (NG)) is the transmission owner for England and Wales, but also the electricity system operator (ESO) in GB responsible for the balance of supply and demand, and system safety and security. A process of legal separation is underway to split the transmission function from the ESO role of NG. In April 2019, separate legal companies within the NG Group will be created (ESO and Electricity Transmission (ET)); stopping short of full separation. Outside NG's ET remit, offshore transmission networks are owned by a variety of offshore transmission owners (OFTOs) which follow a dedicated regulatory framework devised by Ofgem. Transmission operators charge connection charges and transmission network use of system (TNUoS) and NG collects the balancing service use of system charges. NG's subsidiary ELEXON carries out the balancing and settlement requirements (financial reconciliation of the estimated and actual physical positions of market participants) under the Balancing and Settlement Code.

There are 14 licensed distribution network operators (DNOs), each responsible for planning, constructing, operating, and maintaining the network in their geographical areas (Figure 8.8). The 14 DNOs are owned by six different groups. There are also 14 licensed independent DNOs responsible for network extensions in commercial areas. The regulator, Ofgem, approves the connection and use of system charges that are published by the DNO. The Figure 8.8. shows the distribution areas (NEDL is now NPg, United Utilities is now ENWL, Southern Electric now SSE, SEEBOARD now UKPN).

Network regulation

Ofgem regulates the transmission and distribution tariffs through incentive regulation. In 2010 the United Kingdom pioneered a new output-based method with the revenue = incentives + innovation + outputs (RIIO) model (Box 8.1) with an eight-year regulatory period which started in 2013. RIIO focuses on the delivery of a specified range of outcomes for customers, which encourages distributors through a regime of incentives with rewards and penalties to achieve an efficient and cost-effective delivery of the specified services. It also provides opportunities for distributors to profit from innovation and incorporating third parties in the delivery of energy services. RIIO is being used to facilitate the delivery of public policy outcomes in relation to reliability, vulnerable customers, and the environment. Performance-based regulatory regimes are designed to promote timely and efficient investment and innovation that benefits consumers, while providing distributors with the ability to respond to a complex business environment.

Across GB, the latest distribution price control for 2015-23 allowed around GBP 24.6 billion in funding for the distribution network. Ofgem incentivises DNOs to minimise losses on their networks. The DNO performance is assessed against four criteria – understanding of losses, stakeholder engagement, processes for managing losses, and innovative approaches to managing losses.

Interconnectors

The GB electricity system is connected with North-West Europe via 4 000 MW of interconnector capacity – 2 000 MW with France (IFA) and 1 000 MW with the Netherlands (BritNed) and 1 000 MW with Belgium (Nemo Link) (Table 8.1). Two interconnections link Great Britain and the SEM – the 500 MW Moyle interconnects Great Britain with Northern Ireland and an East-West interconnector of 500 MW capacity links Great Britain to the Republic of Ireland. An additional 3.4 gigawatts (GW) of capacity is under construction to link Great Britain with Norway (North Sea Link) and France (GridLink) by 2021. A further 9.5 GW of projects have sought regulatory approval, and the government has stated its support for at least 9 GW more than is currently operational.

Ofgem's "cap and floor" regime offers revenue for interconnectors from the allocation of capacity to users who want to flow electricity between Great Britain and its neighbours. The cap and floor regime was developed by Ofgem in collaboration with Belgium's regulator CREG.

The floor is the minimum amount of revenue that an interconnector can earn, which means that if an interconnector does not receive enough revenue from its operations, its revenue will be "topped up" to the floor level from national transmission revenues. NG will, in turn, recover them from transmission charges applied to all users, and thus consumers may pay part of the commercial risk of an otherwise merchant project. The cap is the maximum amount of revenue an interconnector can earn. Should an interconnector's revenue exceed the cap, it will transfer the excess revenue to NG, which will, in turn, reduce transmission charges. For consumers, the cap on revenues provides benefits in return for their exposure in underwriting the floor. For each interconnector project, the cap and floor values are calculated ex ante for the project lifetime of 20+ years based on operational expenditure (opex) and capital expenditure (capex), and cap/floor returns approved and scrutinised by Ofgem.

Offshore transmission regime

The government developed a competitive offshore transmission regulatory regime that supports the renewable energy targets. The Electricity Act 1989 allows Ofgem to adopt regulations for competitive tenders for OFTOs. The Electricity (Competitive Tender for Offshore Transmission Licences) Regulations 2015 set out the process that is to be followed by all parties involved in the tenders managed by Ofgem.

Figure 8.8 Electricity transmission networks in the United Kingdom

This map is without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries and to the name of any territory, city or area.

Note: km = kilometre.

Box 8.1 Overview of the United Kingdom's RIIO performance-based regulatory framework

RIIO is Ofgem's new performance-based framework for setting price controls for regulated energy businesses. The new regulatory period for distributors commenced in 2015. RIIO encourages distributors to: 1) put stakeholders at the heart of their decision-making process, 2) invest efficiently to ensure continued safe and reliable services, 3) innovate to reduce network costs for current and future consumers, and 4) play a full role in delivering a low-carbon economy and wider environmental objectives. Key elements of the regime include:

Eight-year regulatory period: the extended regulatory period provides more regulatory stability and encourages longer-term focus.

- Upfront (*ex ante*) assessment: sets the base revenues and basis for changes in the revenues over the subsequent eight-year period with limited possible reopeners that provide a high level of certainty for regulated distributors.
- Cost-sharing mechanism: if the distributor spends less than the target set, the savings are shared between the distributor and customers. This produces strong incentives to outperform. Conversely, if the distributor overspends, the extra costs are shared between the distributor and its customers in the same way. This mitigates the impact of cost overruns.
- Weighted average cost of capital approach: reimburses debt and equity investors at an appropriate level. The cost of debt is updated annually.
- Comprehensive quality outputs: distributors' business plans need to be informed by and tailored to their customers' needs, e.g. level of network reliability, availability, and environmental impacts.
- Regulatory asset value (RAV) approach: outlays for long-term investments are recovered over lifetime revenues as a return on the RAV so the costs are shared between all the customers who benefit from the investment.
- Totex approach: assesses the total expenditure (totex), taking opex and capex together. This provides the company with incentives to choose the most economic option when deciding between opex and capex solutions.
- Uncertainty mechanisms: limited provisions to manage specific cases of uncertainty risk through possible revenue changes during the period, e.g. extra revenues to provide a greater network capacity.
- Promoting innovation: encourages distributors to consider different ways to achieve greater cost savings or increase the scope of future delivery.

Under RIIO, Ofgem asks distributors to submit business plans on how they intend to meet the RIIO established by Ofgem. RIIO places a strong emphasis on stakeholder engagement and distributors must obtain stakeholders' input and use in the plans. Ofgem reviews the plans. Where a distributor's business plan is considered of high quality, its new price control settlement may be fast tracked.

Table 8.1 Interconnectors of the United Kingdom

Interconnector	Connection	Completion/ Due	Capacity	Voltage	Capacity allocation*	Congestion management***
Interconnectors in operation						
IFA	France	1986	2 000 MW	270 kV	Forwards ECA Day-ahead ICA (ECA if not ICA) Intraday ICA	Electricity Regulation 714/2009 with maximisation of capacity available to the market
Moyle	Northern Ireland	2002	500 MW	250 kV	** Forwards ECA Day-ahead ICA (ECA if not ICA) Intraday ICA	Day-ahead capacity is calculated and released ahead of time
BritNed	The Netherlands	2011	2000 MW	450 kV	Forwards ECA Day-ahead ICA (ECA if not ICA) Intraday ECA	Electricity Regulation 714/2009 with maximisation of capacity available to the market
East-West	Republic of Ireland	2012	500 MW	200 kV	** Forwards ECA Day-ahead ICA (ECA if not ICA) Intraday ICA	Electricity Regulation 714/2009 with maximisation of capacity available to the market
NEMO	Belgium	2019	1 000 MW	HVDC 400 kV	Forwards ECA Day-ahead ICA (ECA if not ICA) Intraday ECA	Observer CACM for CCC
Interconnector under construction						
GridLink	France	2022	1 400 MW	HVDC	Forwards ECA Day-ahead ICA (ECA if not ICA) Intraday ECA	Observer CACM for CCC
ElecLink	France	2019	1 000 MW	HVDC 320 kV	Forwards ECA Day-ahead ICA (ECA if not ICA) Intraday ECA	Observer CACM for CCC
IFA2	France	2020	1 000 MW	HVDC 320 kV	Forwards ECA Day-ahead ICA (ECA if not ICA) Intraday ECA	Observer CACM for CCC
North Sea Link (NSL)	Norway	2020	1 976-82 MW	HVDC 525 kV	Forwards ECA Day-ahead ICA (ECA if not ICA) Intraday ECA	Observer CACM for CCC
Interconnector with regulatory approval and advanced development						
NorthConnect	Norway	2022	1 400 MW	HVDC 525 kV	UK regulatory approval received	
GreenLink	Ireland	2021	500 MW	HVDC 320 kV	UK regulatory approval received	
VikingLink	Denmark	2022	1 400 MW	HVDC 400 kV	UK regulatory approval received	
FABLink	France	2022	1 400 MW	HVDC 320 kV	UK regulatory approval received	
NeuConnect	Germany	NN	1 400 MW		UK regulatory approval received	
Aquind	France	NN	2 000 MW	HVDC 320 kV	Exemption request not granted by ACER, decision 22 June 2018	

* The introduction of the Cross-Border Intraday Market Project, which is due to have both phases completed in 2019, will introduce intraday implicit capacity allocation in line with provisions of the CACM Guideline (Commission Regulation 2015/1222).

** On completion of the I-SEM on the island of Ireland, the East-West and Moyle interconnectors will allocate capacity on the forwards market through financial contracts, while day-ahead allocation will be implicit, and intraday will be implicit allocation and market coupled.

*** The Capacity Allocation and Congestion Management Guideline (Commission Regulation 2015/1222) introduces a new regional process for congestion management called the Coordinated Capacity Calculator.

Notes: CACM = capacity allocation and congestion management; CCC = coordinated capacity calculator; ECA = explicit capacity allocation; HVDC = high voltage direct current; ICA = implicit capacity allocation; kV = kilovolts.

Towards a low-carbon electricity sector

The share of variable renewables (wind and solar) in total installed capacity has nearly doubled from 18% in 2006 to 29% in 2016. Although the total installed power-generating capacity reached 97.6 GW in 2016, up from 83.6 GW a decade ago (Table 8.2), wind power capacity amounted to 16.2 GW and solar power to 11.2 GW. In November 2018, for the first time, the installed RES capacity in Great Britain has overtaken that of fossil fuels. The capacity of wind, solar, biomass, and hydropower reached 41.9 GW, above the 41.2 GW capacity of coal, gas, and oil-fired power plants. However, in terms of electricity generation, RES only accounted for 28% in 2018 (Imperial College/Drax, 2018).

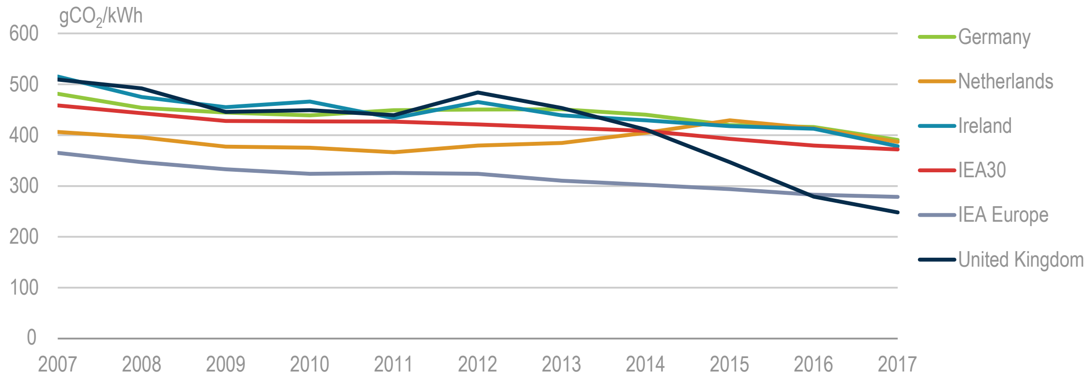
The carbon dioxide (CO_2) intensity in power and heat generation in the United Kingdom has rapidly decreased in recent years, compared to that neighbouring countries (Chapter 3) to 280.7 grammes of carbon dioxide per kilowatt-hour (gCO_2/kWh), a 46% decline since 2006. Although this trend is consistent with that of other IEA member countries, the decline was much more rapid in the United Kingdom after 2012 (Figure 8.9). New regulations introduced under the EMR were a strong driver and, combined with low gas prices, the CPF has made coal unprofitable to operate since 2015.

Table 8.2 Installed electricity-generating capacity, 1995-2016 (MW)

Energy source	1995	2000	2006	2011	2012	2013	2014	2015	2016
Nuclear	12 762	12 486	10 969	10 663	9 946	9 906	9 937	9 487	9 497
Hydro	4 220	4273	4 131	4 423	4 437	4 453	4 474	4 521	4 579
Solar	0	2	14	1 000	1 753	2 937	5 528	9 535	11 899
Wind	200	412	1 955	6 596	9 030	11 282	1 3074	14 316	16 217
Tide	0	1	0	4	9	8	9	9	13
Total combustible fuels	*52 943*	*61 219*	*66 453*	*71 141*	*70 872*	*65 034*	*63 600*	*59 431*	*55 435*
Steam	40 795	36 504	33 608	32 053	28 816	23 449	21 672	19 144	15 070
Internal combustion	166	177	153	122	119	102	105	109	105
Gas turbine	2 552	2 556	1 918	2 022	1 959	1 927	1 934	1 725	1 799
Combined cycle	9 185	21 138	26 965	32 188	35 150	34 872	33 807	31 696	31 766
Other generations	245	844	3 366	4 756	4 828	4 684	6 082	6 757	6 695
Total capacity	**70 125**	**78 393**	**83 632**	**93 827**	**96 047**	**93 620**	**96 622**	**97 299**	**97 640**

Source: IEA (2019), *World Energy Balances 2019 First edition (database)*, www.iea.org/statistics/.

Figure 8.9 CO_2 intensity of power and heat generation in the United Kingdom and in other selected IEA member countries, 2007-17



United Kingdom's CO_2 intensity in the power sector fell by 45% in the past four years, and in 2017 the United Kingdom ranked below neighbouring countries and the IEA Europe average.

Source: IEA (2019b), *CO_2 Emissions from Fuel Combustion 2019*, www.iea.org/statistics/.

Carbon price floor

In 2013, the government introduced the CPF in Great Britain composed of two components: 1) the EU Emissions Trading System (EU ETS) allowance price and 2) the Carbon Price Support (CPS), which tops up the EU ETS allowance prices. The CPF helped in making coal less profitable than gas for power generation. Every year, the UK Treasury confirms CPS rates in advance of delivery at the budget. The CPS was set at British pounds (GBP) 4.94 per tonne of carbon dioxide-equivalent (GBP/tCO2) for 2013/14, 9.55 GBP/tCO2 for 2014/15, and 18.08 GBP/tCO2 for 2015/16. At the 2014 Budget, the government confirmed that it would freeze the CPS rate at 18 GBP/tCO2 from 2016/17 to 2019/20 due to competitiveness concerns, despite the initial intention to raise the CPF to 30 GBP/tCO2 in 2020 and 70 GBP/tCO2 in 2030. Budget 2016 maintained the cap at 18.08 GBP/tCO2 from 2016/17 to 2019/20. At Budget 2018, the government announced that CPS rates will be frozen at 18.08 GBP/CO2 in 2020/21 following the rise in the EU ETS price. From 2021/22 the government will seek to reduce CPS rates if the total carbon price (TCP) remains high.

Contracts for difference

CFDs were created to incentivise investment in low-carbon electricity generation (nuclear and renewables). A generator party to a CFD is paid the difference between the "strike price" (a price for electricity that reflects the cost of investing in a particular low-carbon technology) and the "reference price" (a measure of the average market price for electricity in the GB wholesale market). The first CFDs were concluded based on an administered strike price, decided by the government – this included the Hinkley Point C (HPC) nuclear plant. On the government side, the Low Carbon Contracts Company is the CFD counterparty and consumers pay for the difference. In 2016, the nuclear power plant (NPP) project HPC (3 200 megawatts electrical) was awarded a CFD for 60 years at a strike price of GBP 92.50 per megawatt hour (GBP/MWh). The government moved to competitive auctions in 2015 (established technologies in "pot 1" and less-established technologies in "pot 2") and in 2017 (less-established technologies only). The next auction is set to take place in May 2019. CFDs have brought about investment in renewables and nuclear generation. Although the early CFDs with administered prices led to high costs for consumers, competitive auctions contributed to scale with lower strike prices and lower cost of capital for investors, notably for offshore wind (Chapter on Renewable Energy and Grubb and Newbery [2018]). Plants that receive CFDs are not allowed to participate in the capacity market (which is described in detail in "Security of supply" below).

Emissions performance standards

Under the Energy Act of 2013 and the Emissions Performance Regulations of 2015, the EPS for new fossil fuel capacity is set at an equivalent rate of 450 gCO_2/kWh of "base load generation". The EPS also complements the National Planning Policy, which requires new coal-fired power stations to be equipped with carbon capture and storage (CCS). The EPS provides a regulatory backstop to prevent the construction of new carbon-intensive forms of electricity generation, such as unabated coal-fired power stations. In August 2018, the government announced the five-year review of the EPS.

In addition, the government set the goal of ending unabated coal power generation in Great Britain by 2025. In January 2018, the government responded to its coal closure consultation "Implementing the End of Unabated Coal by 2025". The government is developing legislation for a similar 450 gCO_2/kWh emissions limit to apply to existing plants from 1 October 2025. The remaining coal-fired plants will most likely reduce operations by 2023 and close by October 2025 when the government intends to implement new CO_2 emissions limits for UK power plants.

Table 8.3 Operational and closed coal plants in the United Kingdom

Station	Owner	Capacity (MW)	Status
Ratcliffe	Uniper UK Limited	2 000	No plans to close
Drax	Drax Power Ltd	1 980	No plans to close
Cottam	EDF Energy	2 008	No plans to close
West Burton	EDF Energy	2 012	No plans to close
Eggborough	Eggborough Power Lit	1 960	Stopped operations and plans to close in September 2018
Aberthaw B	RWE Npower Plc	1 586	Reduced running
Uskmouth Power	SIMEC	230	Mothballed April 2017
Fiddlers Ferry	SSE	1 961	Contracts up to 2019
Kilroot	AES	520	Plans to close but not authorised
Lynemouth	Lynemouth Power	420	Closed pending biomass conversion
Rugeley	ENGIE	1 006	Closed
Ferrybridge C	SSE	980	Closed
Longannet	Scottish Power	2 260	Closed

Note: SSE = Scottish and Southern Energy.

In November 2017, the government initiated the international "Powering Past Coal Alliance", which in 2019 totals 80 members, including 30 national governments, 22 subnational governments and 28 businesses.

Most of the United Kingdom's coal-fired power plants underwent air pollution upgrades, were converted to biomass or closed (Figure 8.10 and Table 8.3). All the coal-fired capacity that had opted out of the EU Large Combustion Plants Directive had been closed by the end of 2014 and 4.8 GW closed since. In 2016, three power stations closed (Rugeley, Ferrybridge, and Longannet). Kilroot in Northern Ireland and Eggborough announced plans to close during 2018, but Kilroot was not granted the permit to close by the UR. Both Uskmouth and Lynemouth stations are being converted to run on biomass and waste. The United Kingdom's largest power plant and emitter, the Drax station, converted its four coal units to biomass and plans to convert its remaining two coal units to 3.6 GW closed-cycle gas turbine units and 200 MW battery storage. In 2017, there were eight active coal-fired power stations operating in the United Kingdom with a total capacity of 14 257 MW (Table 8.3).

A power market for business and consumers

The wholesale electricity market in the United Kingdom is dominated by vertically integrated companies, the "Big Six", who are engaged in power generation and the supply and/or retail of electricity (and gas). The Big Six are the former gas and/or electricity monopoly suppliers, Centrica, Électricité de France (EDF) Energy, Uniper, RWE Npower, SSE, and Scottish Power. Their share has come down over time. By the end of 2017, the Big Six owned about 50% of the total installed capacity of around 100 GW. By installed capacity at the end of 2016, RWE Npower, British Energy, SSE, Uniper, EDF Energy, Drax Power, and ENGIE were the largest generators (Table 8.4).

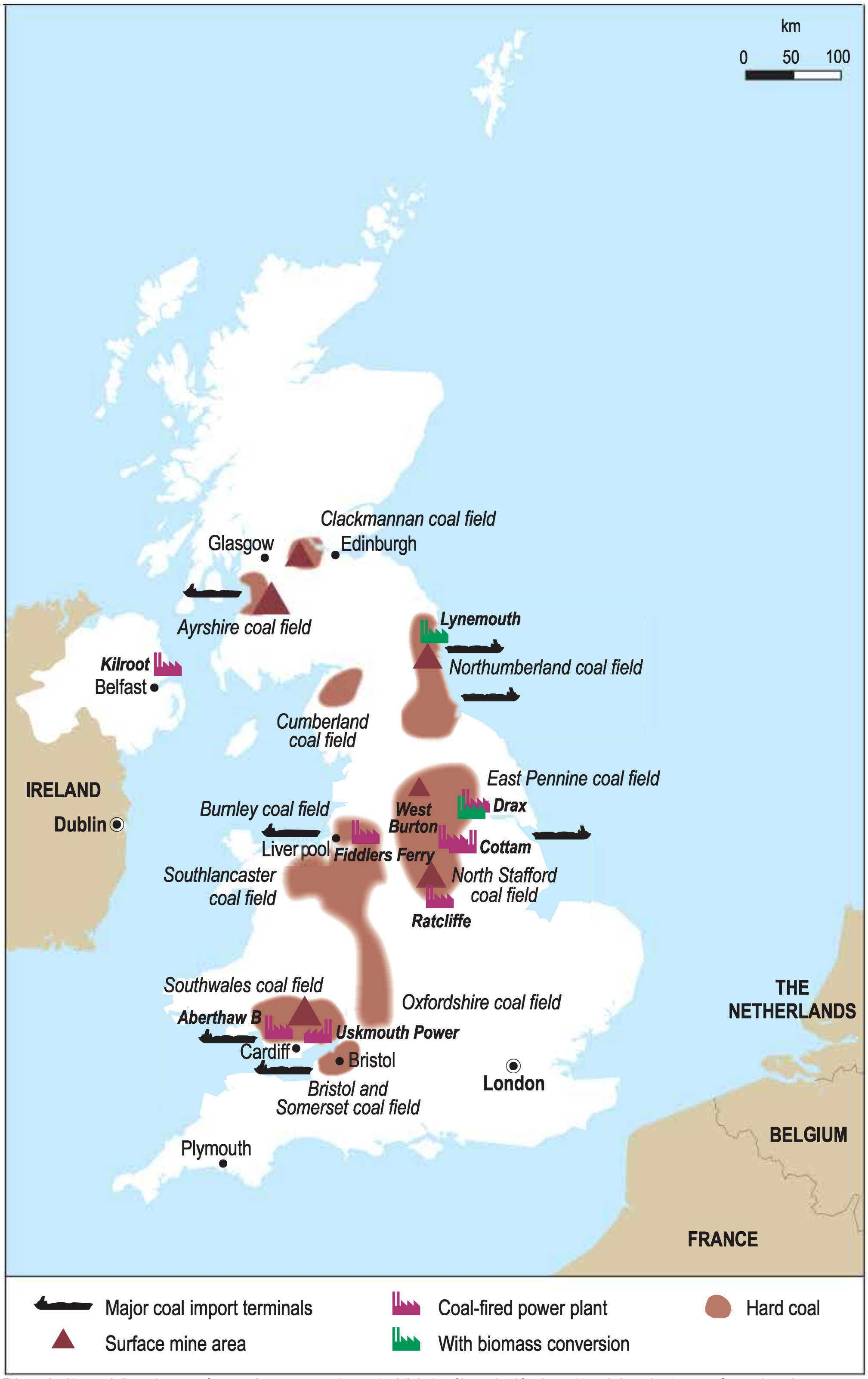
Table 8.4 Ownership structure of generation (2016)

Owner	Total maximum capacity (MW)	Share (%)
RWE Npower	9 909	10.1
British Energy	8 918	9.1
SSE	6 802	7.0
Uniper	6 421	6.6
EDF Energy	5 402	5.5
Drax	4 035	4.1
ENGIE	4 015	4.1
Centrica	2 840	2.9
Intergen	2 490	2.6
Others	46 808	47.9

EDF Energy, owned by the French company EDF, accounted for 24% of the GB electricity supply, RWE Npower for 14%, Scottish Power (owned by the Spanish company Iberdrola) accounted for 8%, Drax for 7% followed by Centrica and E.ON UK (owned by the Germany company Uniper) with 5% each. SSE and Centrica are United Kingdom-listed companies.

The Big Six are all partially vertically integrated in electricity (active in generation and retail). Centrica is vertically integrated in the gas segment, as the company is active in upstream and generation. Both SSE and Scottish Power also have interests in electricity transmission and gas and electricity distribution.

Figure 8.10 UK coal sector, 2018



This map is without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries and to the name of any territory, city or area.

Note: km = kilometre.

The wholesale market is moderately concentrated as eight generators provide 71% of metered volumes in 2017. The index of market concentration, the Herfindahl-Hirschman Index (HHI)[1], fell from 1 267 in 2015 to 1 117 in 2016 and a historic low of 1 034 in 2017.

The most recent inquiry into the energy market was carried out by the CMA from 2014 to 2016. The CMA found that vertical integration was not a concern and that generators' profits were not excessive (CMA, 2016) and that no generator would be pivotal in clearing demand in limited periods, notably amid declining coal-fired generation. The CMA judged competition in the wholesale electricity market to be satisfactory, but proposed a set of recommendations and remedies to improve retail competition to avoid weak consumer response that would indirectly provide market power to the major suppliers (CMA, 2016).

In 2014, Ofgem introduced a requirement on eight large generators to provide better access to hedging products for smaller companies, with a view to increase the market access and liquidity. Ofgem has reviewed this market-making obligation, introduced under the Secure and Promote policy, and proposes to suspend it as it beleave the liquidity and forward trades have improved. The CM, which started operations in 2015, has also offered forward liquidity (four-years ahead).

In recent years, electricity imports increased and new entrants entered the market. However, no small player has reached a 5% market share, despite a simplified "Licence Lite" introduced by Ofgem in 2015 to reduce barriers to entry into the supply market and enable greater third-party participation. In 2018, seven suppliers had a wholesale market share between 1% and 5% and 60 suppliers below 1% (Ofgem, 2018a). However, several new entrants have not been able to sustain their business and exited the market.

In 2018, there were 170 licensed electricity generators and 73 suppliers active in the GB electricity market, which is considered as liquid with a churn rate[2] of 3.7, below that of Germany (14.6), but at the same level as that of the Nordic markets (3.9) (EC, 2018).

Wholesale electricity prices in Great Britain were low between 2012 and 2016 but have increased since (Figure 8.11). Prices are, in general, higher than the European average, with resource and system costs included. The UK electricity prices reflect the levies and cost of low carbon schemes (CPF, CFDs, feed-in tariffs, and the CM), according to a review of the energy costs in the United Kingdom (Helm, 2017). These environmental costs are contained in the wholesale price. The wholesale electricity price also reflects the fact that Great Britain has limited interconnection to continental Europe and a broad set of generation technologies.

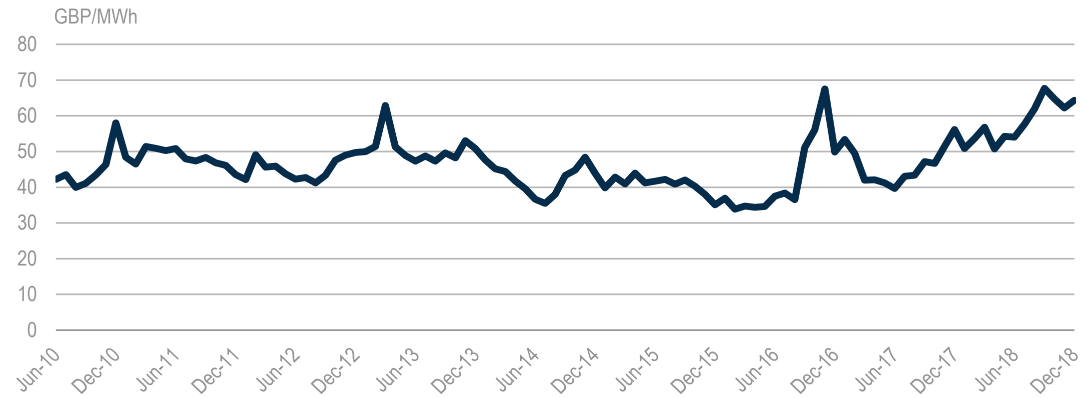
According to Ofgem, during 2010-17, households spent a total of GBP 39 billion on the power sector decarbonisation, with a net cost of carbon saving of 27 GBP/tCO_2 and 101 GBP/tCO_2 for large-scale and 315 GBP/tCO_2 for small-scale renewable subsidies (see the assessment of the cost of decarbonisation policies by Ofgem [2018a]).

[1] HHI is a measure for industry concentration that takes into account the size of firms in relation to the industry. It is calculated by adding the sum of the squares of the percentage market shares of each market participant. For example, a market that consists of five competing firms, each with a 20% share of the market, would have an HHI score of 2 000 (i.e. 400 × 5). HHI is typically used to help assess the degree of market dominance and potential for market power abuse. Views vary on the interpretation of HHI scores. This study uses the scale developed by the European Union, with scores of 750-1 800 considered indicative of moderate concentration, scores of 1 800-5 000 indicative of high levels of concentration, and scores above 5 000 indicative of a very high concentration consistent with the presence of substantial potential market power.

[2] The churn rate measures the liquidity of the wholesale market as a ratio of the total volume of power trade (including exchange executed and over-the-counter markets on the spot and the curve) and electricity consumption in a given time period.

In 2017, the United Kingdom's electricity price for industries was the seventh-highest price by international comparison among IEA member countries (Figure 8.12).

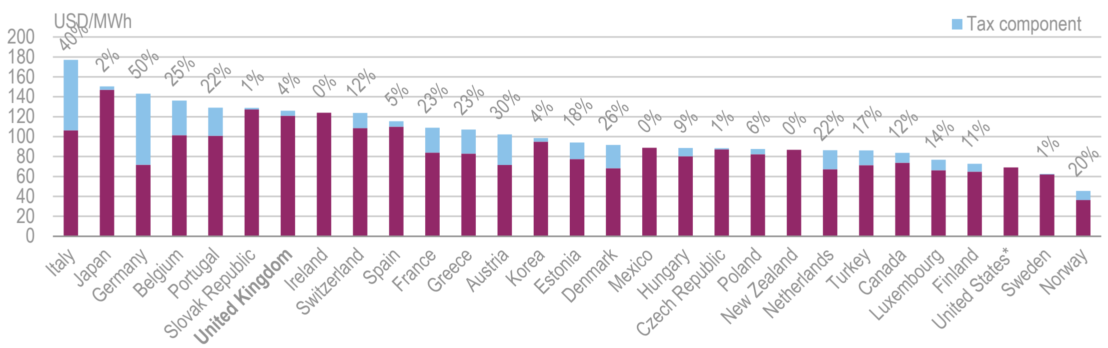
Figure 8.11 Electricity prices in GB, day-ahead baseload monthly average, 2010-18



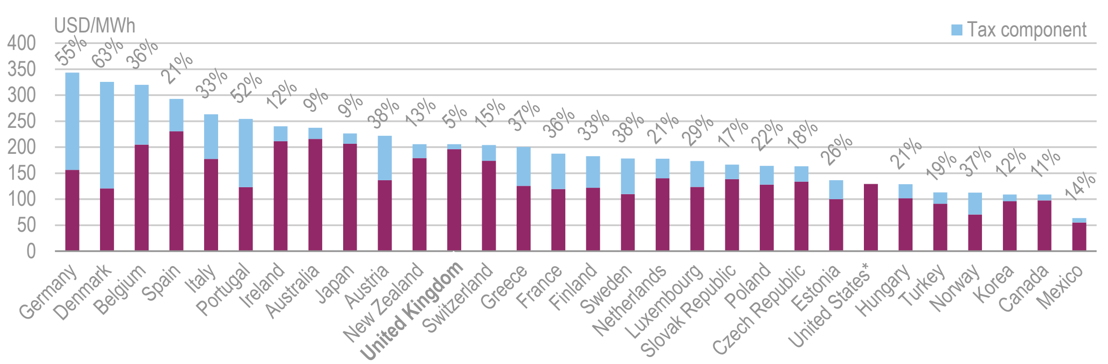
Source: Ofgem, Dataportal (accessed 29 April 2019), www.ofgem.gov.uk/data-portal/electricity-prices-day-ahead-baseload-contracts-monthly-average-gb.

Figure 8.12 Industry and household electricity prices in IEA countries, 2017

Industries



Households



Despite low taxes on electricity, UK industries pay the seventh-highest price in an IEA comparison and the UK household price ranks the twelfth highest.

*Tax information not available for the United States.

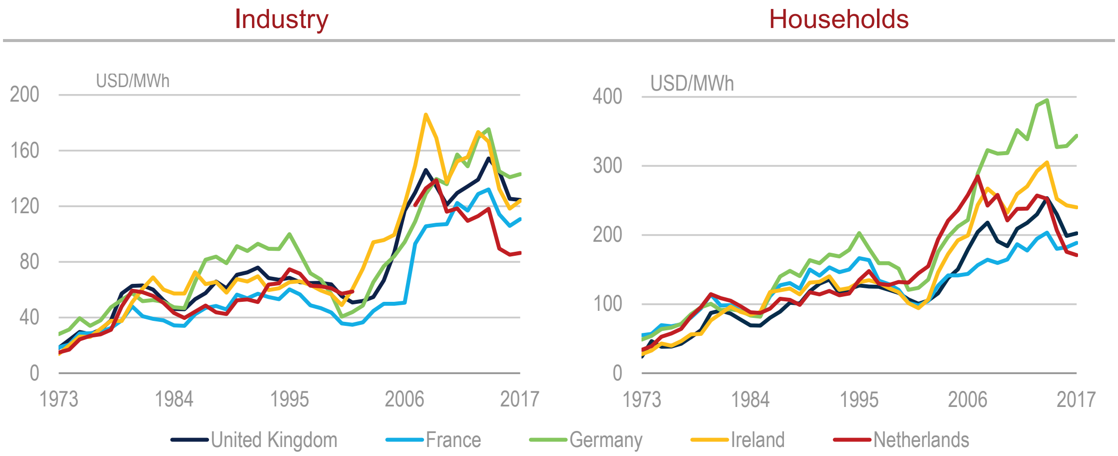
Note: Data missing for industry in Australia.

Source: IEA (2018b), *Prices and Taxes 2018*, www.iea.org/statistics/.

The household price was United State Dollars (USD) 193/MWh on average or the tenth-highest price. However, taxes on electricity prices are very low in the United Kingdom. Electricity price trends have been similar in the neighbouring countries (Figure 8.13). During 2000-14, retail energy prices went up, while energy household consumption came down.

The final electricity retail price is composed of the wholesale energy costs, which account for almost 50%, transmission and system operation costs (25%), environmental costs (15%), and retail cost (20%), which includes the retail profit margin, according to the CMA investigation (CMA, 2016).

Figure 8.13 Electricity prices in selected IEA countries, 1973-2017



UK electricity prices have followed similar trends to those in other neighbouring countries.

Source: IEA (2018b), *Energy Prices and Taxes 2018*, www.iea.org/statistics/.

Electricity retail market performance

The energy market investigation of the CMA from 2014 to 2016 found that the GB retail market needs to improve as consumers on standard variable or default tariffs and prepayment meters are penalised for their loyalty, notably vulnerable consumers. The CMA recommended a suite of remedies, which include the introduction of a half-hourly settlement for small users, faster switching, and consumer engagement. The CMA also suggested reforms towards variable transmission losses and locational signals (CMA, 2016).

The government agreed with the majority of these recommendations and, along with Ofgem, is implementing the remedies proposed by the CMA (UK Government, 2018). In addition, the government agreed with the minority opinion of the CMA that a temporary cap on energy prices until 31 December 2020 would provide protection to consumers while the remedies are implemented, smart meters are rolled out, and the conditions for effective competition are established. Professor Stephen Littlechild offers a different view point on competition – that competition was working reasonably well and that price differentiation or discrimination is a reflection of competition rather than of market power (Littlechild, 2018).

The United Kingdom has around 5 million households on regulated prices with three types of price caps in place. Since April 2017, a price cap for customers on prepayment meters (PPMs) (around 4 million customers), the so-called safeguard tariff, was put in place, which was extended by Ofgem in February 2018 to include another million vulnerable customers who receive the "Warm Home" discount. From 1 October 2018, the level of the safeguard tariff will rise by GBP 47 per year for dual fuel customers to GBP 1 136. As of 1 January 2019, a default price cap entered into force which applies to another 6 million consumers on standard electricity and gas tariffs in addition to consumers on permanent meters, as a temporary measure until 2020. In 2019, a total of 11 million households are under price cap. In 2019, Ofgem reviewed the caps and decided to increase them from April 2019 onwards because of higher wholesale prices.

The Domestic Gas & Electricity (Energy Tariff Cap) Bill requires Ofgem to review retail prices and the level of the cap at least every six months to ensure that the level takes account of external factors such as wholesale energy costs. The default price cap is planned to be temporary until conditions are in place for a truly competitive market, notably smart meters. The cap expires in 2020, with the possibility of a one-year extension period for up to three years. The decision on whether or not to extend the cap will be taken by the Secretary of State for BEIS and informed by a review by Ofgem.

In 2018, Ofgem and BEIS launched a joint review into the future UK retail market.

Smart grids and meters

GB is in the process of rolling out smart meters by the end of 2020. Over 50 energy suppliers are required to install smart and advanced meters. Ofgem has the authority to fine energy suppliers who do not implement advanced meters. Smart meters are not mandatory and the customer has the right to refuse their installation.

BEIS is monitoring the smart meter roll-out and the number of meters in operation in Great Britain on a quarterly basis until the end of 2020. According to BEIS statistics, at the end of March 2018, over 11 million smart and advanced meters operated in homes and businesses across GB. Overall, so far around 21% of all domestic meters are smart.

However, almost all the smart meters that have been installed to date are first-generation (SMETS1) meters. SMETS1 smart meters often lose their "smart" capabilities after switching to another energy supplier and essentially revert to a traditional meter as they cannot send the meter readings automatically to the new supplier. Second-generation smart meters (SMETS2) are beginning to be installed and allow customers to switch energy provider without losing their smart features as they operate via a new central data and communications network (the Data Communications Company). Work is underway to integrate SMETS1 meters into the Data Communications Company's systems. This means that they are interoperable and smart services will be retained when consumers switch supplier; therefore, the consumer will have broadly the same experience as if they had a SMETS2 meter.

As smart meters are not yet rolled out everywhere, consumers are largely settled based on a profile of an average consumer. UK suppliers offer a large number of time-of-use pricing and innovative pricing with specific electric vehicle (EV) tariffs or dynamic tariffs; however, their share is very small in the retail market amid the slow progress of smart meter roll-out. By mid-2019, Ofgem is working on a mandatory market-wide half-hourly settlement that will increase consumer information, awareness, and engagement on their energy bills.

Supplier switching

The Energy Switch Guarantee was launched in June 2016 and provides consumers with the right to switch suppliers within 21 days. Ofgem is working to implement reliable and fast switching through a centralised gas and electricity switching service. In 2018, the annual switching rate was about 18.4%, a very high rate by comparison with other IEA EU countries, which means five out of six households did not switch energy supplier in the previous 12 months (between October 2016 and September 2017) (Ofgem, 2018a). However, more than 60% of households only switched once or never and around 54% were on default tariffs for more than 3 years.

Consumer engagement and vulnerable consumers

Focus on the energy poor and vulnerable consumers has been strong in the United Kingdom. Despite the reduction in real terms of the average dual fuel bill since its peak in 2013, many consumers still worry about the level of their energy bills. Vulnerable customers are more likely to be on expensive standard variable tariffs, despite being less able to afford them. In 2016 – the latest year with available data – 11% of the customers, which represents 2.5 million households in England, were living in fuel poverty. Financial support is given to pensioners and the elderly, in particular the Warm Home Discount Scheme and Winter Fuel Payment.

Demand response (wholesale and retail)

The GB electricity market has advanced demand-side flexibility thanks to the rising deployment of demand-side response (DSR) and increased storage participation in contracted markets. However, retail market DSR remains limited as consumers are not yet able to benefit from DSR because smart meters are not yet fully rolled out. NG's "Power Responsive" programme promoted DSR or storage from industry and large energy users through innovative Information technology platforms or aggregators. In the T-4 CM auction for capacity in the 2021/2022 delivery year, 1.2 GW (2.4%) came from DSR. Half of the accepted capacity was from dispatchable generation, DSR through load shifting, onsite generation or storage, and stand-alone storage.

Security of electricity supply

IEA in-depth reviews focus on the adequacy dimension of electricity security, which includes generation and network adequacy. Adequacy in the GB context refers to the physical capability of the power system to generate and transport electricity to meet consumers' demand. This section also includes an assessment of the challenges and opportunities that stem from the integration of larger shares of variable renewables into the system. In the GB context, flexibility refers to the ability of the system to respond to changes in demand or supply to avoid disruption and limit price spikes. Provided here is a short overview of the legal framework for the security of electricity supply, emergency preparedness, and response for electricity in the United Kingdom.

Legal framework and institutions

BEIS is in charge of the security of electricity supply together with NG and Ofgem. NG needs to ensure the overall power supply meets the demand and that the system stays within the frequency required. Ofgem monitors the security of supply on a regular basis, also as part of the State of the Energy Market reports.

BEIS sets the reliability standard for the GB electricity market equivalent to a loss of load expectation (LOLE)[3]. Since 2013, the LOLE has been set at 3 hours per year (or around a 5% margin of capacity over peak demand), which balances the cost of additional capacity against the costs that a consumer would face if there was ever a shortage in supply. The reliability standard is legislated in Regulation 6 of the Electricity Capacity Regulations 2014 and is used to determine how much capacity the government will procure in the CM auctions annually.

NG monitors the adequacy of demand and supply and models the outlook for both, using NG's Future Energy Scenarios (NG, 2017). Based on this least-worst regrets assessment of a variety of different scenarios and sensitivities, NG makes an annual assessment of how much capacity is needed to meet the reliability standard. This assessment accounts for the amount of capacity provided by power plants that are not eligible for capacity payments, such as low-carbon generation in receipt of other government support. It is the basis of a recommendation to the Secretary of State for BEIS in its annual Electricity Capacity Report.

The Secretary of State also takes advice from an independent Panel of Technical Experts (PTE) before deciding on the final target for the auctions. The PTE impartially scrutinises and quality assures the analysis of NG. It provides an independent view on NG's methodology (PTE, 2017). Alongside the decision on auction targets, the BEIS Secretary of State must also set the non-target parameters that determine the slope of the demand curve. BEIS establishes a cycle for running CM auctions, and has been reviewing and improving the mechanism.

The United Kingdom has a National Emergency Plan: Downstream Gas and Electricity, which sets out the national arrangements established between the government, the electricity industry, Ofgem, the European Commission, and other interested parties for the safe and effective management of electricity supply emergencies.

Network adequacy

NG also plans network investment needs across Great Britain for the period of ten years ahead, set out in its annual Electricity Ten Year Statement (ETYS) and related Network Options Assessment. The latest ETYS indicates that high north-south flows across Scotland and the north of England to the Midlands and the south are increasing and network adequacy needs to evolve in step (National Grid Electricity Systems Operator, 2018a).

The Winter Outlook of NG ESO also assesses the short term electricity security situation and possible network and generation shortages (NG ESO, 2018b).

Most recently, the Western HVDC project to link south-west Scotland to north Wales added 2.2 GW to the network. Staffel (2018) estimates that by Q1 2018 the link had already helped NG save around GBP 9 million per month on constraint payments.

[3] This is the number of hours per annum in which, over the long term, it is statistically expected that supply will not meet demand through the market without mitigating actions being taken by the system operator.

Generation adequacy

Peak electricity demand in Great Britain was 61 GW in 2016. National Grid's future scenarios assesses generation adequacy in the medium to longer term (NG, 2017). NG's scenarios estimate electricity demand to remain flat, but projects GB peak demand to rise (Table 8.5). Under NG's "Two Degrees" scenario peak demand could be 62 GW in 2020 and 65 GW in 2030. The forecast electricity demand is higher depending on the speed of electrification of heat and transport, consumer behaviour around the use and uptake of EVs, and smart charging appliances ("Consumer power" scenario). Overall, capacity margins have come down in the United Kingdom since 2010, with the retirements of coal and slow progress on nuclear new builds. In recent years, the capacity reserve margin was around 20%.

Table 8.5 Evolution of peak demand (GW)

Scenario	Electricity year beginning		
	2016	2020	2030
History	61		
Two Degrees	61	62	65
Slow Progression	61	60	61
Steady State	61	61	61
Consumer Power	61	62	66

Table 8.6 Cumulative new capacity (GW) for all power producers by fuel type

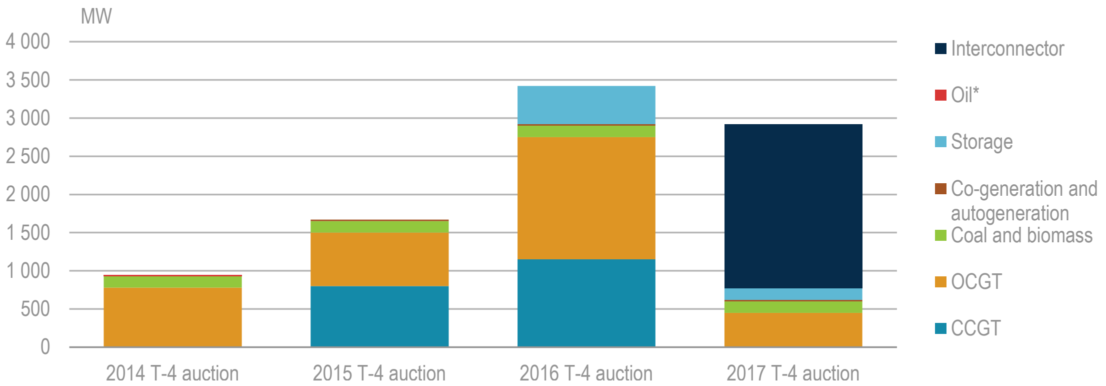
Fuel type	2017	2018	2019	2020	2021	2022
Coal	0.00	0.00	0.00	0.00	0.00	0.00
Coal and natural gas CCS	0.00	0.00	0.00	0.00	0.00	0.00
Oil	0.00	0.20	0.35	0.82	0.94	0.94
Natural gas	0.00	1.02	1.73	2.27	3.83	3.83
Nuclear	0.00	0.00	0.00	0.00	0.00	0.00
Other thermal	0.00	0.00	0.00	0.00	0.00	0.00
Renewables	3.59	6.93	8.30	9.76	11.60	15.14
Interconnectors	0.00	0.00	1.00	1.00	3.00	5.80
Storage	0.00	0.21	0.21	0.21	0.60	0.60
Total cumulative new build	3.59	8.36	11.58	14.06	19.96	26.31

Source: NG (2017), *Reference Scenario*, also available under www.gov.uk/government/uploads/system/uploads/attachment_data/file/666266/Annex-k-total-cumulative-new-capacity.xls.

The GB capacity market

Based on the Energy Act of 2013, the Electricity Capacity Regulations came into force in 2014 for Great Britain (Ireland has its own CM) with a first CM auction in December 2014. The main objective of the CM was to ensure security of supply and close the anticipated supply gap related to the large-scale retirement of old coal and NPPs. All types of capacity (and technology, including demand response, storage, and interconnectors) are able to participate, except for capacity providers already in receipt of support from other policy measures (most importantly renewable energy). Existing diesel and coal generators can participate in the CM until 2024. Capacity payments are determined via competitive auctions, held four years (T-4 auction) and one year (T-1 auction, which tops up the targeted capacity) before the delivery period. In total, there were four T-4 auctions and a special early auction (T-1 auction), with clearing prices that ranged from GBP 6.95 kilowatts per year (GBP/kW/yr) to 22 GBP/kW/yr. The CM has cleared increasing amounts of new capacity – in the December 2016 auction 3.4 GW and in January 2018 2.9 GW, mostly new interconnectors. The share of open cycle gas turbines (OCGTs) being awarded capacity remuneration in T-4 auctions has been in decline (but up in T-1 auctions).

Figure 8.14 New build capacity by fuel and technology in T-4 CM auctions



*Oil refers to oil generation and reciprocating engines.

Notes: 2017 T-4 auction refers to the auction in January 2018. OCGT = Open Cycle Gas Turbine; CCGT = Combined Cycle Gas Turbine.

Source: Ofgem (2018b), *Annual Report on the Operation of the Capacity Market in 2017/18*, https://www.ofgem.gov.uk/system/files/docs/2018/08/20180802_annual_report_on_the_operation_of_cm_2017-18_final.pdf.

The government was keen that the CM should allow for new gas-fired power plants. To-date, the CM has secured over 5.4 GW of new build capacity for delivery between 2018/19 and 2021/22 (Figure 8.14 and Table 8.6). This includes a new combined cycle gas turbine (CCGT) plant (at Kings Lynn), a new OCGT plant (at Spalding), and a significant number of small-scale gas engines, but so far only the Carrington CCGT (800 MW) is in commission (since 2017).

The most recent T-4 auction secured in total 50.41 GW of capacity at a cost of 8.40 GBP/kW/yr from 2017/18 through to 2021/2022 (Ofgem, 2018b). Most of the cleared capacity in this T-4 auction was from existing generators (86%) and interconnectors (BritNed, IFA, and Moyle). The three new interconnector projects (ElecLink, IFA2, and Nemo Link) were awarded contracts, too. In terms of fuels, 46% were CCGTs, 16% nuclear and 9% co-generation[4]. The T-4 auction for 2021/22 had 6 GW of unabated coal capacity secured agreements (Drax and Ratcliffe) and 4 GW did not secure agreements.

[4] *Co-generation* refers to the combined production of heat and power.

Battery storage was successful for the first time in December 2016, with a 500 MW clearing for delivery in 2020/21. DSR has come forward through the CM, with 1.4 GW and 1.2 GW clearing in the previous two main auctions, respectively. At the same time, the inclusion of these technologies is not straightforward (in terms of de-rating factors, availability, and penalties). Large amounts of storage, DSR, and embedded generation did not clear the T-4 2017.

In 2018/19, the forecast LOLE is 0.001 hours, much below the three-hour standard (NG ESO, 2018b). Electricity supply has consistently been more reliable than the standard (with fewer market actions needed by NG) as NG consistently underestimates the contribution from the demand side (Ofgem, 2018b). NG recently evaluated that the risk of loss of load is much lower than 3 hours (in fact, only 45 minutes) with the start of the half-hour settlement in the wholesale market and acknowledged that it underestimates the distributed generation, battery and EVs, demand response, and on-site generation.

In terms of participating companies, the share of the Big Six has been falling in favour of small-scale generation companies (so-called embedded generation), which were highly competitive as they were able to avoid transmission network usage charges. The CM arguably over-encouraged the entry of embedded generation (connected to the distribution grid), which do not pay but receive the TNUoS. Ofgem decided to cut the Triad payment to reduce these embedded benefits, and the court confirmed Ofgem's decision against Peak Gen Power in June 2018.

The Great Britain CM is now in a standstill period, and NG postponed the upcoming T-4 and T-1 auctions for delivery years 2022/23 and 2019/20 after the ruling of the European Court of Justice (ECJ) on 15 November 2018, which annulled the state aid clearance for the CM on the grounds that the European Commission should have conducted a more extensive investigation before granting approval, in particular of certain DSR-related elements of the scheme. The judgement does not challenge the design of the Great Britain CM as such. Since Tempus filed its complaint with the ECJ, the CM has undergone several adjustments and reforms. The ruling halts capacity payments until the European Commission grants a new approval. Among other aspects, Tempus argued that the European Commission had not fully investigated issues that relate to the design of the Great Britain CM as to the treatment of DSR in the CM, and discrimination in the contract length.

- Procedure – Tempus argued that the European Commission could not conclude that the CM did not have a problem as to its compatibility with the internal market given the procedure followed, as there was no distinction between the preliminary stage and the investigation stage.
- Length of discussion – Tempus's view was that the length of the discussion was insufficient to reach every dissenting opinion.
- Assessment of the DSR in the CM – Tempus argued that the entry threshold of 2 MW should not be the same for DSR and for generators.
- Discrimination against DSR – Tempus claimed that maximum one-year contract period for DSR is unfair when the generation can get periods up to 3 or 15 years. Tempus claimed that to impose the same amount of bid bond to DSR causes an "entry barrier" for DSR.

The government is running a replacement auction for the winter of 2019/2020, and will also look for the T-4 auction to be held as T-3 next year, if approval is achieved. If and when State aid approval is received, back payments will be paid to those Capacity Market agreement holders who have delivered against their obligations and will be subject to reductions to account for fees and penalty charges for non-compliance, which would otherwise have been levied but for the standstill period. There is also a general requirement for the CM to be reviewed (under domestic UK law) as soon as possible after five years of the Energy Act 2013. BEIS has conducted a consultation as a first step and aims to report in summer 2019 on the results. The consultation related to the adaptation of the CM to a market with higher shares of variable renewables (which include from distributed generation), the rising role of interconnections (which will require more locational signals as well as flexibility), the DSR products (related issues of de-rating, availability, and penalty), and the interplay of the CM with the balancing markets and strength of penalties.

Short-term electricity security

There have been no major outages in recent years other than those caused by external natural factors such as storms and flooding. The “Beast from the East” in the winter of 2017/18 produced a cold spell that was well managed on the side of gas security, thanks to stable electricity supplies (wind and coal), as explained in detail in Chapter on Natural Gas. The increasing interlinkage of the gas and electricity system require a stronger focus on system operations. NG is well placed as the joint operator of both systems to develop the even closer coordination of these systems. However, the coordination of demand-response measures will require greater attention across both systems (Chapter on Natural Gas). According to NG, the freeze of the CM will not raise any risks to the supply in the winter of 2018/19.

The overall reliability of supply for the NETS during 2016/17 was 99.999962%, with the annual system availability for the year being 94.31%. In 2016/17, there were 29 loss-of-supply incidents in total, 11 incentivised and 18 non-incentivised, which resulted in a total estimated unsupplied energy of 105.01 MWh, or roughly 0.03% of the total annual consumption. During 2016/17, there were zero reportable voltage excursions or frequency excursions within the NETS. Since 2015, there have been significant improvements in network reliability, which currently stands at 99.99%. Customer interruptions as well as interruption duration have both fallen by 11%.

Table 8.7 Interruptions and customer minutes lost in distribution networks

	2014/15	2015/16	2016/17
Customer interruptions*	50.83	46.26	45.06
Customer minutes lost**	39.16	34.43	34.71

* Number of customers interrupted per 1 000.

** Duration of interruption per customer affected.

Source: Ofgem (2017)

Emergency response reserves

NG has a wide range of tools at its disposal to ensure short-term electricity supply. The Electricity Margin Notices are formal requests to the market to bring forward additional capacity. This measure was last required in May 2016; it is employed to maintain NG’s operating margin of approximately 900 MW above the forecast demand. To meet system reliability and stability, NG has several reserves, e.g. the frequency response (617 MW), short-term operating reserve (1 369 MW), and fast reserve (300 MW). These numbers denote the volumes of these services between 1 April 2017 and 30 September 2017. This capacity may not all be available at the same time. Plans are in place for the restoration of power system operations through a black start service, which is procured on a bilateral basis, mainly from generators that have the capability to start main blocks of generation from an on-site auxiliary generator without reliance on external site supplies. NG uses a range of out-of-market measures (new balancing services, voltage reduction, maximum generation, emergency interconnector assistance, and demand disconnection). Before the need to enact controlled disconnection arises, NG can also call on generators to deliver the maximum technical generation for short periods and/or reduce voltage across the system.

Agreements are also in place to request up to 2 GW of emergency assistance via interconnectors, with the total current interconnector import capacity being 4 GW.

The Electricity Emergency Supply Code is a publicly available document which details steps the UK Government can direct industry to take in an electricity supply emergency. The ESEC sets out how electricity network companies will operate in the highly unlikely event of a prolonged period of shortfall in electricity supplies. This is achieved through implementing a well-managed process to equitably share electricity through rolling three hour power cuts, generally at times of peak demand, whilst ensuring that pre-designated 'Protected Sites' maintain their supplies for as long as possible. The ESEC also ensures that a communications strategy is put in place and customers are aware of when their power will be affected.

Flexibility of the power system

The UK energy system is changing, with a fast increase in the amount of decentralised and variable renewable energy (VRE), which brings about a growing discrepancy between peak loads and installed generation capacity. Out of the 100 GW installed capacity today to cover the 60 GW peak demand, 30 GW may not always be available due to their variable nature and the inaccurate forecasting of wind or solar, which is improving but remains a challenge for NG. One indicator to measure system flexibility and system integration challenges is the rate of wind curtailment, which reached above 10% in 2015 but has come down since (Staffel [2018]).

System operation and Great Britain wholesale market reforms

At high shares of VRE, the system operations need to better manage frequency, maintain voltage and system stability, and address bottlenecks and/or congestion in the networks.

NG manages over 20 ancillary services for voltage, frequency and rate of change of frequency (ROCOF), thermal constraints, and black start. Ancillary services were originally designed for a power system with thermal plants and expanded over time to suit the changing system. NG acknowledges that this has created a high complexity and a lack of transparency. NG has undergone a standardisation and simplification of these services to move markets closer to real time.

NG has to constrain wind (notably in the winter months) and compensate generators for their loss of revenues during such periods. As monthly wind constraints fall, the costs to NG also fall. The NG system management cost reached a new peak of GBP 1.15 billion in 2016/17. In 2015, the imbalance "cash-out-system" was reformed to increase the incentives for settlement by the generators themselves. In 2017, the wholesale market was moved to half-hour settlement. Although the NG system balancing costs fell in 2017/18 compared to the previous two years, system costs increased due to the need for higher countertrading within the Great Britain single price zone amid network congestion. In 2018, system costs accounted for GBP 500 million out of GBP 980 million system balancing costs in 2017/18, down from around GBP 1.1 billion in 2016/17 (Ofgem, 2018a). The new network reinforcement north-south will foster the integration of Scottish wind power into England.

The Balancing Significant Code Review, set out by Ofgem in 2015 to encourage a more-efficient balancing behaviour and stronger signals for the provision of flexible capacity, is progressing fast. The latest reforms in phase 2 reinforce the effect of the net imbalance volume by basing the system price on the most expensive 1 MWh rather than on the weighted average price of the most expensive 50 MWh[5]. This is likely to increase the incentive to invest in flexible resources. Industry analysis also points out that this may lead to greater price volatility in the wholesale market.

Phase 2 of the review also includes a better recognition of the value of short-term operating reserves (STOR) in the balancing mechanism. In Phase 1, STOR bids below the reserve scarcity price (RSP) were adjusted upwards to meet the RSP, but bids above were not. In Phase 2, the RSP is determined based on a dynamic LOLP aimed at better reflecting real-time system conditions in each settlement period. Previously, LOLP was calculated statically based on historical tables that mapped the reserve margin directly to a set LOLP value. RSP = VOLL × LOLP. In Phase 2, LOLP was also updated from 3 000 GBP/MWh to 6 000 GBP/MWh.

NG is also in the process of testing procurement auctions for STOR that are closer to delivery. Previous auctions were held three times a year to cover the seasons. This was seen to favour providers who can forecast and control their availability over a longer period. Moves towards shorter lead times in the procurement of ancillary services is seen as welcome to encourage a greater participation of flexibility resources with a reduced forecasting horizon, e.g. dispatchable wind, solar, and distributed energy resources. Overall, these reforms should contribute to reduce the costs of balancing the system, both by improving the incentive to maintain a balanced position and by improving liquidity.

Smart systems with demand-side technologies

The system is, however, changing. A range of smart technologies, such as electricity storage and DSR, are emerging at a fast pace. New business models are being developed, such as those that reward consumers for using electricity when supply exceeds demand on the grid.

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[5] From 2001 to 2006 the price average reference was based on the weighted average of all the balancing bids in the net imbalance volume, from 2006 to 2015 it was based on the most expensive 500 MWh, and from 2015 to 2018 it was based on the most expensive 50 MWh.

The *Smart Systems and Flexibility Plan (*UK Government/Ofgem, 2017) and the October 2018 progress update, produced jointly by Ofgem and the government, contains a wide range of actions that the government, Ofgem, and industry will take to remove barriers to smart technologies, enable smart homes and businesses, and make electricity markets work for flexibility. Several regulatory measures are under way.

Ofgem and the government aim to create a level-playing field for storage through a number of measures: defining storage in legislation, creating a modified generation licence for storage, enabling the co-location with renewables that participate in subsidy schemes, and ensuring unbundling of storage and networks.

The GB CM has seen a growing participation of flexible technologies, including DSR, battery storage, pumped hydro, and interconnector capacity. However, there are serious concerns that the CM reduces the scarcity signal and remuneration for DSR and storage providers in the energy market.

Flexibility from interconnection

The UK interconnection capacity is expected to increase by 2023 to 9.8 GW given the projects approved by regulators and three projects already under construction (Table 8.1). The 1 400 MW NSL between Scotland and Norway will begin construction in 2019 to be commissioned in 2022. Another 2 000 MW of interconnection capacity to France (ElecLink and IFA2) was approved in September 2016 to enable imports from 2022 – ElecLink started construction in February 2017. An interconnector is in the planning stage with Denmark (Viking Link) which obtained all permits and consent and took a final investment decision. NG expects a need for further interconnection capacity to 2030, with an increase from a level of 9.8 GW to 19.8 GW, amid nuclear retirements in Great Britain during 2020 and delays in building new ones, as well as growing offshore wind capacity of up to 30 GW by 2030 and 43 GW by 2050.

Impact of Brexit

Brexit is expected to impact the investment case for the planned interconnector projects, as it may change the social costs and benefit assessments by regulators and possible access to EU funding. Brexit will also affect the operations of existing interconnectors and eventually the volume of trade (IFRI, 2018). In the event that the United Kingdom leaves the internal market, the European Commission has stated that without a withdrawal agreement, the inter-TSO compensation mechanism (Commission Regulation No. 838/2010) will no longer apply, which thus potentially requires grid-access charges on the interconnectors to "third countries" and the return to explicit auctions on the interconnectors. If the UK leaves the EU without a deal, European energy law (EU market coupling, EU electricity market rules and regulations) will no longer apply to the UK and the UK's electricity markets will be decoupled from the Internal Energy Market (UK Government, 2019). In addition, there are implications for trade between Great Britain and the Single Electricity Market (SEM) on the island of Ireland through interconnectors, meaning trade will no longer take place on a day ahead basis. Market participants will be able to trade across these interconnectors using intraday auctions.

Regional security and flexibility

With existing nuclear and coal capacities coming to the end of their lifetime, the rising share of variable renewables will also evolve across the North Sea region (United Kingdom, Ireland, Norway, Denmark, the Netherlands, Germany, France, Belgium, and Luxembourg). Interconnections are extremely important for the United Kingdom, especially in winter, in a low nuclear power scenario and given the current CM freeze. The region is becoming more exposed to weather impacts (hydro, wind and solar power) and requires more flexibility to manage variable suppliers from grids and interconnections, storage (batteries and flywheels), fast-acting peaking generation, and DSR, as well as regional storage solutions, such as compressed air energy storage, power to gas, and power to heat.

According to NG, electricity imports to the United Kingdom (net imports) are expected to rise to 77 TWh in 2025 and decrease thereafter to 48 TWh in 2035, thanks to the expected rise of nuclear and renewable energy, and 50% of the capacity in the market will come from flexible sources (DSR, dispatchable generation, and storage).

A high interconnection capacity, however, also raises the challenges of the local concentration of interconnector landing points. Distribution operator UK Power Networks already anticipates that this may aggravate line congestions in the South East. Increased interconnection may also lead to rising costs of countertrading by the NG ESO to avoid grid stability issues. Increased interconnection also emphasises the importance of coordination between neighbouring ESOs and coordinating ramping agreements.

The United Kingdom is interconnected with Ireland, Belgium, the Netherlands, and France and, as imports are expected to increase, electricity security is becoming more reliant on the strong collaboration of NG with its European partner TSOs (TenneT, Stattnet, Eirgrid, and RTE), which includes through the European Network of Transmission System Operators for Electricity (ENTSO-E). In the future, ENTSO-E expects the North Sea region to have strong market trades across different timeframes (day-ahead, intraday, balancing, etc.) because of complementarities between Norway's hydropower, France's nuclear power, and Great Britain and Irish wind and solar power according to its latest regional North Sea Investment Plan (ENTSO-E, 2018).

Interconnector flows are determined on the basis of price differentials. However, despite the general expectation of trade flows to the United Kingdom from the European continent, the NEMO interconnector will rather export power to Belgium, because Belgium faces several supply concerns and its power prices are, generally, the highest in Central West Europe.

Within the EU framework, regional security collaboration is being stepped up, based on the collaboration among TSOs, with the rise of variable renewable sources and stronger integration across the European Union. The System Operation Guideline established under EU law the Regional Security Coordinator (RSC). The United Kingdom is part of the Coreso network of TSOs, which was established in 2008 among seven TSOs: REE (Spain), Elia (Belgium), RTE (France), NG (United Kingdom), Terna (Italy), 50Hertz (Germany), and REN (Portugal). However, the United Kingdom will also need to work with the Nordic RSC established in 2016, which involves Fingrid (Finland), Svenska Kraftnät (Sweden), Statnett (Norway), and energinet.dk (Denmark).

Assessment

Wholesale electricity markets and decarbonisation

The United Kingdom was an early mover with the liberalisation, privatisation, and deregulation of its energy markets and decarbonisation under the Climate Change Act of

2008. The UK power mix is moving towards a fast increase in variable renewables over the next 5-10 years, which are expected to reach 53% by 2030.

With the aim to reconcile the markets approach and climate action, in 2013 the government introduced the EMR as part of the Energy Act, which provided for a radical change away from the energy-only market. The EMR comprises four policy instruments to encourage investment in low-carbon technologies (nuclear and renewables) and security of supply: the CPF, CFD scheme, capacity mechanism, and EPS.

The EMR was the response to the energy transition period and the government builds on a future of low carbon electricity. The Secretary of Energy (usually we do not mention names)indicated that the EMR was instrumental for the transition to a future energy market, where there would be no more trilemma between clean, affordable and secure energy (Clark, 2018).

As a transition toolbox, the EMR aims to move the energy sector towards decarbonisation.

The CPS rate sets a level for the price of carbon in the electricity sector; the price has been frozen at 18.00 GBP/tCO_2 since 2016/17 and contributes to the government´s plan to end unabated coal power in Great Britain by 2025. Between 2012 and 2016, coal power generation fell sharply, driven by the CPS rate, and the decline is expected to continue in line with the 2025 target. The future TCP, made up of the CPS rate and the EU ETS price, is uncertain beyond 2021; it will depend on the linkage to the EU ETS or plans for a domestic alternative.

The CFDs have delivered substantial new renewable electricity production and, over time, have generated significant cost reductions through competitive auctions. For example, the clearing price has halved for offshore wind power between the auctions in 2015 and 2017.

The CM was introduced with the objective to ensure security of supply by incentivising investments. New flexible resources are now participating in the CM, including batteries, DSR, and interconnectors (at a heavily derated capacity). In November 2018, the ECJ sided with DSR provider Tempus Energy that the European Commission failed to run a proper assessment of the Great Britain CM. Following the ruling of the ECJ of November 2018, the CM is deemed illegal state aid and is currently suspended until the European Commission clears the market for state aid.

Overall, the UK has regularly adapted the CM. In 2019, the GB CM is being reviewed as a whole by the United Kingdom under its regular five year domestic review. It is important to implement the lessons learned, notably the need to adapt the CM to new technologies, notably demand response. The issues relate to the calculation of the required capacity volume in the CM, the derating of DSR, and storage. Besides, the government is undertaking a comprehensive review of the reliability standard and its level.

A well-functioning energy market with efficient wholesale price formation is important to deliver cost-effective results for consumers. The UK wholesale electricity market is moderately concentrated, with eight vertically integrated generators that provide three-quarters of the metered volume. The situation is improving; for example, in 2017 the HHI-index (a measure of market concentration and competition) fell to the lowest value this decade to around 1 000. The market-making measures introduced by Ofgem are no longer considered needed, as the market design has been reformed with the CM, which provides for hedging and the participation of flexible sources.

In conclusion, the EMR was conceived as a series of targeted interventions to manage the transition into a decarbonised electricity market. CFDs provided revenue certainty and an element of subsidy to renewables through competitive allocation, the CM placed a value on the security of supply through a market-wide auction process, CPS underpinned the value of carbon in the power sector to supplement the EU ETS and was able to drive coal-to-gas switching, and the EPS effectively prohibited new coal power stations. The government together with Ofgem have refined these mechanisms over time, and learned from the early challenges in setting administered CFDs, which promote the role of competitive auctions.

Going forward, there is a need to foster and consolidate the current set of policy instruments introduced as part of the EMR with regard to the costs, the flexibility, and the security of the power system.

Although some may argue that the EMR presented a departure from the reliance on wholesale markets as a sole mechanism, the model was successful in driving investment during the transition, although at a high cost to consumers. Despite record investment and cost reductions from renewables, questions have been raised about the costs for consumers (costs for renewable support schemes in total will be GBP 10.6 billion in 2022/23 and the increasing system costs.

The CMA estimated that consumers are paying about GBP 250-310 million more per year for their electricity than necessary because of the lack of competition in the first allocation of CFDs at the administered strike prices. Similarly, support for HPC was allocated without competition. The study by Professor Dieter Helm commissioned by the government concludes that the cost of energy (Helm, 2017) in the United Kingdom is higher than necessary to meet the targets of the Climate Change Act. By international comparison among IEA countries, the United Kingdom has relatively high electricity prices before taxes.

In the medium term, the decarbonisation of the power sector will continue and the United Kingdom is expected to reach very high shares of VRE in the power mix – above 50% by 2030. Solar photovoltaics (PV) already enjoys very high shares in the United Kingdom. It is therefore critical to prepare now for a more flexible, decentralised, and intermittent power system after 2025. In an electricity system with high levels of distributed and renewable generation, demand-side flexibility becomes increasingly important. New demand, such as EVs and at a later stage electrified heat, could become important flexibility technologies, supported by the new technologies and energy services that are transforming the electricity sector thanks to a greater digitalisation, which also supports energy efficiency. Market and regulatory frameworks need to adapt to this development.

One example is to assess the procurement of grid ancillary services, which are numerous today, and their contribution to locational signals to increase the transparency and liquidity in these markets. The government has already identified steps in the smart systems and flexibility plan, which sets out a range of market and regulatory reforms.

Third, security of supply will also depend on the future level of interconnection between Great Britain and its neighbouring markets, which is relatively low today. The interconnection level should increase to an appropriate and cost-effective level, both for commercial reasons and to improve the security of supply and cost-effectiveness in the regional mix. The United Kingdom is today well below the 10% interconnection target of the European Union. However, Brexit may pose serious investment challenges to new interconnector projects, as costs and benefits may change depending on the future trade relations with the European Union countries.

Today's UK regulatory framework is the result of years of modifications, adaptations, and improvements, which in turn have created very complex regulations that could become a barrier to entry for new players in the market. Although the shift to half-hourly settlements and the ongoing reforms of network pricing are welcome steps, the regulatory system still evolves around the supplier and is based on industry-driven network codes. The energy code review is a major opportunity for the UK market design.

Retail electricity markets for consumers and business

Government efforts are focused on the retail market outcomes with significant reforms being implemented.

In March 2014, Ofgem referred the gas and electricity market to the CMA after indications that the market was not working as well as it could. Despite strong evidence that the UK retail market has seen new entry and that consumers are benefiting from more dynamic and innovative prices and services, there is a lack of consumer trust that the UK energy industry will serve them well. The UK retail market could benefit more from engaged household consumers; only 40% of UK customers shop around for the best price, whereas 60% are less active and have kept their standard variable tariff. Historically, tariffs were around GBP 320 more expensive each year than today's cheapest fixed-term deals, according to Ofgem.

From April 2017, following the CMA (2016) recommendations, Ofgem implemented a cap on PPM tariffs (4 million consumers) and extended the scheme to the consumers with the warm home discount (another 1 million). As of 1 January 2019, a temporary price cap through the Energy Tariff Cap Bill expanded existing caps to all consumers on standard variable tariffs that have not yet switched. This has broadened the current price cap from 5 million households on PPMs and added another 6 million households.

There is a risk that suppliers will charge up to the price cap and consumers that have not switched will remain with the default tariffs which becomes the de facto safety net. Without a proper exit strategy and clear guidance from Ofgem with regard to the conditions under which competition and success are measured against the situation prior to the introduction of the cap in 2018, such a price cap risks being in place for a long time. The cap will be reviewed yearly in April and October. The cap is temporary and will end in 2020 if conditions for effective competition are in place, but with a facility for the Secretary of State to extend it year by year – to 2023 at the latest – when the cap will end. Ofgem will be required to report to the Secretary of State on whether the conditions for effective competition are in place so that the cap can be lifted. To date, rising price caps have pushed consumers to supplier switching.

The decision of CMA to force suppliers to stop locking firms into automatic rollover contracts from June 2017 is a very positive step towards improving the retail market for small businesses. Suppliers are no longer able to charge exit fees or to include no-exit clauses in automatic rollovers. Developed in the late 1990s, the current switching arrangements are still complex and are around 20 days and can lead to delays, errors, and costs. Ofgem initiatives to deliver a faster, more reliable switching for consumers are very promising. In fact, the recent switching rates of 20% are relatively high by international comparison.

The transition towards a smart and flexible power system

The benefits of a smart and flexible energy system are expected to amount to GBP 17-40 billion by 2050 (Carbon Trust/Imperial College London, 2016), thanks to the avoided or deferred network reinforcements and generation build, avoided curtailment of low-carbon generation, and greater efficiency in system usage.

The UK power system has addressed well the challenges of wind integration into the system and is actively working to support the integration of solar PV, batteries, and EVs, as the next frontier. Although wind curtailments have increased during the past five years, the reform of the balancing code and the investment in the north-south network expansion in 2018, which better integrates Scottish wind farms, helped to reduce curtailments.

However, the United Kingdom has a large amount of ancillary services, still largely supplier-based regulation, and non-cost-reflective network pricing. There is a need to move towards more cost-reflective network pricing (to end the freeride of embedded generation that avoids network charges) and improved open access arrangements. This will remove barriers to the efficient development and uptake of new technologies and business models, especially the more distributed technologies. Removing market barriers is a strong driver to improve market entry and contestability. The role of Ofgem is critical and the rules currently under discussion to ensure its independence, resources, and more proactive role to advise government on competition and retail markets are a welcome development. Ofgem is conducting a review into the future of network charging, a very important assessment to ensure the recovery of fixed costs in the energy system amid rising shares of demand-side technologies (solar PV, battery storage, or EVs).

The United Kingdom is taking leading steps to develop markets for flexibility, notably through a wider range of black start services, the redefinition of parameters for frequency response participation, and the consultation on exclusivity clauses and principles for revenue stacking. This gives clarity to the market.

Demand response is expanding in the United Kingdom. Given the saturation in the frequency response and reserve markets and the freeze in the CM, new avenues could be explored for its participation in the wholesale market. Battery storage can deliver demand response services and can contribute to increasing liquidity in the balancing market and reduce the overall balancing cost. Ofgem and the Government are placing focus on electricity storage. Ofgem is going to publish a modified generation licence for storage, which will include a definition. The Government has committed to defining storage in legislation, once parliamentary time allows. However, current efforts fall short of addressing issues around self-consumption and other storage types, which include heat storage. Given the United Kingdom's goal to electrify heat (besides transport), heat storage is becoming increasingly important.

Locational aspects of flexibility markets will be critical. These markets are always local or regional in a sense that the market is cleared taking into account bids from a specific geographic region. However, many market players are active across several regional markets. In this sense, a lack of harmonisation of market rules and products is an important consideration and might lead to illiquidity of the markets. For example, DNOs are geographic monopolies and they set their flexibility procurement tenders individually. This structure creates a situation in which flexibility providers must understand and bid under different market rules in each DNO's geographic region with significant transaction costs for the service providers, which poses a barrier to entry.

The potential advantages of smart meters, which provide real time information on customer energy consumption, a better management of energy use and enable savings. Smart meters open up untapped sources of demand management and new ways in which consumers can switch and engage with the market, provided dynamic tariffs are available to them. However, the smart meter roll-out is proceeding at a slower pace than expected. British energy suppliers are responsible for installing smart metering equipment at no upfront cost while consumers may refuse the installation. Ofgem can fine suppliers. Gas and electricity suppliers are required by their license to take all reasonable steps to roll out smart meters to all of their residential and small business customers by the end of 2020, when consumers can opt into such a service. The roll-out has been progressing more slowly than expected, with 11 million smart meters of the SMETS1 generation being deployed so far. The targeted full roll-out for 2020 is at risk if there is no proactive policy to improve the benefits for consumers associated with smart meters, which include dynamic prices, consumption monitoring, and real-time data monitoring for smart appliances, which are becoming more and more widespread among consumers.

Moreover, the digitalisation of the electricity system offers new opportunities to support the integration of distributed renewable resources, EVs, and smart systems. There are new risks emerging linked to cybersecurity, privacy, and economic disruption, and the government should integrate digital resilience in its energy market policies.

A smarter energy system requires a stronger emphasis on independent system operations. The government has taken steps to reform NG, which is transitioning to its role as an ESO on the basis of legal unbundling, and should lower the focus on transmission investment and shift it towards system operation. Also, distribution companies transition to a system operator role. Both the distribution system operators and the ESO will need to exchange a growing amount of data. It is critical for Ofgem to facilitate the discussion and data sharing between the ESO and DNOs. The creation of the Energy Data Taskforce and the upcoming Engineering Standards Review, alongside a broader review of all industry codes and their governance, are welcome steps.

Recommendations

The UK government should:

- ☐ Wholesale electricity
  - > Assess the possibilities to simplify and consolidate the policies introduced as part of the EMR, following a review of the capacity market.
  - > Prepare for a more flexible energy system with ever higher shares of variable renewables to deliver low-carbon energy, which includes in heat and transport.

- > Continue to enable the development of interconnectors and strive for the reduction of future uncertainties for these investments when it comes to the trading of energy.
- > Prioritise demand-side flexibility within future reforms to the electricity market, e.g. in the intraday and balancing market, for industry, and for the aggregation of end-consumer flexibility.
- > Provide certainty on the future carbon price regime in the United Kingdom.

☐ Retail electricity markets

- > Evolve the UK regulatory framework and remove barriers to new types of participants in the retail market, such as aggregators.
- > Ensure that energy suppliers continue to deploy smart meters in accordance with their licence obligations.
- > Encourage the take up of cost-effective tariffs for networks.
- > Integrate digital resilience into technology research and development, and to the policy and market frameworks to address cybersecurity and privacy concerns.
- > Substantially reduce the switching time and simplify the switching process.
- > Provide as much guidance as possible on the conditions for the removal of the retail price caps on natural gas and electricity.
- > Protect vulnerable customer through a social programme financed by the general budget of the government and not financed through the consumer energy bills.

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9. Oil

Key data

(2017)

Crude oil production: 46.5 Mt (1 mb/d), -39% since 2007

Crude oil net imports: 15.0 Mt (201 kb/d) (53.4 Mt imported, 38.4 Mt exported)

Oil product production: 60.0 Mt (1.3 mb/d), -26% since 2007

Oil product net imports: 10.1 Mt (210 kb/d) (33.2 Mt imported, 23.1 Mt exported)

Share of oil: 34% of TPES and 43% of TFC

Consumption by sector: 70.3 Mt (1.4 mb/d) (transport 72%, industry 15%, transformation, and energy 7%, residential 3%, commercial 3%)

Overview

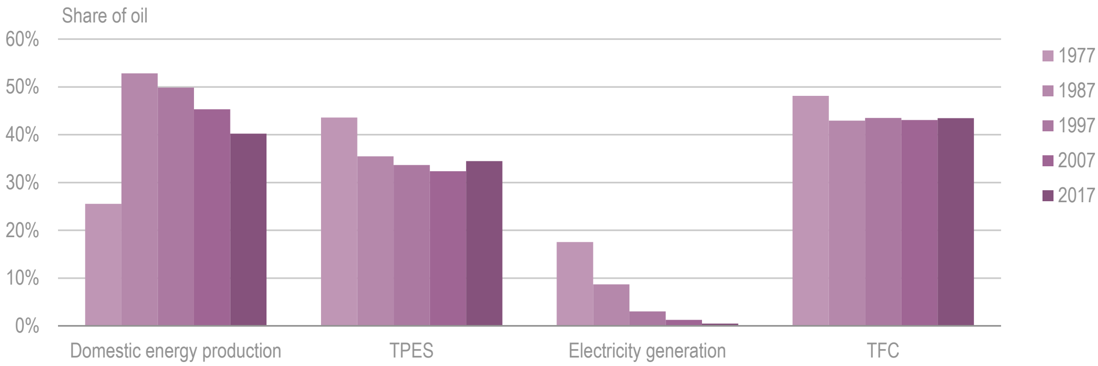
Oil has traditionally been one of the most important energy sources for the United Kingdom. Oil is the largest energy source in total final consumption (TFC) and the second largest source in total primary energy supply (TPES) after natural gas. Despite a small decline in total oil supply, the share of oil in TPES has slightly increased in the past decade, and the share of oil in TFC has been stable over four decades (Figure 9.1).

Domestic crude oil production declined from 1999 and the United Kingdom became a net importer of crude oil in 2005. In recent years, there has been a slight increase in production, but a long-term decline seems unavoidable. Domestic production of refined oil products has also declined, and the United Kingdom has been a net importer since 2013.

While becoming more import dependent, the United Kingdom diversified its supply sources and thereby reduced the impact of a potential supply disruption. Therefore, the United Kingdom remains well supplied by a combination of domestic refining and imported fuels and no significant disruptions to the oil supply have occurred since the previous in-depth review.

Oil is consumed mainly in transport and industry, and small amounts of heating oil are used in both the residential and non-domestic sectors. Under its Clean Growth Strategy, the United Kingdom has committed to phase out high-carbon fossil fuel heating in buildings not connected to the gas grid, such as unabated oil and coal, during the 2020s. The country is supporting zero and ultra-low emission vehicles and will end the sale of new petrol and diesel cars and vans by 2040.

Figure 9.1 Share of oil in different energy metrics, 1977-2017



Domestic oil production has decreased over the past decades, while the shares of oil in TPES and TFC have remained relatively stable.

Note: TPES does not include bunkering fuel.
Source: IEA (2019a), *World Energy Balances 2019 First edition (database)*, www.iea.org/statistics/.

Supply and demand

Production, import, and export

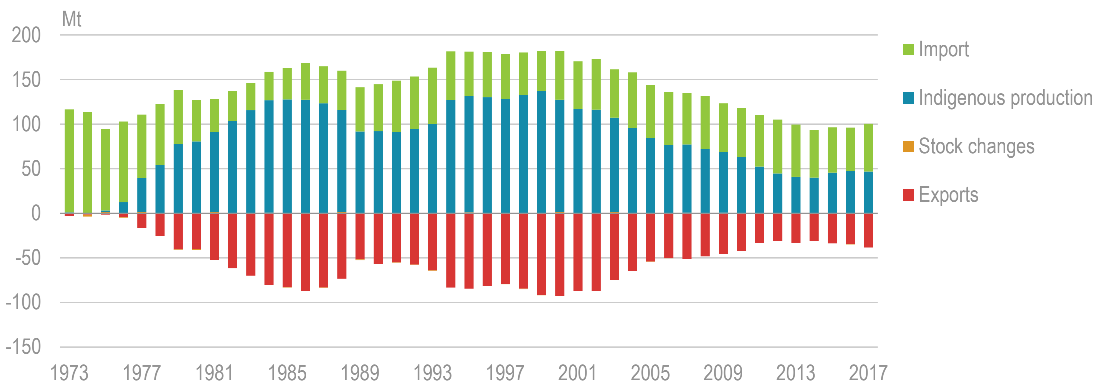
The United Kingdom has significant levels of domestic crude oil production – it ranks highest in the European Union and fourth among the International Energy Agency (IEA) member countries, after the United States, Canada, and Norway. However, the country's oil production is on a long-term declining trend at an average rate of 6% per annum since its peak at 137 million tonnes (Mt) (2.8 million barrels per day [mb/d]) in 1999. Bucking the trend, thanks to government interventions and higher oil prices, recent production increased slightly to 46.5 Mt (1 mb/d) in 2017 from 40 Mt (0.8 mb/d) in 2014 (Figure 9.2), but in the longer run a further decline seems unavoidable due to the lack of new investments. Almost all UK oil is produced from offshore fields, mainly in the North Sea where petroleum development projects generally have long lead times. Despite the large drop over the past decades, in 2017 the United Kingdom's domestic crude oil production still corresponded to around two-thirds of its total consumption and more than 70% of its refinery intake.

The latest estimates of the remaining recoverable hydrocarbon resources from the United Kingdom's offshore resources is in the range of 10-20 billion barrels of oil-equivalent, which could potentially sustain production for the next 20 years and beyond. Compared with historical oil and gas exploitation, to extract the remaining reserves is likely to be more technically challenging and therefore expensive. In response to this challenge, the government established the Oil and Gas Authority (OGA), with the objective to maximise economic recovery from the UK continental shelf (UKCS). In 2016, the OGA released the strategy for enhanced oil recovery (EOR) with a monitoring system to support the Maximising Economic Recovery (MER) Strategy (UK Government, 2016). The government also provided several packages of fiscal support and funding, including effectively abolishing the petroleum revenue tax and reducing the marginal rate of tax levied on company's upstream profits from 81% to 40% to attract more upstream investments. A unique mechanism, the transferable tax history, was also introduced to give companies that buy UK oil and gas fields greater certainty that they will be able to obtain tax relief to decommission the field at the end of its life.

The United Kingdom became a net importer of crude oil in late 2005 due to decreasing production; by 2017 its import dependency accounted for 36% with net imports of 571 kilobarrels per day (kb/d) (which includes both crude and products). As for its crude oil imports, Norwegian oil from pipelines in the North Sea represented around 44%, followed by Nigeria (8%), the Russia Federation (8%), and Algeria (8%) (Figure 9.3).

The United Kingdom is also producing fewer oil products in domestic refineries. In 2017, the gross refinery output was 60 Mt, down from 82 Mt in 2007. The United Kingdom became a net importer of refined products in 2013 for the first time – with a net 1.5 Mt (31 kb/d) that year, which increased to 10 Mt (210 kb/d) in 2017 (Figure 9.4). The United Kingdom has a well-developed infrastructure for the trade of oil products from a diverse range of countries. The largest trading partners are the Netherlands, Russia (mainly imports), Ireland (mainly exports), the United States, Sweden, and Belgium.

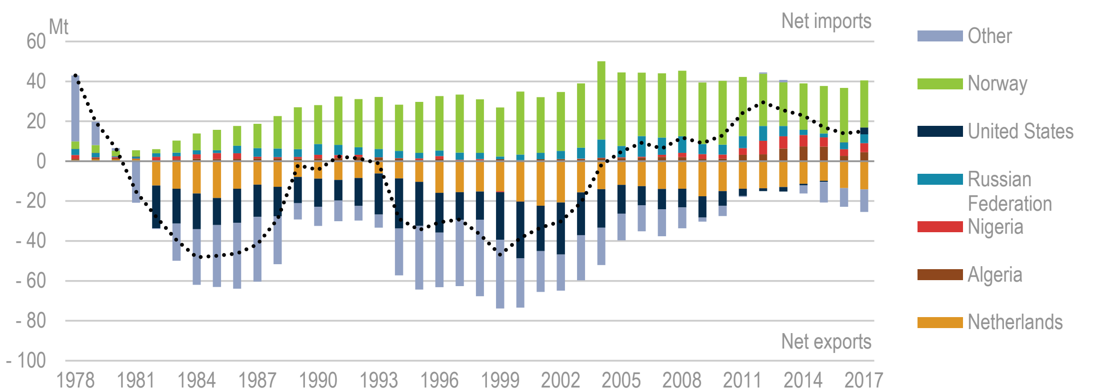
Figure 9.2 Crude oil supply by source, 1973-2017



The United Kingdom's oil production has decreased since 1999, and the country has become more dependent on imports of crude oil.

Source: IEA (2018a), *Oil Information 2018*, www.iea.org/statistics/.

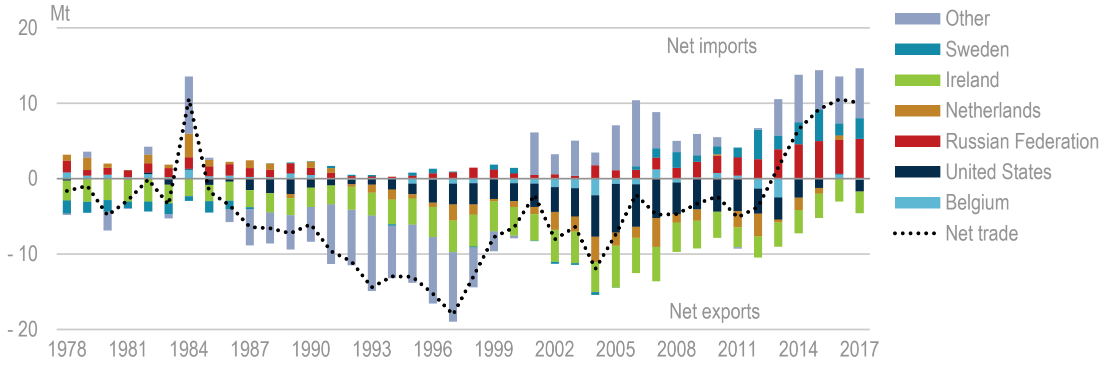
Figure 9.3 Crude oil imports by country, 1978-2017



Crude oil imports have increased with the largest source consistently from Norway.

Source: IEA (2018a), *Oil Information 2018*, www.iea.org/statistics/.

Figure 9.4 Oil product imports and exports by country, 1978-2017



The United Kingdom became a net importer of oil products in 2013, and has a well-diversified trade.

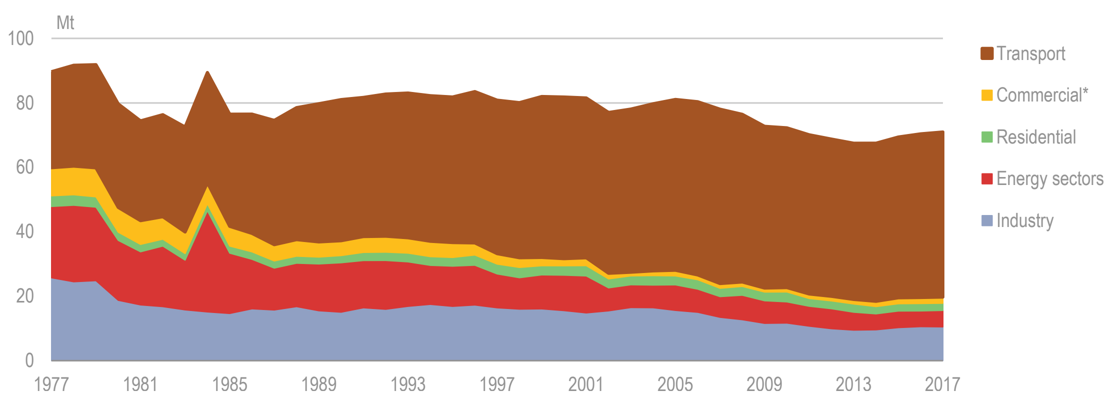
Source: IEA (2018a), *Oil Information 2018*, www.iea.org/statistics/.

Oil consumption

Oil consumption in the United Kingdom has declined over the past decade, but it has picked up slightly since 2013. In 2017, the total oil consumption was 71.0 Mt, a 9% decrease from 2007 (Figure 9.5). The transport sector is the largest oil-consuming sector at 72% of the total in 2016. Road transport accounts for more than half of the total consumption (54%) and aviation also accounts for a significant share (17%, more than doubled from the share of 8% in 1990). Oil use for transport has been relatively stable, while consumption in other sectors has declined.

The industry sector was a distant second at 15% of the total oil consumption. In the past decade, oil use in industry decreased by 22% in line with an overall decline in industrial energy consumption. The rest of the oil is used in the energy transformation sector (7%), the residential sector (3%) and the commercial sector (3%).

Figure 9.5 Oil consumption by sector, 1977-2017



Recent increase in oil consumption was mainly driven by the demand for transport fuels.

* Includes agriculture, forestry and fishing.

Note: Total consumption comprises refinery fuels, bunker backflows from the petrochemical sector, and international aviation (which does not appear in the TPES) and excludes international marine bunkers.

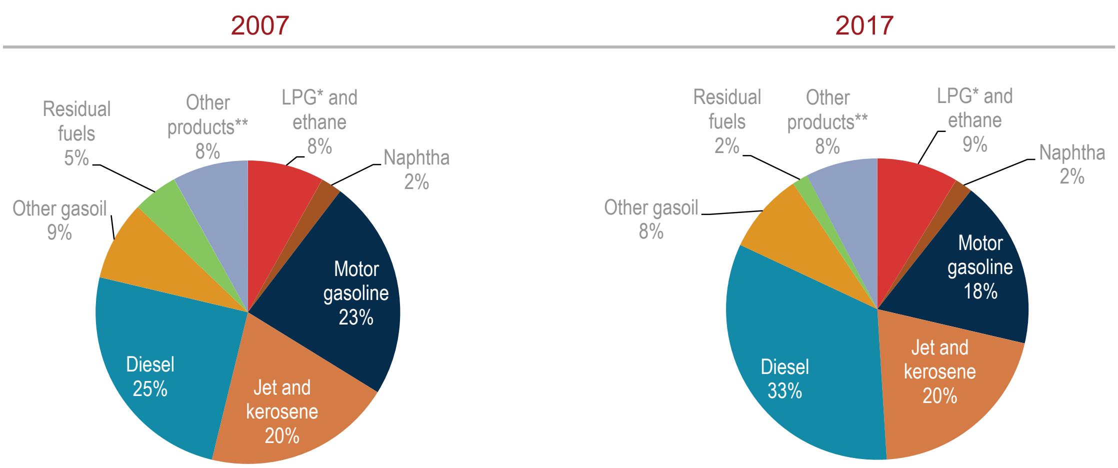
Source: IEA (2018a) *Oil Information 2018*, www.iea.org/statistics/.

As for oil demand by fuel type, diesel is the most used oil product in the United Kingdom at 33% of the total oil demand in 2017 (up from 25% in 2007), followed by jet fuel and kerosene and motor gasoline (Figure 9.6). The share of motor gasoline has fallen from 23% in 2007 to 18% in 2017 as car owners switched to diesel vehicles and vehicle efficiency increased.

In July 2018, the government announced its intention to prohibit the sale of new petrol and diesel cars and vans by 2040 (and at least 50% of that target to be reached by 2030) as part of its air quality plan. It will have a large impact on the future trend of oil product consumption, which is currently dominated by transport-related fuels.

At the end of 2016, the International Maritime Organization (IMO) confirmed that, from January 2020, ships would have to use marine fuel with a sulphur content below 0.5% compared to the current 3.5% limit. The implementation of the IMO's new marine fuel specifications will also affect the oil product mix of the country. As an island nation, shipping and the maritime sectors are among the most important industries to the UK economy. Oil used for international marine bunkers was 2.5 Mt (47 kb/d) in 2017 (which excludes 3.8 Mt or 71 kb/d in Gibraltar).

Figure 9.6 Oil demand by product, 2007 and 2017



Diesel alone accounts for 33% of the total oil demand, followed by jet fuel and motor gasoline.

* LPG = liquefied petroleum gases.

** Other products include bitumen, lubricants, petroleum coke, refinery gas, white spirit, paraffin waxes, aviation gasoline, and other undefined oil products.

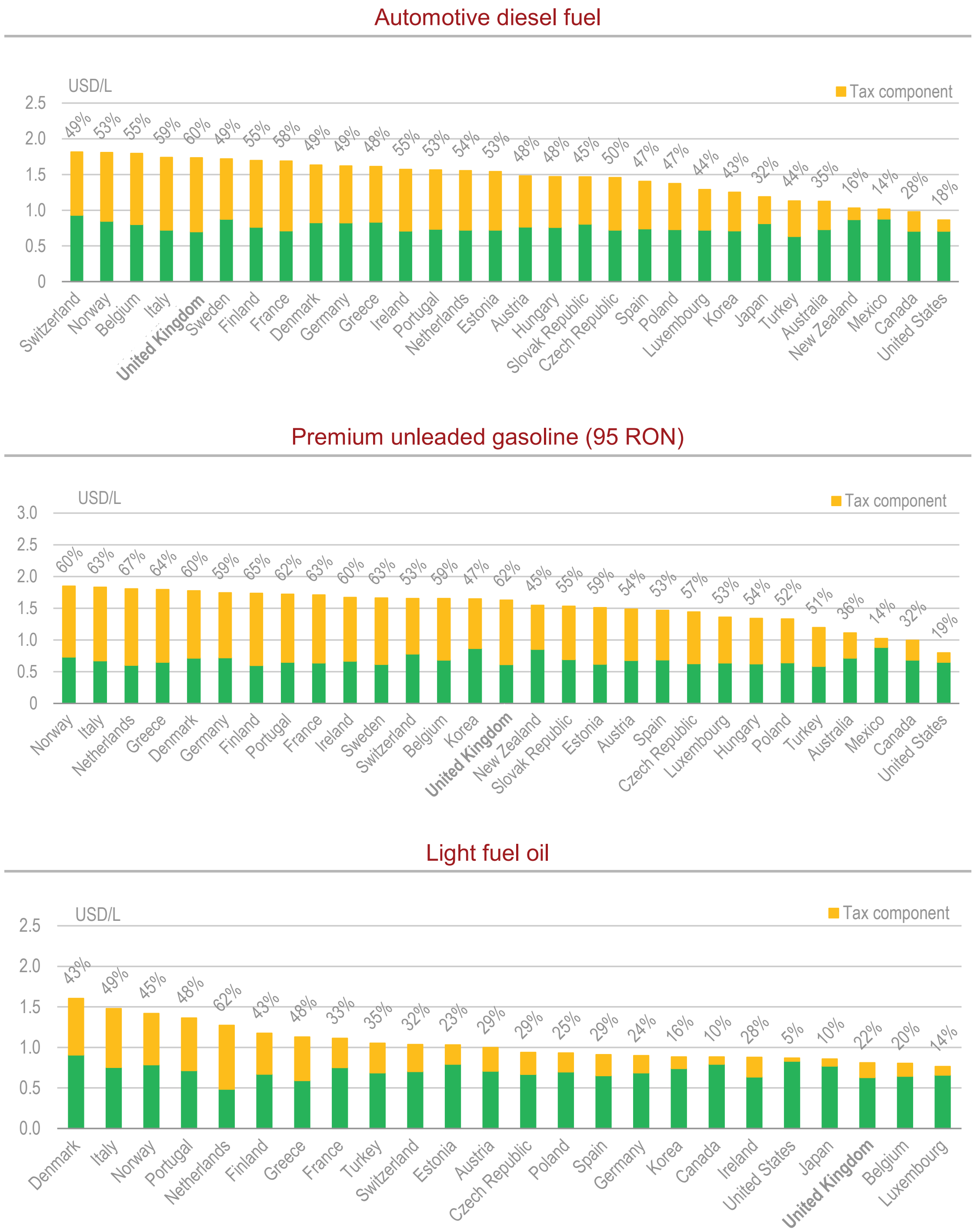
Note: Includes international aviation, which is not included in Figure 9.5.

Source: IEA (2018b) *Oil Market Report 2018*, www.iea.org/statistics/.

Retail market and prices

The United Kingdom operates an open market in which the wholesale price of petroleum products is set by market dynamics. The government influences retail prices for consumers solely through taxation.

Figure 9.7 Oil fuel prices in IEA member countries, Q4 2018



The United Kingdom has one of the highest retail prices for diesel oil with high taxes among the IEA member countries, while it has the third lowest price for light fuel oil.

Notes: Data are not available for gasoline in Japan and for light fuel oil in Australia, Hungary, Mexico, New Zealand, Slovak Republic, and Sweden. RON = research octane number.

Source: IEA (2019b), *Energy Prices and Taxes 2019*, www.iea.org/statistics/.

In the fourth quarter of 2018, the household price for automotive diesel was US dollars (USD) 1.7 per litre (USD/L), the fifth highest among the IEA member countries (Figure 9.7). Petrol and diesel are charged an equal fixed duty, currently 57.95 pence per litre. Petrol and diesel are also subject to value-added tax (VAT) at a rate of 20% since March 2011. When VAT is included, tax represents 62% of the final pump price for petrol and 60% of the final pump price for diesel (as of fourth quarter 2018), which are among the highest levels in the IEA countries. The gasoline price was 1.6 USD/L, which was close to the median among IEA countries, despite the high tax level.

In heating, oil boilers for heating have a reduced VAT rate of 5%; by contrast, renewable technology installations tend to be subject to the full 20% rate. The United Kingdom maintains, and recently extended, its Rural Fuel Duty Relief scheme, which in essence reduces road fuel taxes in certain rural areas. The Rural Fuel Duty Relief provides support for motorists by compensating fuel retailers in specific rural areas with high road fuel prices. The rebate provides a 5 pence per litre reduction to fuel retailers in the specified rural areas on the standard UK rate of Excise Duty of 57.95 pence per litre for unleaded petrol and for diesel sold for use in road vehicles. As of 1 April 2015, further changes were made to extend the relief to more specified rural areas, which allowed an additional 125 000 people living in the selected areas to benefit from cheaper fuel. This followed a year-long EU approvals process – although the United Kingdom's most rural islands already received this discount, this was the first time that the European Union approved this fuel discount anywhere in mainland Europe.

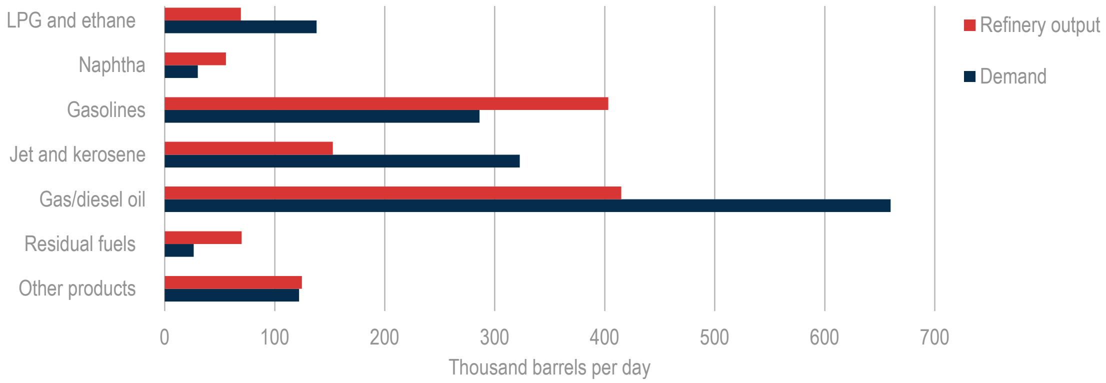
Infrastructure

Refining

Six major crude oil refineries operate in the United Kingdom and supply the bulk of the inland market for petroleum products. There are also two smaller speciality refineries that produce bitumen and other specialised products. The refineries are situated around the coast and most are connected to pipelines for product distribution. The refinery gross output in 2017 averaged 59.9 Mt (1.3 mb/d), down from 81.2 Mt (1.6 mb/d) in 2007, principally owing to production losses from the closure of the Coryton refinery in 2012 and the Milford Haven refinery in 2014 and to capacity reductions. Gas and diesel oil accounted for around 32% of the refining output in 2017, followed by gasoline at 31% (Figure 9.8).

With regard to the supply and demand imbalance of refined products, the United Kingdom imported a net 397 kb/d of middle distillates in 2017, and exported a net 174 kb/d of gasoline. As the demand for middle distillates continues to increase and with no plans to increase the domestic production, it is anticipated that the United Kingdom will rely increasingly heavily on imports to meet future supply – particularly in the case of diesel and jet fuel. Import dependency for diesel has increased from 13% in 2012 to 37% in 2017. The largest source of imported diesel was Russia at 30% of the total diesel imports in 2017, followed by the Netherlands (24%). Import dependency of jet fuel is higher (more than two-thirds of the demand must be met by imports) and has a higher security concern for its relatively long supply lines. Middle Eastern countries accounted for 60% of jet fuel imports in 2017, with the United Arab Emirates and Kuwait being the main suppliers at 22% and 21%, respectively. Another 19% was imported from Asia (8% from India, 6% from Korea, and 4% from Singapore). Significant demand for jet fuel is accounted for by activities at Heathrow, the world's third-largest airport.

Figure 9.8 UK refinery output, 2017



Source: IEA (2018b) *Oil Market Report 2018*, www.iea.org/statistics/.

To help identify and address the challenges that face the UK refining sector, a Midstream Oil Sector Government and Industry Taskforce was set up in 2014. As one of its conclusions, the Taskforce identified the need for a greater understanding of the resilience of the country's fuel supply chain and the risk that rationalisation of the infrastructure could erode the downstream oil resilience over time. Also, the need for increased collaboration between government and industry was identified. Since the end of the Taskforce, relationships have been maintained through the biannual Downstream Oil Industry Forum, which is attended by the major trade associations that represent companies in the fuel supply chain. In October 2017, the Department for Business, Energy and Industrial Strategy (BEIS) launched a consultation on possible new measures to maintain security of fuel supply to consumers. As part of this consultation, the government provided an economic impact assessment by setting out indicative examples of the costs of disruptions of different durations on two major types of infrastructure: refineries and terminals. The government's response to this consultation was published in April 2018 and work is underway on possible legislation.

Pipelines

The major oil terminals (about 50) are supplied by pipeline (51% of the volume) and rail (15%) from UK refineries, and by sea (34%) from a mixture of domestic production and imports. The United Kingdom has a 4 800-kilometre-long domestic oil pipeline network – all of which are privately owned and operated. The pipelines are used both for short-distance transport, e.g. from jetty or import terminal to storage terminal or refinery, and over longer distances to supply inland distribution terminals. Pipelines also connect the United Kingdom to offshore North Sea oil production platforms, both from domestic and Norwegian fields.

Around half of the UK oil pipeline network comprises assets that were part of the government Pipeline and Storage System (GPSS). In March 2015 the GPSS was sold to CLH Pipeline System (CLH-PS) Ltd, a wholly owned company of the Spanish company, Compania Logistica de Hidrocarburos. CLH-PS supplies 35% of the demand for aviation fuel in the United Kingdom. Heathrow, Gatwick, Stansted, and Manchester are among the main airports it supplies, in addition to another ten regional airports that are supplied by road tanker.

The United Kingdom has four major land-based terminals through which about two-thirds of the country's crude oil production flows and which are an integral to parts of the pipeline systems. These are Sullom Voe on the Shetland Islands of Scotland (landing point for the Brent and Ninian pipeline systems), Flotta on the Orkney Islands of Scotland, Kinneil (at the end of the Forties pipeline system), and Teesside (landing point for Norwegian Ekofisk production) on the east coast. Figure 9.9 shows the oil infrastructure of the United Kingdom.

Ports

The United Kingdom has six major oil ports with crude and product import capacity co-located with the six main refineries. These ports have a combined oil and product import capacity of 73 million tonnes per year (Mt/yr). Another two specialist refineries also have crude and product port facilities with a combined import capacity of 4 Mt/yr. In addition to the oil ports co-located with refineries, the United Kingdom has 36 coastal product distribution terminals (with a combined storage capacity of 7.8 million cubic metres [Mm^3]). The combined import capacity of all the United Kingdom's oil and product port facilities is 89.4 Mt/yr.

Storage capacity

A total of 83.4 million barrels (mb) of oil and product stocks were held on UK territory as of end-June 2018. The main storage facilities for crude and oil products in the United Kingdom are located at the six main refineries. In addition to the refineries, there are 49 coastal and inland terminals with a total oil and product storage capacity of 8.4 Mm^3 or 125.1 mb (32.3 mb of crude oil and 92.7 mb of product). These facilities are owned by major oil companies, independent operators, and joint ventures, and are generally located near major population centres.

Oil security

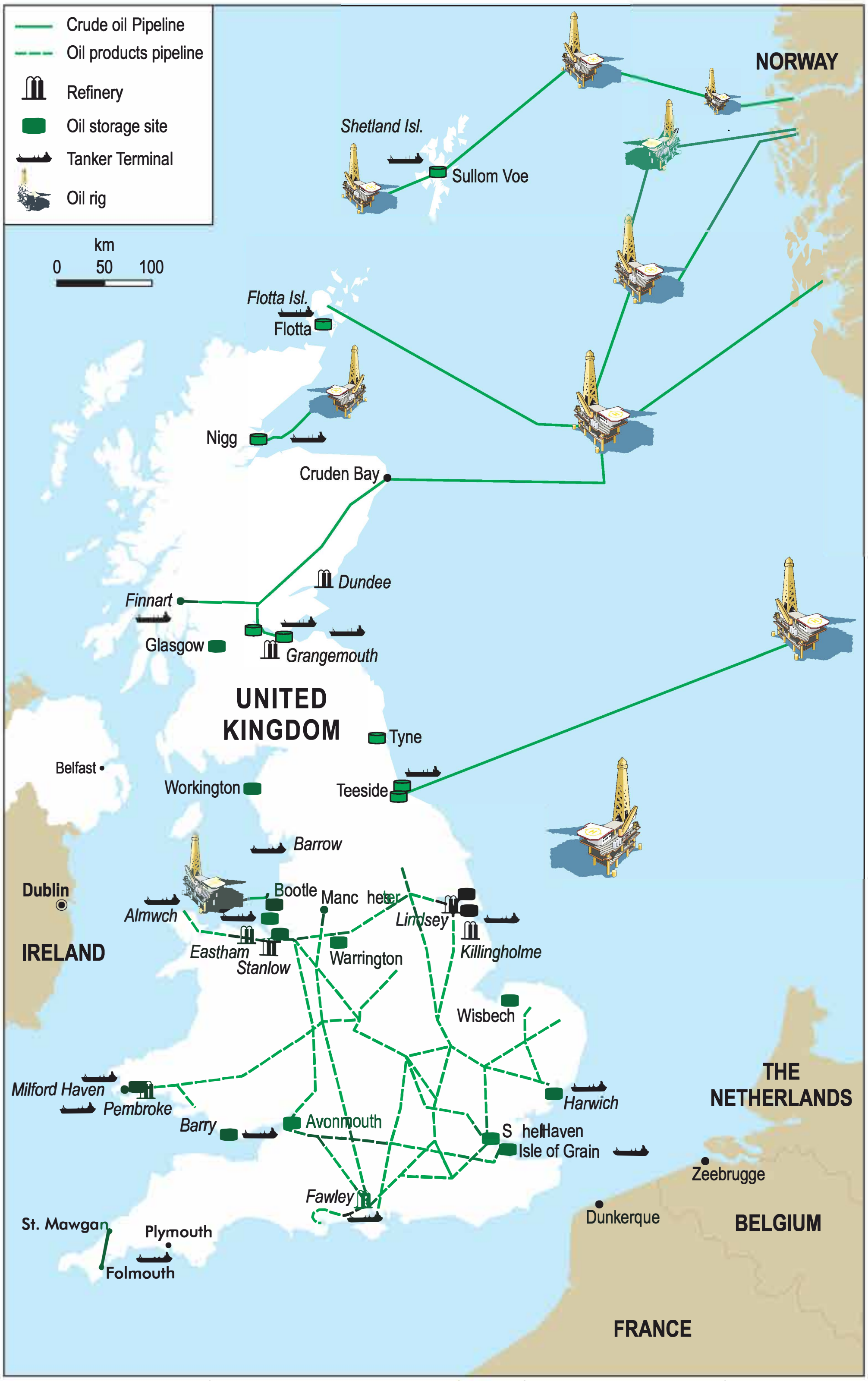
Stockholding regime

The United Kingdom meets its IEA stockholding obligation by placing compulsory stocking requirements on oil companies under powers in the Energy Act 1976. The Act allows the Secretary of State for BEIS to direct companies that produce, supply, or use petroleum products within the UK market to hold minimum levels of stocks and to release them to the market if directed to do so during an emergency. The stockholding obligation applies to companies who supply more than 50 000 tonnes of oil per year to the UK market. Refiners are obligated to hold 67.5 days of supply, while importing companies must hold stocks equivalent to 58 days.

There are no public stocks and the country does not have a public stockholding agency.

Stocks are either held as physical stocks by the company in their own facilities within the European Union, or via "tickets" with other companies – either in the United Kingdom or in other EU member countries – under a number of different arrangements (memorandum of understanding [MOU], bilateral agreements, or less formal arrangements between governments). The United Kingdom has such arrangements in place with Belgium, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Malta, Netherlands, Portugal, Slovakia, Slovenia, and Sweden. Although the United Kingdom is unable to count stocks held outside the European Community under the terms of the EU Oil Stocks Directive (Council Directive 2009/119/EC), the United Kingdom has single-direction MOUs with both New Zealand and Australia.

Figure 9.9 Map of oil infrastructure



This map is without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries and to the name of any territory, city or area.

Note: km = kilometre.

The United Kingdom has a strong record of compliance with its 90-day obligation. As of June 2018, the country held stocks of almost 110 mb (or 14 Mt), equivalent to 238 days of net imports (all of which are industry stocks). It held 68 mb (8.7 Mt) in excess of the IEA's required minimum (41 mb (or 5.3 Mt)). Around one-third of the stocks that make up the United Kingdom's total are held abroad (around 37 mb in June 2018 – equivalent to 79 days of net imports).

As the United Kingdom's oil production is decreasing, net imports are set to rise significantly in the short-to-medium term and, consequently, its stockholding obligations to the IEA and European Union are expected to rise progressively. Under the EU Directive, the United Kingdom is obliged to hold "90 days of average daily net imports or 61 days of average daily inland consumption, whichever of the two quantities is greater". The country's 90 day IEA/EU obligation is not expected to overtake the consumption-based EU obligation until the early-to-mid-2020s. Once this takes place and the United Kingdom switches to calculating its minimum stockholding requirements on the basis of the IEA/EU 90 day obligation, the country will need to hold progressively more stocks than it has previously.

In addition, the storage capacity for oil products in the United Kingdom is limited, which means that, with an increased obligation, the United Kingdom needs to hold more stocks overseas. According to industry, the incentives to invest in new storage capacity in the United Kingdom are limited. Given these issues, in April 2013 BEIS (then the Department of Energy and Climate Change [DECC]) launched a public consultation on the future management of the Compulsory Oil Stocking Obligation in the United Kingdom, which sought views on the possible establishment of an industry-owned and operated Central Stocking Entity (CSE) in the United Kingdom. DECC published the government response to the consultation in April 2014 and concluded that the government was willing to consider the establishment of such a CSE, with mandatory membership for obligated companies. However, the government communicated to the industry in 2015 that a CSE was no longer being pursued. In October 2015, a further consultation on oil stocking was issued by DECC that considered a range of possible options to amend the UK approach to company obligations to enable the United Kingdom to ensure compliance with the EU Directive. The process is on hold pending the United Kingdom's exit from the EU.

United Kingdom Petroleum Industry Association, the trade association that represents the main oil refining, distribution, and marketing companies in the United Kingdom, has reportedly shown concerns about the implications of Brexit, which include the potential loss of flexibility if cross-border ticketing is no longer possible, and it has reiterated calls to create a centralised stock holding agency.

Demand restraint

Under the Energy Act 1976, the government has the authority to regulate or prohibit the production, supply, acquisition, or use of oil or petroleum products. The demand restraint measures available in the United Kingdom are set out in the National Emergency Plan for Fuel (NEP-F). The NEP-F is intended for use by the downstream oil supply industry, Local Resilience Fora (in England and Wales), Regional Resilience Partnerships (in Scotland), and resilience planners for essential services. It specifies the role each should play to prepare for or respond to a fuel supply crisis, clarifies the government's approach, and sets the context for the level of fuel resilience appropriate to the essential services. The NEP-F contains a range of measures for the administration to consider as part of its response to any fuel supply disruption, which range from light-handed measures to the allocation and rationing of oil products. In a disruption that requires central government action, light-handed measures are preferred.

Light-handed measures include: communication strategies to disseminate the relevant information quickly and to reassure the public to limit panic buying; demand-reducing measures, such as speed limit reductions and voluntary demand reduction campaigns; and the relaxation of regulations that affect the supply or use of petroleum products (e.g. gasoline, diesel, heating oil, and LPG) – such as those relating to drivers' hours.

In the event of industrial action that affects fuel deliveries, this may include the provision of military fuel tanker drivers to industry to maintain civilian fuel supplies as a last resort. BEIS works with the downstream oil industry, which includes haulage companies, to maintain a capability within the armed forces to make fuel deliveries in the event of a serious disruption to normal deliveries. It is likely that situations prompting the deployment would be both urgent, and so require an immediate response, and regionally or nationally significant.

BEIS has also worked with the downstream oil sector to develop an operational process for the deployment and use of the reserve tanker fleet of 80 road tankers available at 24-72 hours' notice to replace any shortfall in logistics. The fleet will operate on a rental basis to industry, with the additional supply chain capacity only being available in disruption events.

The Federation of Petroleum Suppliers launched the Cold Weather Priority Initiative in October 2017 to identify those most at risk of loss of heating oil, so these customers can be prioritised during periods of extreme cold or fuel shortages.

The use of more heavy-handed demand restraint and allocation measures by central government is unlikely but, in the event of a crisis, can be introduced as necessary.

Assessment

Oil upstream

The United Kingdom has been a relatively large oil and gas producer since the 1980s. UK oil production peaked in 1999 at 137 Mt (2.9 mb/d), after which it fell by 71% to 40 Mt (0.9 mb/d) in 2014. Thanks to government interventions and higher oil prices, production increased slightly to 47 Mt (1 mb/d) in 2017, but in the longer run further decline is inevitable. Carbon capture, usage, and storage (CCUS) for EOR is not practised in the United Kingdom.

In 2013-14, Sir Ian Wood conducted a review that looked at how the economic recovery of oil and gas production in the UKCS could be maximised (Wood, 2014). Based on his review, the government took a number of measures. In 2015, it established the OGA as an independent regulator to regulate, influence, and promote the UK oil and gas industry, as part of its mandate to implement the binding Maximising Economic Recovery UK Strategy to secure maximum value from the remaining hydrocarbon resources. Among other things, the OGA with Treasury funding has commissioned programmes to improve seismic data availability to the industry, which helped to attract a higher interest from industry in licensing rounds. Commendably, the government also attracted investments with packages of fiscal measures, and thereby reduced the government take in upstream profits to 40%, which is still high compared with other private business activities. Finally, the UK and Scottish governments established the Oil and Gas Technology Centre in Aberdeen to boost research in upstream activities.

Although the government rightly promotes upstream activities in many ways, it should also prepare for the decommissioning of depleted fields. The government established a regulatory framework, and it has some experience as around 10% of the offshore oil and gas infrastructure has already been decommissioned. Decommissioning comes with large costs for companies, and the government should ensure that the companies make financial provisions for it. Some of the fiscal measures recently taken aim to decrease the financial burden of decommissioning on industry, but the government should still ensure companies are up to fulfilling their decommissioning commitments.

With the measures described, the government was able to reverse a trend of reduced interest in its continental shelf and attract new companies and investments. Other countries in the region face similar challenges and are taking comparable measures. Therefore, the government should continue to monitor developments closely in other countries to ensure that its regulatory framework remains competitive.

Oil downstream

With the falling domestic crude oil production, the United Kingdom is also producing fewer oil products in domestic refineries. After the closures of two refineries in 2017, the gross refinery output was 60 Mt (1.3 mb/d), down from 81 Mt (1.6 mb/d) in 2007. Since 2013, the United Kingdom has been a net importer of oil products, with 10 Mt (210 kb/d) of net imports in 2017.

In 2016, total oil consumption was 70.3 Mt (1.4 mb/d), 13% down from 2006, but a 4% increase from 2013. The transport sector, mainly road transport, accounted for 72% of total oil consumption and the industry sector for another 15%. In the past decade, oil consumption in industry decreased by 30% in line with an overall decline in industrial energy consumption, whereas oil consumption in the transport sector only fell by 6%.

The government committed in the Clean Growth Strategy to the phase out of high-carbon fossil fuel heating in buildings not connected to the gas grid, starting with new build during the 2020s. The government should examine current taxation and subsidies, which include the Rural Fuel Duty Relief scheme, and set out actions and legislation to implement the commitment.

The government has announced that as of 2040 no new conventional petrol and diesel cars and vans can be sold in the country. This timely announcement should trigger a wide range of actions by businesses, for instance by the car industry, electricity sector, charging stations, etc. Also, the oil industry should prepare itself for declining demand, notably of petrol, which might have implications for security of supply during a transition period. The government and industry should carefully review the implications for the whole supply chain.

As a maritime nation, the United Kingdom will be confronted with upcoming IMO regulations to reduce significantly the sulphur content in bunker fuels. As in many other countries, the oil industry in the United Kingdom does not seem well prepared to accommodate such a major shift in demand. The government could do more to support both the oil and maritime industries by promoting and facilitating the switch towards cleaner alternative fuels in shipping.

The United Kingdom's oil stocking regime has not changed greatly since the previous IEA in-depth review, although the implementation of the new EU Directive at the end of 2012 represented a major undertaking. The idea of creating a stockholding agency was investigated, but not implemented. To comply with European Union and IEA regulations, the United Kingdom imposes a stockholding obligation on refiners and oil importers who supply more than 50 000 tonnes of oil products to the UK market in a year. The stockholding obligation for the United Kingdom that stems from the Directive (61 days of oil demand) is larger than the IEA obligation (90 days of net-imports). The IEA notes that the United Kingdom's oil stockholding obligation in terms of volume is expected to increase significantly due to the declining North Sea production, which will require an increased obligation towards the IEA.

The government has a well-developed resilience strategy for the oil sector. Unlike other IEA countries, the government has access to a dedicated tanker fleet of 80 vehicles and to trained military personnel. The government also established an informal agreement with oil and LPG suppliers to identify customers most at risk of the loss of heating fuels during cold weather and supply them as a priority. The government is also one of the few IEA countries that calculated the potential economic impacts of a range of potential supply disruptions to support further policy development.

Recommendations

The UK government should:

- ☐ Continue to encourage upstream investments by benchmarking the UK commercial regime for exploration and production and exchanging best practice with other countries.
- ☐ Review, together with industry and the OGA, progress made in identifying the potential of CCUS for EOR and the potential for carbon dioxide storage in old and depleted oil/gas fields, notably in the context of hydrogen deployment.
- ☐ Continue to engage with the oil industry, notably refining, on the implications of the announced end of the sales of conventional new petrol and diesel cars and vans.
- ☐ Set out actions to implement the phase out of high-carbon fossil fuel heating in buildings not connected to the gas grid.
- ☐ Create favourable investment conditions for liquefied natural gas bunkering services to facilitate access to cleaner supply sources for the shipping industry, while at the same time increasing security of supply for domestic customers.
- ☐ Monitor and assess the storage capacity adequacy given the increased import dependency to compensate for the eventual North Sea production decline.

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10. Natural gas

Key data

(2017)

Natural gas production: 36.0 Mtoe (42.1 bcm), -44.6% since 2007

Net imports: 30.9 Mtoe (36.4 bcm; imports 47.3 bcm, exports: 10.9 bcm)

Share of natural gas: 39% of TPES, 41% of electricity generation, and 30% of TFC

Gas consumption by sector: 67.8 Mtoe (79.5 bcm) - power and heat generation 36.2%, residential 34.1%, industry 12.1%, commercial 10.6%, and other energy 7.0%

Historic gas peak demand: 465 Mm^3/d (8 January 2010)

Overview

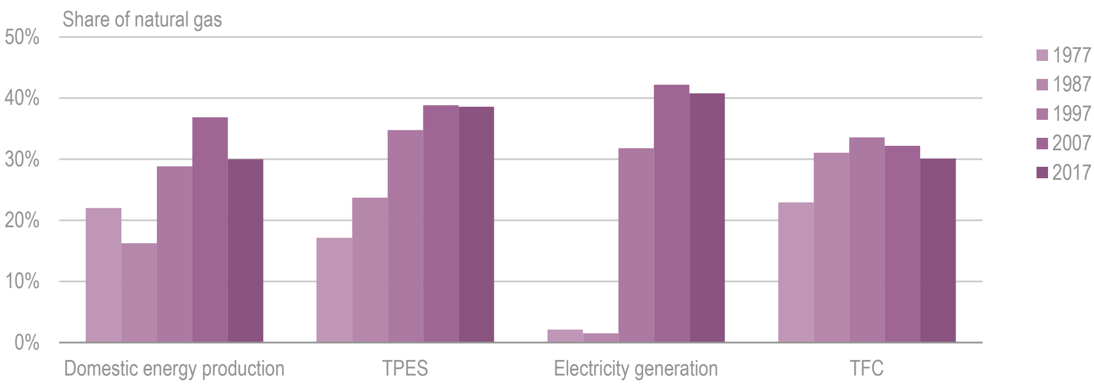
Natural gas is the largest energy source in the total primary energy supply (TPES) in the United Kingdom. The United Kingdom has the third-largest share of natural gas in the TPES among International Energy Agency (IEA) member countries after the Netherlands and Italy. Most of the gas is consumed in heat and power generation and for domestic heating. The United Kingdom's domestic gas production fell sharply in the early 2000s to about 42 billion cubic metres (bcm) in 2017, which resulted in a rapid increase of gas imports between 2007 and 2017. Since 2004, the United Kingdom has been a gas net importer and two-thirds of the imported gas comes via pipelines from Norway, with the remaining share mostly as liquid LNG from Qatar. The United Kingdom also imports gas from the Netherlands and Belgium and exports to Belgium and Ireland.

Security of gas supply mechanisms are strong: the United Kingdom has a liquid gas market, abundant gas infrastructure, and a diverse supply from domestic production, liquefied natural gas (LNG), and pipeline imports. Great Britain uses price signals to ensure flexibility, to cover potential shortages, and to allow gas to flow to the United Kingdom, notably in the winter. The United Kingdom's gas emergency preparedness was proven robust at the end of February 2018 during a period of cold weather (referred to as the "Beast from the East"). The high gas demand during this period resulted in the first gas deficit warning issued by National Grid Gas (NGG) since 2010. The security of gas supply has to be kept under review as several changes are impacting the outlook. Gas is the largest source for electricity, and so coordination between gas and power systems becomes an important issue for the security of electricity supply, notably with the planned phase out of coal-fired power generation by 2025. The long-term decline of Dutch and UK gas production, and lower contributions from seasonal storage, will make flexibility from interconnections and LNG critical for the security of gas supply. Neighbouring European countries Belgium, the Netherlands, and France are also expected to rely on higher gas imports.

Supply and demand

In 2017, natural gas accounted for 39% of TPES and 44% of electricity generation. However, natural gas consumption has gradually declined across all sectors (except for a revival in power generation since 2014), despite population and economic growth (Figure 10.1.) In 2017, the total gas consumption was 68 million tonnes of oil equivalent (Mtoe) (80 bcm), 17% lower than a decade previously. Increased efficiencies in heat use, which include greater levels of home insulation, and the rise in the deployment of renewable electricity generation explain this trend.

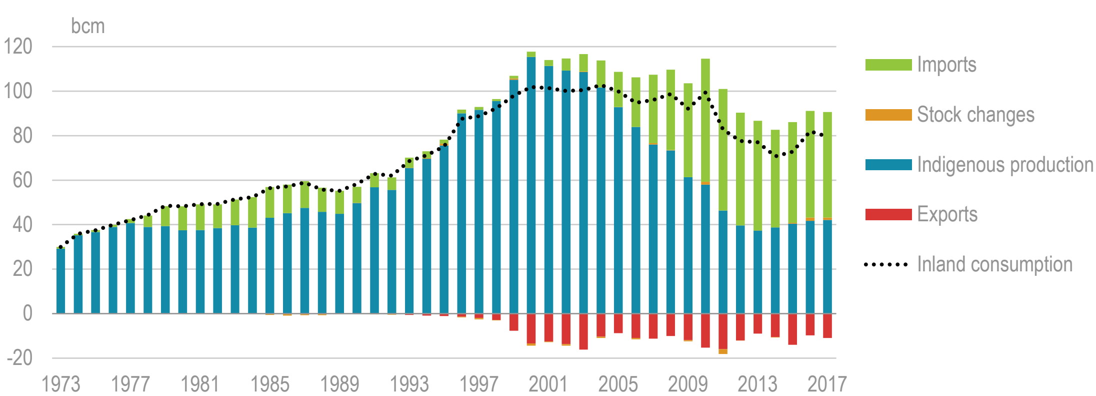
Figure 10.1 Share of natural gas in production, TPES, electricity mix, and total final energy consumption, 1977-2017



The role of natural gas in the United Kingdom's energy supply remains important, but gas usage declined across all sectors.

Source: IEA (2019a), *World Energy Balances 2019 First edition (database)*, www.iea.org/statistics/.

Figure 10.2 Natural gas supply by source, 1973-2017



Gas imports increased rapidly in the early 2000s as domestic production declined. In recent years imports have stabilised thanks to the maximised recovery of domestic gas.

Source: IEA (2019a), *World Energy Balances 2019 First edition (database)*, www.iea.org/statistics/.

Domestic gas production

The United Kingdom's natural gas production increased gradually in the 1990s to peak at 115.4 bcm in 2000, after which it fell rapidly to 36.4 bcm in 2013. From 2014 it picked up slightly to 42.1 bcm in 2017 (Figure 10.2). Despite production decline, the United Kingdom is one of the three major gas-producing nations within IEA-Europe along with Norway and the Netherlands. The majority of the domestic production of natural gas comes from the North Sea and the East Irish Sea. The development of the Laggan field near the Shetland Islands is one of the main contributors to the recent increase.

Recovery has improved in the UK Continental Shelf (UKCS) since 2014 thanks to a strategic reorientation of the upstream policy. The United Kingdom set out a strategy to maximise the economic recovery of petroleum from the UKCS, based on the UKCS Maximising Recovery Review (Wood, 2014). Based on the recommendations of the review, the government established an independent regulator, the Oil and Gas Authority (OGA), which is now a government company with new competences under the Energy Act 2016 to enable Maximising Economic Recovery (MER) Strategy of the UKCS hydrocarbons. OGA issued the MER UK Strategy in March 2016 and supports the cost-effective decommissioning of offshore installations (UK Government, 2016).

Among the measures, the government abolished the petroleum revenue tax and cut the supplementary charge from 32% to 10%, and has supported seismic surveys in underexplored areas of the UKCS. Operators in the UKCS will be able to transfer part of their tax history when assets change hands to facilitate the transfer of late-life oil and gas assets. This will allow new investors to benefit from tax relief when assets are eventually decommissioned and help extend field life.

The OGA estimates that there are 279 bcm of proven and probable gas reserves left as at the end of 2017, of which 181 bcm are proven reserves (UK Government, 2018). There has been a steady decline in proven and probable reserves since 1994, initially associated with a higher rate of production.

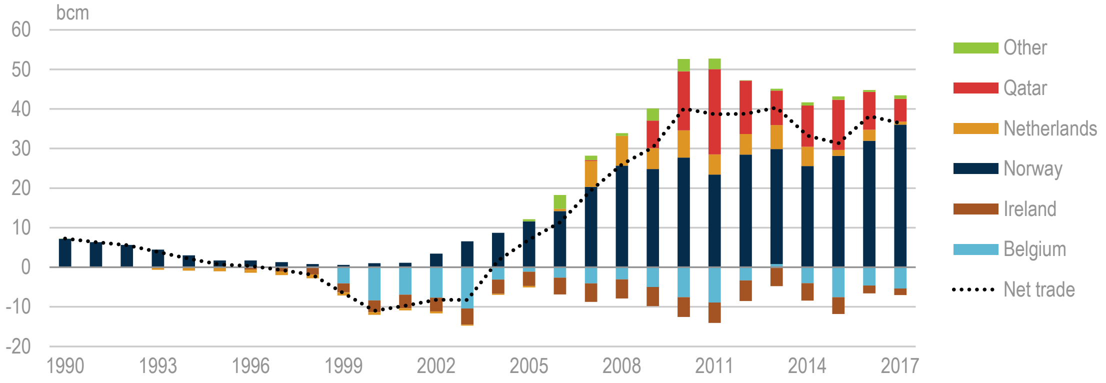
Natural gas imports and exports

In line with the decline in domestic gas production, the United Kingdom has increased its gas imports since 2002. In 2017, the United Kingdom's imported 47.4 bcm – an increase of almost 40% on 2007 import levels (Figure 10.3). The United Kingdom has been a net importer since 2004, and the increase in imports has been supported by the development of new interconnector pipelines and LNG import terminals.

In 2017, the main gas imports to the United Kingdom came through pipelines from Norway (75% of total imports) and the Netherlands and Belgium (10%), as well as shipped LNG from Qatar (13%). Imported gas by pipeline had volumes that ranged from 29.4 bcm to 40.4 bcm over the past decade. LNG imports have increased from 1.4 bcm in 2007 to 7.4 bcm in 2017.

The United Kingdom also exported 11.3 bcm in 2017, mainly to Belgium (71% of the total) and Ireland (15%). The overall exported volumes have increased from 2016, partly due to the increased export to Belgium.

Figure 10.3 Natural gas imports and exports by country, 1990-2017



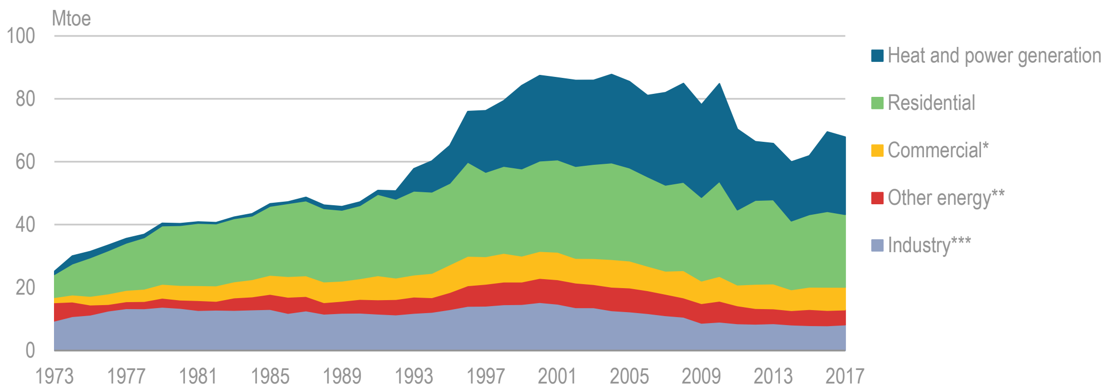
After a rapid increase, net imports of natural gas have stabilised at around 40 bcm, with most gas supplied by pipeline from Norwegian gas fields and LNG from Qatar.

Source: IEA (2018a), *Natural Gas Information 2018*, www.iea.org/statistics/.

Largest gas consumption in heat and power sector

The total natural gas consumption peaked at 87.8 Mtoe in 2004. Since that peak, consumption declined until 2014, after which it recovered slightly to 67.8 Mtoe or 79.5 bcm in 2017 (Figure 10.4).

Figure 10.4 Gas consumption by sector, 1973-2017



Power generation and households account for over two-thirds of the total gas demand, and consumption has recovered slightly in recent years after a sharp decline.

* Commercial includes commercial and public services, agriculture, and forestry.

** Other energy includes the energy sector's own consumption and losses in gas production and refineries.

*** Industry includes non-energy consumption.

Note: TPES of natural gas by consuming sector.

Source: IEA (2019a), *World Energy Balances 2019 First edition (database)*, www.iea.org/statistics/.

The largest consuming sectors are heat and power generation and the residential sector, each of which accounts for more than one-third of the total gas consumption. The consumption of gas in power and heat generation increased by 38% in 2013-17. A range of measures, which include the government's introduction of the carbon price floor

(CPF), the price of gas, and the impacts of EU environmental directives, significantly displaced the use of coal.

Gas consumption in power generation saw a large fluctuation over time; the share fell rapidly from 31 Mtoe in 2010 to 18 Mtoe in 2013. Since 2016, gas power generation has picked up again and, in 2017, gas power accounted for 41% of the total power generation. This is slightly below the peak share of 46% in 2010, but higher than 27% in 2013.

Natural gas infrastructure

The United Kingdom has an extensive natural gas supply infrastructure (Figure 10.5). This includes the production capacity offshore, which provides about half of the United Kingdom's demand, and an extensive import infrastructure from Norway and continental Europe, capable of importing around 100 billion cubic meters per year (bcm/yr) compared to actual imports of less than 40 bcm/yr. The United Kingdom has a LNG import capacity of around 49 bcm/yr but the actual annual imports are around 10 bcm. Besides having a significant export capability to continental Europe (20 bcm/yr) and to Ireland (11 bcm/yr), the United Kingdom has gas storage of a total capacity of around 1.4 bcm or around 2% of annual demand. Total storage deliverability is at over 116 mcm/d and thus capable, in principle, of providing nearly one-quarter of the gas supply on 1-in-20 peak days.

NGG is the system operator that owns and operates the National Gas Transmission System. Ownership unbundled, NGG has the right to buy, sell, and store gas only to keep the system in balance across Great Britain. Besides NGG, there are four other certified transmission system operators in the United Kingdom that own and operate an interconnector:

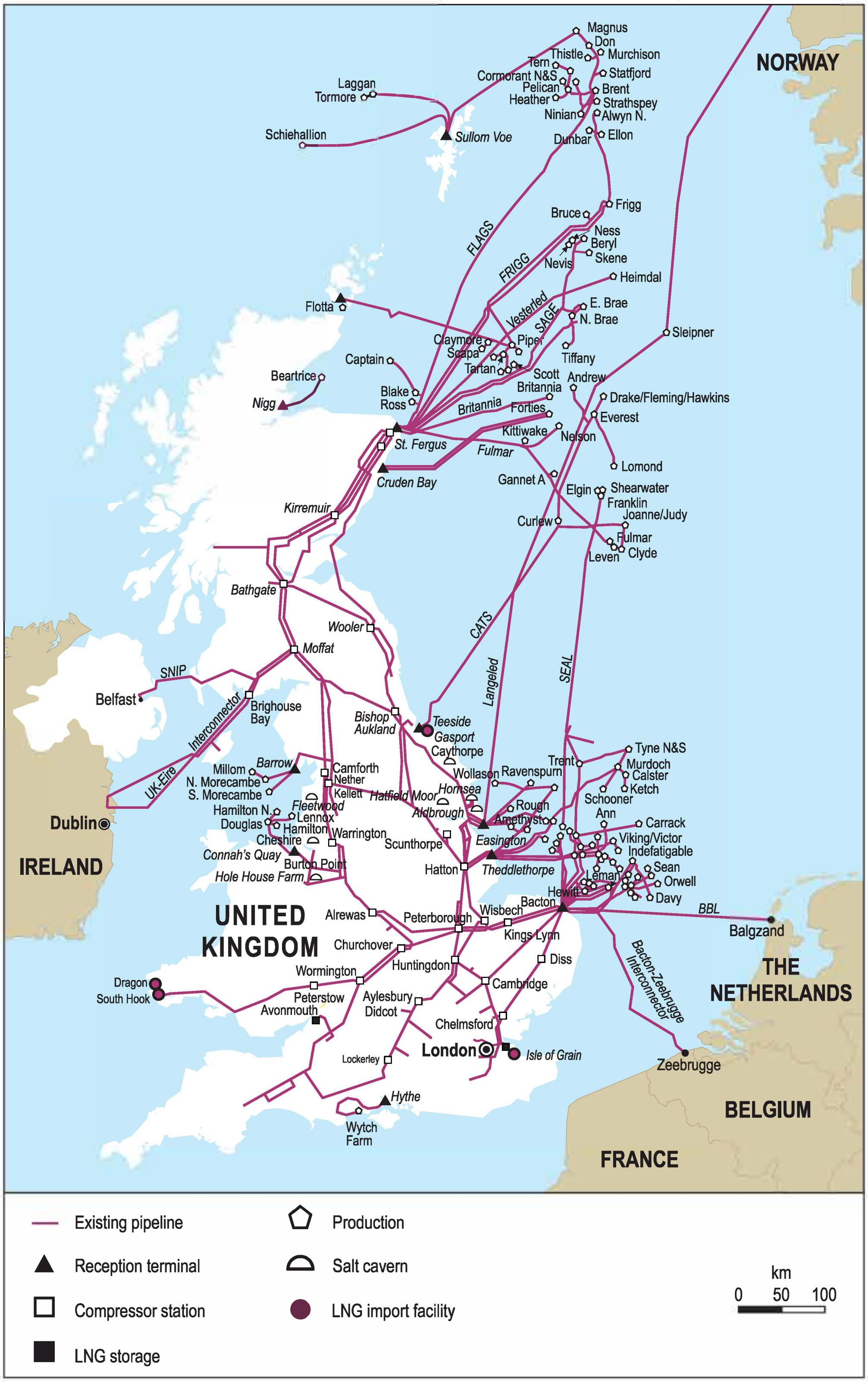
- Balgzand Bacton Leiding Company (BBL) operates the Balgzand Bacton Line, a gas interconnector between Julianadrop near Balgzand in the Netherlands and Bacton in GB. The interconnector provides services for physical gas flow from the Netherlands to Bacton in Great Britain and non-physical interruptible reverse flow services from Great Britain to the Netherlands.

- Interconnector (UK) Limited (IUK) owns and operates a subsea pipeline and terminal facilities that link Bacton in the United Kingdom and Zeebrugge in Belgium.

- Premier Transmission Limited (PTL) owns the gas interconnector between Twynholm in Scotland and Ballylumford in Northern Ireland, otherwise known as Scottish Northern Ireland Pipeline. PTL is a wholly owned subsidiary of Mutual Energy Limited.

- GNI (UK) is the owner of the high-pressure interconnector between Moffat in Scotland and the end of the UK Territorial Waters. GNI (UK) is a wholly owned subsidiary of Gas Networks Ireland, which is within the Ervia Group.

Figure 10.5 United Kingdom natural gas infrastructure



This map is without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries and to the name of any territory, city or area.

Note: km = kilometre.

In 2018, there were 27 gas distribution system operators (DSOs) – eight regional, regulated monopolies, owned and managed by four companies after National Grid (NG) sold its majority stakes in distribution activities in 2016, as well as 19 smaller gas DSOs:

- Cadent Gas Ltd – West Midlands, North West, East of England, and North London
- Northern Gas Networks Limited – North East England (including Yorkshire and Northern Cumbria)
- Wales & West Utilities Limited – Wales and South West England.
- SGN – Scotland and Southern England (including South London).

Cross-border connection and gas pipelines

Besides import pipelines from Norway (Vesterled, Langeled and Tampen Link, Gjøa, SAGE, and CATS), the GB gas system is well interconnected with neighbouring countries – Belgium, the Netherlands, Northern Ireland, and the Republic of Ireland. Great Britain has bidirectional capacity (around 20 bcm/yr) with Belgium via the IUK, and import capacity from the Netherlands through the interconnector BBL, and exports gas to the Republic of Ireland via the Moffatt Interconnector. Since 2011, the Moffatt Interconnector has virtual reverse flows (around 30 mcm/d) from Ireland to Great Britain on an interruptible basis. In 2017, the BBL changed its access regime to support the market merger between BBL and Gasunie Transport in the Netherlands.

Gas storage

In 2017, the United Kingdom had a total gas storage capacity of 1.44 bcm/yr or 1.6% of the country's annual gas consumption (Table 10.1). This is a significant decline from the UK gas storage capacity five years ago, which was 4.5 bcm or 6% of annual demand, as illustrated in the total gas storage compared to a six year average (Figure 10.6). Moreover, all of today's capacity comes from short-range gas storages, after the closure of Rough seasonal gas storage.

Owing to the lower seasonal spread in prices, higher maintenance costs, and the lower integrity of the wells, Centrica Storage Ltd decided in 2017 to end operations permanently at Rough storage, the United Kingdom's only long-range seasonal gas storage. Rough was also the United Kingdom's largest gas storage facility with 42 mcm/d deliverable gas during winter (Table 10.1). Centrica will be gradually drawing down the remaining cushion gas from the facility.

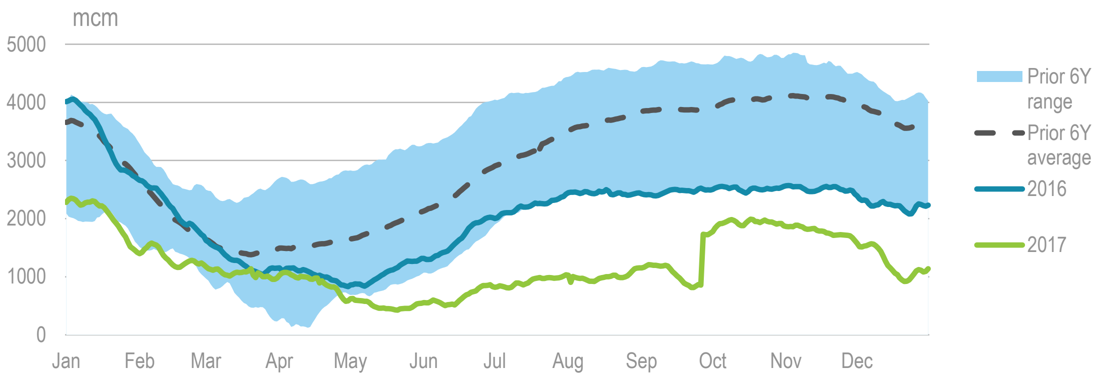
In 2018, Électricité de France (EDF) announced the withdrawal of the Hole House Farm storage facility (the smallest gas storage in the United Kingdom) from commercial operation. BEIS concluded in its recent assessments of gas security that Great Britain has adequate gas supplies to meet a high gas demand even in the absence of Rough (UK Government, 2017a).

Table 10.1 UK operating gas storage sites, 2018

Site	Operator/Developer	Location	Space (bcm)	Approximate maximum delivery (mcm/d)
Aldborough	SSE/Statoil	East Yorkshire	0.3	40
Hatfield Moor	Scottish Power	South Yorkshire	0.07	1.8
Holford	E.ON UK	Cheshire	0.2	22
Hornsea	SSE	East Yorkshire	0.3	18
Humbly Grove	Humbly Grove Energy	Hampshire	0.3	7
Hill Top Farm	EDF Energy	Cheshire	0.05	12
Stublach	Storenergy	Cheshire	0.2	15
		Total	1.442	120.8

Note: SSE = Scottish and Southern Energy.

Figure 10.6 Total Great Britain gas in storage, 2016 and 2017, compared to the prior six year (6Y) average



Source: Based on data from Ofgem (2018a) and NG.

A number of new gas storage and expansion projects have been developed recently, which include the expansion of Storengy's underground gas storage Stublach, a new gas project by Halite Energy, the Keuper Gas Storage Project, and a large storage facility in Northern Ireland (Islandmagee). Apart from Stublach, no final investment decisions (FIDs) have been taken; there is no guarantee that the proposed projects will go on to be operational.

- The Stublach facility in Cheshire near the town of Northwich will see its capacity grow by 74 mcm in October 2018 and 37 mcm by January 2019. However, additional compressors are needed to increase the rate of extraction. According to Storengy (2018), once fully developed the facility will have a capacity of approximately 450 mcm, enough to supply 270 000 homes for 12 months.

- Halite Energy is developing a new facility near Preesall, for which the company obtained permission in 2015 but faces delays. Although Halite Energy has permission to drill 19 caverns in the salt strata, just nine will be created and come online between 2020 and 2025 with 600 mcm.

- The Keuper Gas Storage Project would consist of up to 19 cavities. In March 2017, the project by INEOS received the Secretary of State for BEIS's Development Consent Order.

- The Islandmagee gas storage project in County Antrim, Northern Ireland, would have a capacity of 500 mcm. This project has received partial funding under the European Union's "Connecting Europe Facility" programme.

Liquefied natural gas

GB has three LNG import terminals: Isle of Grain in Kent (owned by NGG with a capacity of 56 mcm/d), South Hook, and Dragon LNG in Milford Haven. Owned by the BG Group and Petronas, Dragon has a capacity of 21 mcm/d, whereas South Hook has a capacity of 58 mcm/d and is owned by Qatar Petroleum, the majority shareholder, Exxon Mobil, and Total. Amid declining production and difficult-to-build gas storage, LNG import terminals can provide a strong flexibility. The market is interested in providing gas to the GB market. NGG's ten-year network development plan (NGG, 2017) contains 11 LNG projects; however, these have not received a FID. It is expected that US LNG will also arrive in the United Kingdom in the coming years.

Policy framework and markets

The GB gas market is considered one of the most liquid gas markets in the world with a robust gas infrastructure and diverse supplies. UK energy and climate policies support a role for gas in power generation. but pave the way for a lower contribution in residential heating. The UK Clean Growth Strategy, adopted in October 2017, confirmed the United Kingdom's decision to maintain the CPF after 2021 at the current level, to phase-out coal power by 2025, increase the support for low-carbon electricity generation (renewables and nuclear), upgrade energy efficiency in buildings and industry, and roll out low-carbon heating and transport solutions. In recent years, gas use has made inroads in power generation, with the start of the CPF, among other factors.

To-date, the capacity market (CM) has secured over 5.4 gigawatts of new build capacity for delivery between 2018/19 and 2021/22. This includes a new combined cycle gas turbine (CCGT) plant (Kings Lynn), a new open cycle gas turbine plant (Spalding), and a significant number of small-scale gas engines. However, only one new plant, Carrington CCGT (800 megawatts) was commissioned in 2017.

The role of gas in the heating sector is uncertain as policies are in place to support low-carbon heat solutions. In the longer term, under all scenarios gas demand in the United Kingdom will decline, according to NGG.

Gas regulation

The regulatory and policy framework that governs the GB gas market is set out by EU and UK (and transposed EU) legislation, licences (which the Office of Gas and Electricity Markets [Ofgem] grants to energy market participants), and industry codes that underpin the functioning of the energy market and define the conditions of access to different market and infrastructure segments.

The 1986 Gas Act was amended in April 2017 by the Electricity and Gas Regulations 2017, which implement the so-called EU Third Package. In 2014, Ofgem completed the

Gas Security of Supply Significant Code Review to consider changes to gas codes to reduce the likelihood, severity, and duration of a gas supply emergency. A final policy decision was announced in February 2014 and changes to cash-out arrangements came into effect on 1 October 2015.

In the entry-exit system, around 260 gas shippers buy gas from producers and importers and arrange for its transportation and sell gas to suppliers. Licensed suppliers buy gas from shippers and compete to supply both domestic and business consumers. Storage and LNG operations do not require a licence in GB.

In GB, access to storage is based on negotiated third-party access (TPA) for the Hornsea storage site, whereas the other six smaller operational storage facilities are not regulated. The LNG facilities have to offer regulated TPA; however, all three LNG facilities have an exemption from the regulated TPA under Section 19C of the Gas Act.

Gas transmission and distribution networks are regulated under Ofgem's performance-based revenue framework, with price controls based on the "Revenue = Incentives + Innovation + Outputs" or RIIO model (RIIO T1 and RIIO GD1), which began on 1 April 2013 will run until 31 March 2021.

Transmission charges are composed by the entry and exit charges of the transmission owner – a capacity and commodity component (levied on actual gas flows) to recover the costs incurred for the provision and maintenance of transmission network assets – and the system operator charge – commodity charges levied on the basis of gas flows at entry and exit points to recover the costs incurred by the day-to-day operations on the transmission system. Transmission entry and exit capacity charges are levied on all network users, which include storage sites, LNG terminals, and beach terminals, in a non-discriminatory way. Transmission owner and system operator commodity charges are not levied on gas storage users.

Wholesale gas market

GB has a gas day-ahead and forward market that is highly liquid with an annually total traded volume of 1 853 bcm and an annual churn rate of 23 in 2017 (Ofgem, 2018a); exchange-based trading alone accounted for 58% of the traded volume. Great Britain also has an intraday market – the on-the-day commodity trading market.

The wholesale gas market has one price for gas irrespective of where the gas comes from. This is called the National Balancing Point (NBP) price of gas. In 2017, the average day-ahead gas price was the highest since the 2014 low at 45 pence/therm, up from 35 pence/therm in 2016, but much below gas record prices in 2013 (68 pence/therm). Rising NBP prices since 2014 have provided a strong incentive for gas flows from the continent to the Great Britain (GB) market.

In 2016, 142 licensed entities traded in the NBP market. Of these companies, 120 traded continuously over the year, and 22 entered and exited the platform over the period, which suggests that entry and exit is not difficult. Concentration is also low for the ownership of total supply capacity and trading activity between gas shippers at the NBP. For total supplies, the Herfindahl-Hirschman Index (HHI) of concentration is 744, below the threshold of 1 000 that would suggest a concentrated market and potential competition concerns (Ofgem, 2018b). For end users, the wholesale costs made up 39% of the gas bill, whereas network costs accounted for 25%, environmental and social costs for 1%, and the remainder from the supply pre-tax margin (9%) and 20% operating costs and other services (6%) (Ofgem, 2018a).

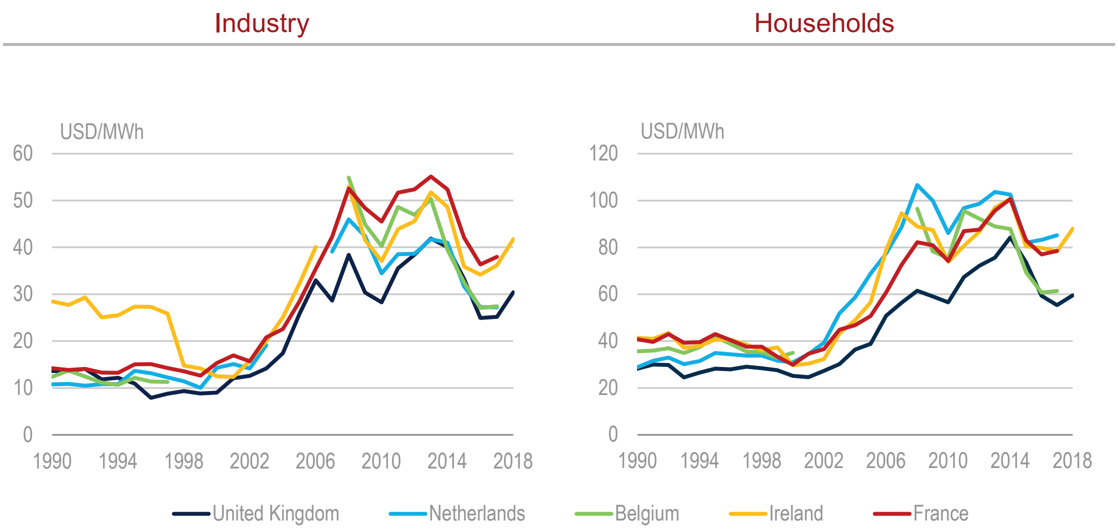
Retail gas market

The retail gas market of around 23.2 million domestic gas consumers is largely controlled by the former monopoly British Gas (31%) and the five large vertically integrated electricity suppliers (EDF Energy, E.ON UK, RWE Npower, SSE, and Scottish Power) which hold equal shares of around 9-10%, besides 58 small and medium-sized gas suppliers that account for 20% of the total (Ofgem, 2018a). Incumbent suppliers thus supplied 78% of the retail gas market in 2017, down from 83% in 2016. A particular feature of the GB market, 49 suppliers offer both electricity and gas in the domestic retail market, besides seven gas-only and four electricity-only suppliers. The industrial segment has more independent suppliers than the domestic segment (households).

In terms of competition in the retail market, GB gas markets are concentrated with a HHI of around 1 400 for domestic and small business consumers in 2017 and 1 130 for large industry clients. Supplier switching rates are on the rise and were 18.6%, with consumers switching away from the six large suppliers. According to Ofgem, 58% of customers that switched during 2017 moved to smaller and medium suppliers, which took around 17 days on average (Ofgem, 2018a).

According to IEA data, the retail gas price for industry and households has declined in recent years in the United Kingdom, similarly to that in other peer countries (Figure 10.7) and UK gas prices are relatively low by international comparison.

Figure 10.7 Natural gas price trends in selected IEA member countries, 1990-2018



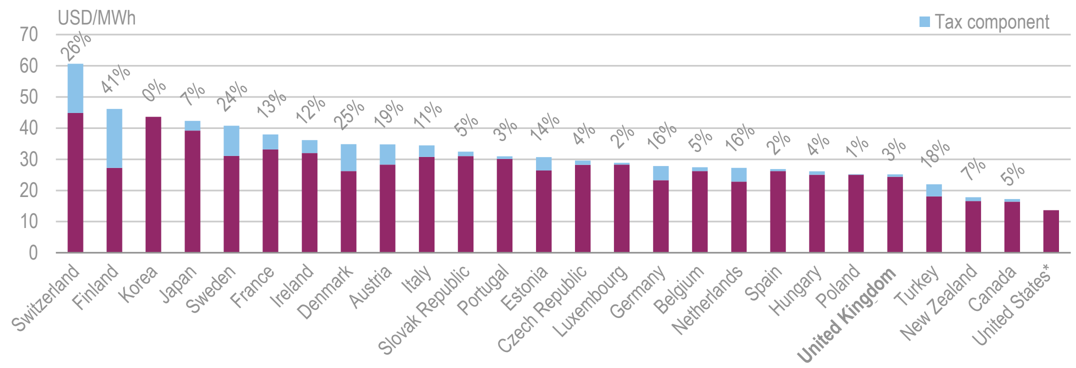
UK gas prices followed the same trends but remained lower than in neighbouring countries, especially in households.

Source: IEA (2019b), *Energy Prices and Taxes 2019*, www.iea.org/statistics/.

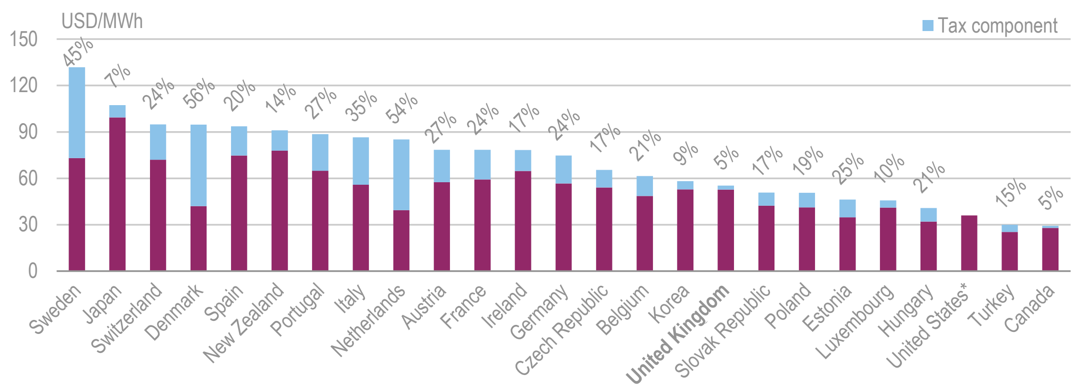
In 2017, United Kingdom had the fourth-lowest gas price for industry and eighth-lowest gas price for households among IEA countries. The share of tax in the UK natural gas price for industry and households each accounts for 3% and 5%, respectively, of the total price, which are among the lowest levels in the IEA comparison (Figure 10.8).

Figure 10.8 Natural gas prices in IEA member countries, 2017

Industry



Households



UK industry pays the fourth-lowest industry price, and the household price is ranked in the lower middle in comparison with other IEA countries.

* Tax information not available for the United States.

Notes: Data are not available for Australia, Greece, Mexico, and Norway (industry); Australia, Greece, Finland, Mexico, and Norway (household). USD/MWh = US dollars per megawatt hour.

Source: IEA (2018b), *Energy Prices and Taxes 2018*, www.iea.org/statistics/.

The Competition and Markets Authority (CMA) undertook an extensive study of the gas and electricity (energy) markets between June 2014 and June 2016. As explained in detail in Chapter on Electricity, the CMA found the wholesale market competitive. However, it judged the retail market as in poor performance. Customers were paying an average of British pounds (GBP) 1.4 bn a year more than they would in a truly competitive market. This was mainly attributed to a lack of switching activity, as two-thirds of all customers remained on the default standard variable tariffs rather than switching to lower cost offers that were available in the market. In their final report, the CMA made a number of recommendations to improve the retail energy market, many of which either have been implemented by the government or are in the process of being implemented.

The government also agreed with the minority opinion in the CMA study that a temporary cap on tariffs would provide protection to consumers until competition was fully functioning and all the CMA recommendations implemented. The Domestic Gas & Electricity (Tariff Cap) Bill received Royal Assent on 19 July 2018. The aim of the new legislation is to cap temporarily the energy prices for gas (or electricity) customers on standard variable and default tariffs. As recommended by the CMA, on 1 April 2017 Ofgem introduced the temporary cap for customers on prepayment meters, and is required to review the level of the cap at least every six months to ensure the level takes account of external factors, such as wholesale energy costs. The cap expires at the end of 2020, with one-year extensions possible until the end of 2023.

Security of gas supply

Legal framework

In GB, several bodies are in charge of security of gas supply, in line with EU and national laws and regulations. Although the GB gas market is the principle mechanism to guarantee security of supply, the government continuously reviews and monitors the security of gas supply.

BEIS is responsible for energy and climate change policy in the United Kingdom. BEIS leads the international engagement with key energy suppliers and monitors gas security. As the competent authority under the EU Gas Security Regulation (EU 2017/193), BEIS regularly prepares a risk assessment, preventive action plan, and emergency plan.

Ofgem is the independent regulator responsible for consumer protection, security of supply, supervising the gas market functioning, and assessing competition. Every year BEIS and Ofgem prepare the joint statutory security of supply report, which is delivered to parliament.

National Grid Gas (NGG), since 2019, National Grid System Operator (NGSO), has the responsibilities to maintain the balance of supply and demand on a daily basis, adequacy during peak demand periods, provide gas demand forecasts to market participants and plan the network in the ten-year horizon through the so-called annual ten year gas statement. In the short term, the UK gas market is incentivised to be in balance, thanks to imbalance charges imposed by NGSO on shippers who are not in balance at the end of the gas day (cash-out payments).

Adequacy of gas supply and demand

Over the next few years, the IEA expects a slight increase in the reliance on imports over the current level for Great Britain (IEA, 2018c). Production from the North Sea, which had increased in recent years, is expected to fall by around 8 bcm by 2023. On the demand side, there is little opportunity for natural gas demand to grow: coal generation is already at low levels thanks to the introduction of the CPF, and renewable generation continues to grow apace while electricity demand does not. The electricity CM mechanism is bringing forward a combination of new gas-fired plants, gas engines, demand response, and other smaller-scale options. Even the gas engines are expected to operate with relatively low capacity factors. Programmes to encourage consumers to use heat pumps will limit the expansion of natural gas consumption in the residential sector. Therefore, the IEA expects gas demand to fall about 5% (4 bcm) by 2023 (IEA, 2018c). This implies an increase of imports of around 4 bcm, which can be met by either pipeline or LNG.

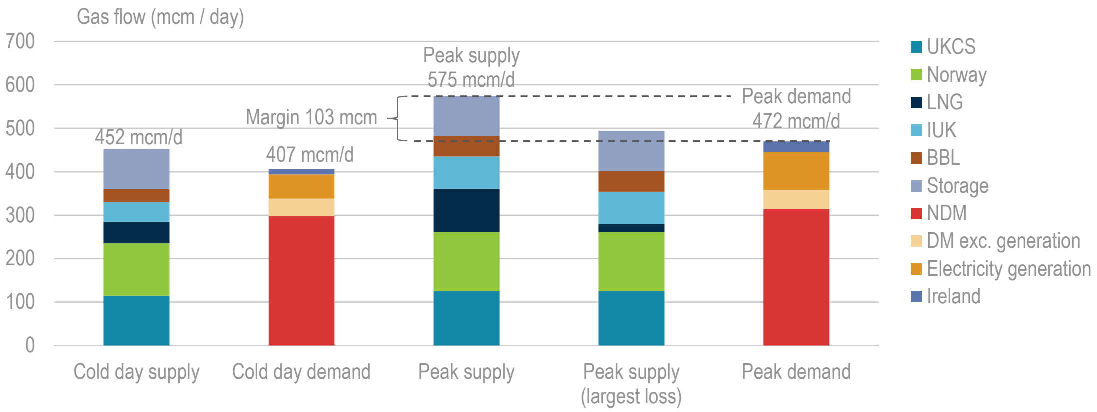
Towards 2030, NG expects the annual gas demand to decline. In the NG UK future energy scenario report (NG, 2017), annual gas demand declines in all scenarios, but the actual decline will be determined by the pace of the deployment of distributed renewable energies and decarbonisation policies for heating and for the heat and power sector.

Short-term security and emergency response

Under the EU Gas Security of Supply Regulation, NGSO has to ensure the security of gas supply over a 1-in-20 peak gas demand scenario in the case of the loss of the largest infrastructure (N-1 rule).

In the 2018/19 Winter Outlook (NGSO, 2018), NGSO indicates that excepted peak demand could rise slightly above the historic peak demand, but that any loss of the largest infrastructure (81 million cubic metres per day [mcm/d]) could be covered thanks to a 575 mcm/d peak supply, which leaves a margin of 103 mcm/d.

Figure 10.9 Gas supply and demand on a cold day and on a 1-in-20 peak gas day



Notes: NDM = non-daily metered; DM = daily metered

Source: NGSO (2018), *Winter Outlook 2018/19*.

Supply-side measures

The United Kingdom has significantly greater natural gas import potential than it currently utilises. Studies carried out by NGSO estimate that the range of supply diversity available to the UK markets (including storage) can deliver 103 mcm/d above the 1-in-20 year[1] maximum daily demand of 472 mcm/d, with a peak supply deliverability of 575 mcm/d. The United Kingdom has a programme to maximise the economic recovery of indigenous resources, with the MER strategy of the OGA. The United Kingdom relies on a flexible short-range storage as well as three large LNG import facilities. Seasonal storage is no longer available with the closure of Rough storage, which leaves the GB market with a significantly lower storage capacity.

[1] 1-in-20 years peak daily demand is the level of daily demand that, in a long series of winters and with the connected load held at the levels appropriate to the winter in question, would be exceeded in one out of 20 winters, with each winter counted only once.

Demand-side measures

The Significant Code Review by Ofgem found the gas market could benefit from a demand-side mechanism to enable large consumers of gas to reduce their demand to avoid an emergency. Ofgem approved the proposed centralised demand-side response (DSR) mechanism for large consumers by NG in October 2016.

Gas quality

Depending on the import origin, the quality of imported gas varies from the high Wobbe index of Norwegian gas to Dutch gas with a low Wobbe index. As domestic production has been in decline, the gas quality and internal gas transmission capacity have been identified as challenges. As the United Kingdom's reliance on LNG and pipeline imports is set to increase, gas specifications will be a critical element for import flexibility. The latest specifications stem from 1996 when the Health and Safety Executive issued the Gas Safety (Management) Regulations 1996 for National Grid. The United Kingdom may be disadvantaged when procuring LNG on the international market because of the narrow gas specifications compared to those of other European countries (Jackson et al., 2005).

Recent supply disruptions

Regional gas market events during winter

A controlled shutdown of the Forties Pipeline System on 11 December 2017 resulted in the curtailment of about 40 mcm/d of gas that flowed from the St Fergus Gas Terminal – equivalent to around 12% of the national daily demand on a winter day. Other sources – notably from continental Europe – met this deficit until the pipeline returned to full operation on 30 December 2017. To manage the increased flows from Europe (from Belgium and the Netherlands), NGG temporarily reduced flows through the Bacton gas terminal to bring another compressor unit online. This routine process was completed by the end of the day, and allowed both interconnectors to import into the United Kingdom at near capacity.

Also, on 12 December 2017 there was an explosion at a gas pipeline hub in Baumgarten, Austria, as a result of a technical fault. Although there were no gas security-of-supply concerns for GB, transit through Austria to Southern Europe was impacted, which resulted in short-term price increases across Western Europe and, most notably, the declaration of a gas emergency in Italy. The Baumgarten hub returned to full operations by 13 December 2017. Italy drew on alternative interconnector flows, plus storage facilities, and weathered their emergency with no impact on supplies to consumers.

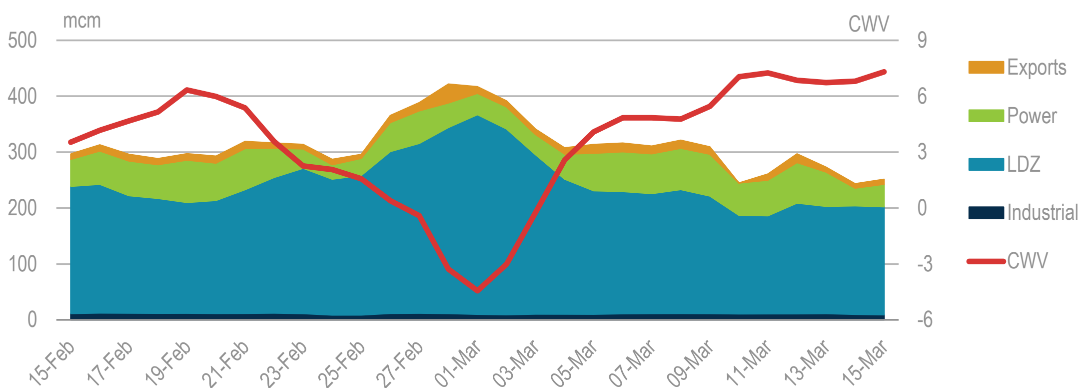
Despite these coincident events, at no time was Great Britain gas security threatened. NG were confident that supplies remained adequate throughout the period. In some ways, the events served as a test of the strength and flexibility of the gas supply system and market. Although security was not threatened, there was some impact on prices. UK wholesale day-ahead gas prices spiked (moderately) on 12 December 2017, but quickly fell to close at 67.3 pence/therm (compared to 57.7 pence/therm in the preceding week, when average temperatures were higher).

Cold spell during February 2018 – The "Beast from the East"

Starting on 24 February 2018 and ending on 4 March 2018, the United Kingdom and Ireland suffered a cold wave, the named "Beast from The East", responsible for unseasonable low temperatures and heavy snowfall. According to NGG 1 March 2018 was the seventh coldest day in their 58-year weather record history and triggered the highest gas demand in seven years. However, the highest gas demand on record of 465 mcm/d (January 2010) also included exports via the IUK interconnector, which was flowing at full capacity. Once exports to the Republic of Ireland are accounted for, it is possible that 1 March 2018 is the highest domestic demand on record.

On 1 March 2018, NGG issued a gas deficit warning, which indicates that additional network balancing measures were potentially required on that day. This was in combination with a series of flow reductions that affected Norwegian assets, storage, LNG terminals, and UKCS production. As shown in Figure 10.10, demand from the distribution network (serving primarily households and commercial entities) rose the most significantly by over 100 mcm/d from 243 mcm on 24 February 2018 to 357 mcm on 1 March 2018 as the composite weather variable[2] (CWW) dropped to -4.44.

Figure 10.10 UK gas demand, 15 February to 15 March 2018



Note: LDZ = local distribution zone. CWV = composite weather variable

Source: IEA (2018d), *Gas 2018*, based on data from NG.

To meet the rapidly climbing natural gas demand was challenged by the fact that the severe weather conditions caused a number of outages on some of the key supply infrastructure, which resulted in reduced flows from the Netherlands and from North Sea production, and further tightened the market. The gas system, already under stressed conditions, then suffered a further blow due to the unavailability of the regasification unit at the South Hook LNG terminal early in the morning of 1 March 2018. Soon after, NGG issued a gas deficit warning at 05:47 with the supply deficit estimated to be around 45 mcm. This was the first gas deficit warning issued since the winter storms of 2010. As a result of the tight market situation, gas prices in the United Kingdom soared on 1 March 2018 to a 20-year high, above 370 pence/therm (127 GBP/MWh, see Figure 10.11)[3]. The market reacted by optimising both the demand and the supply side.

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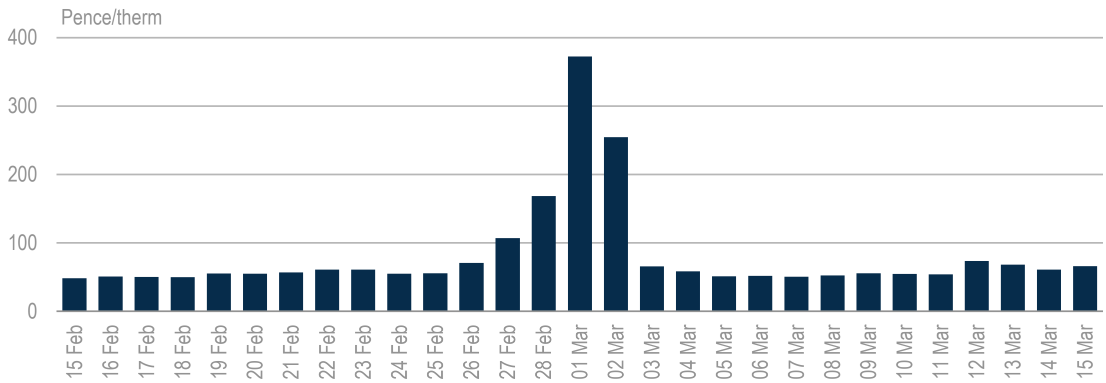
[2] The CWV is a single measure of daily weather and is a function of actual temperature, wind speed, effective temperature, and seasonal normal effective temperature (Gasgovernance, 2014).

[3] The SAP reported by NG stood at 372 pence/therm.

Figure 10.11 UK system average price (SAP), 15 February to 15 March 2018



Source: NGG (National Grid Gas) (2018a), Transmission Operational Data, NG, Warwick, www.nationalgridgas.com/data-and-operations/transmission-operational-data.

On the demand side:

- Exports to Ireland were cut from 33.7 mcm on 28 February to 11.8 mcm on 1 March 2018.
- The power sector diminished its gas burn from 58 Mm^3 on 27 February to 38 Mm^3 on 1 March 2018, with gas further losing its price competitiveness vis-à-vis other supply sources. Coal power generation increased to 25% of the system supply. Electricity imports increased by over 60% between 28 February and 3 March 2018 as electricity prices soared to reach a 10-year high.
- Flows to industrial gas consumers decreased by around 2 mcm/d between 27 February and 1 March 2018. NG scaled back the off-peak exit capacity on the day, exercising a right included in the industrial users' commercial contracts for capacity allocation.

The supply side reacted quickly as well:

- Flows from the European continent through the BBL and the IUK interconnector pipelines rose by 150% from 32 Mm^3 on 28 February to 80.3 Mm^3 on 1 March 2018.
- Norwegian deliveries to Easington through Langeled rose by ~20%, from 63 Mm^3 on 28 February to 75 Mm^3 on 1 March 2018.
- Rough storage added 5 Mm^3 to the market on 2 March 2018 (produced from cushion gas).

Simultaneously, weather conditions also started to improve, as shown by the CWW rising from -4 on 1 March to +4 on 5 March 2018. Heating demand fell and prices returned to typical seasonal levels.

Interlinkages of the gas and electricity systems

During the "Beast from the East" significant wind and coal-fired generation was able to support the high heating and power demand. This favourable outcome in 2018 may not be replicated in the future. Planned coal and nuclear closures, and cold but less windy weather, could diminish the power system's support in a future event. The question arises as to the level of gas price and power system flexibility (interconnections and batteries) that will be needed to balance both systems. With low wind levels, gas prices would need to rise higher. However, very high gas prices create an incentive for gas users, which includes power generators, to offer gas through the NGG DSR or the on-the-day commodity market, which further exacerbates a power system crunch. As natural gas accounts for 40% of the power generation, the closer coordination of emergency measures, notably demand response across the sectors, is required. NGSO operates both the national gas and electricity grid in Great Britain and is well placed to ensure synergies in the system operation and security of supply.

Assessment

Natural gas plays a crucial role in the United Kingdom's energy sector. It is used by 80% of households for residential heating, and gas plays an important role in reducing the carbon intensity of the UK electricity supply as it has recently replaced larger shares of coal. Consumption in the industrial and commercial sectors, by contrast, forms a small share in gas demand.

Since 2015, UK gas demand has increased, reversing a trend in which demand had been declining thanks to a higher boiler and building efficiency in the residential sector and the changing industrial structure. The increase was due to a decrease in global gas prices, environmental regulation on coal-fired power plants, and the government's introduction of the CPF in the power sector, which favoured the operation of gas generation at the expense of coal. Although coal generation is expected to decline further in the next few years, gas generation is expected to remain stable, as the growing renewables supply and the flat electricity demand constrain the growth opportunities for gas.

UK gas production has also seen a modest reversal, with the increase in production from the UKCS in the past few years encouraged by a more favourable tax policy for the exploration and development of new offshore resources. That said, the decline in UKCS production is expected to resume and the UK market will become more dependent on imports, primarily from Norway and continental Europe, and on LNG.

The United Kingdom has a well-developed competitive wholesale gas market, which appears to be working well. The market is characterised by high liquidity and low concentration, bolstered by good interconnections with neighbouring markets in Europe and by access to global markets through a significant LNG regasification capacity. Wholesale prices for natural gas, although they have increased, are competitive by European standards.

Amid the increasing reliance on natural gas in the energy system and increasing imports, potential security of supply concerns were raised, notably in the light of two events: the closure of the Rough storage facility, which accounted for over 70% of gas storage volume in the United Kingdom, and the "Beast From the East" weather event which resulted in a gas deficit warning.

Yet closer examination of these developments suggests that these concerns might be misplaced. In the case of Rough storage, although very sizeable in volume, it could only release its gas very gradually. Such slow-responding storage is most valued when seasonal differences in the price of gas are great and conversely the pipeline infrastructure limited. This storage closure in the United Kingdom is in line with the developments in other European gas markets, where many slow-acting storage facilities had to close.

What is more relevant to the United Kingdom's security of supply is its ability to perform on a peak gas day. With significant domestic supplies, pipeline imports from Norway, interconnections with continental Europe, and LNG import capabilities, the United Kingdom appears to be in a very strong position when it comes to natural gas security of supply.

NGG estimates that the system could manage a 1-in-20 year peak day of around 472 Mm^3 thanks to an around 103 Mm^3/d spare capacity in interconnection capacity. By contrast, during the cold weather experienced on 1 March 2018, gas demand – although higher than on any day in the previous seven years – amounted to 418 Mm^3, still below the historic peak demand of 465 Mm^3/d (8 January 2010).

Indeed, closer examination of the "Beast from the East" reveals at least three points that were key to the response, but these are also areas worth monitoring more carefully. The first was that gas and electricity security are increasingly interrelated as the response of the electricity market, coincided with a very strong wind output. Second, although they had little or no effect on annual gas bills, higher prices over a few hours is a feature of both gas and electricity markets to maintain supply security. Third, the event showed that the interconnected nature of the UK and continental European gas and electricity markets, in fact, enhanced the security of supply of each.

Experience with similar events in North America demonstrated the importance of coordinating gas and electricity system operations during such events, something that is currently only permitted in the United Kingdom in emergency circumstances. One area worth further investigation is improvements to programmes for DSR, particularly for large customers. On 1 March 2018, NG asked customers for bids to cut their gas load but received no offers as a seasonal electricity demand response programme had ended as planned the day before the event. Finally, the future relationship of British and European markets remains uncertain because of the United Kingdom exiting the European Union.

The second area of concern is the future evolution of the retail markets (both gas and electricity). The government enacted legislation to cap the standard tariff prices. These caps will remain in place until at least 2020 and may remain through 2023, subject to the decision of the Secretary of State, and only after a review has taken place. Although the sunset provision implies that the measure is a temporary one, the legislation does provide limited guidance to Ofgem for their review beyond the sunset date whether conditions are in place for effective competition for domestic supply contracts.

The third area is the decarbonisation policy that is being applied to the residential heating sector. A desire to focus on residential heating is understandable given its prominence in gas use. However, the relative affordability of natural gas means that the substitution of gas by other heating fuels is not attractive economically in the future, notably as in a market with relatively high electricity prices electric heating or heat pumps are not economic. In the short-to-medium term, the decarbonisation policy should prioritise the focus on improvements in building energy performance to bring forward cost-effective results; also, technology costs are declining over time and district heating solutions or hydrogen or electrification are beginning to see a revival in some cities and communities.

Finally, note that access to new gas resources faces a technical barrier because of the United Kingdom's particularly narrow quality specification, developed when most UK gas came from the UKCS. The narrow specification requires certain LNG imports to be blended. Similarly, other methane sources, such as biomethane, may find it more challenging to meet the current standard. Field trials are being conducted on a new gas quality standard that would, if adopted, allow a broader range of supplies to be integrated more easily and cost-effectively.

Recommendations

The UK government should:

- Enhance the coordination of security-of-supply responses between gas and electricity systems, including with regard to the role of demand response.
- Maintain the security-of-supply benefits of interconnection with European gas and electricity markets.
- Continue to prioritise energy efficiency improvements in existing gas-heated buildings while promoting fuel switching in new constructions to decarbonise the residential sector.
- Continue to review gas quality standards to accommodate new sources of supply.

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ANNEX A: Organisations visited

Review criteria

The Shared Goals, which were adopted by the International Energy Agency (IEA) Ministers at their 4 June 1993 meeting in Paris, provide the evaluation criteria for the in-depth reviews (IDRs) conducted by the IEA. The Shared Goals are presented in Annex C.

Review team and preparation of the report

The review team visited London from 14 to 18 May 2018, met with government officials, regulators, stakeholders in the public and private sectors as well as other organisations and interest groups. The discussions helped the team identify the key challenges facing energy-policy makers in the United Kingdom. The report was drafted on the basis of these meetings, the government's initial submission to the IEA energy policy questionnaire and several updates since the review visit.

The IEA and the peer review team are grateful for the co-operation and assistance of the many people it met throughout the visit. The review team wishes to express its gratitude to the hosts at the Department Business Energy and Industrial Strategy: Mr Pete Betts, Director for International Climate and Energy, and Mr Dan Dorner, Head of International Energy Unit. Special thanks for the organisation of the review on the government side go to the UK Foreign and Commonwealth Office and BEIS staff, Ms Julie Evans and Ms Julia Nolan, Head of International and EU energy diplomacy, for their professional support and excellent management of the entire review process, notably the organisation of the review week in London, the peer review and the launch of the report.

IEA member countries and observers

Mr John Rampton, New Zealand (team leader)

Mr Kevin Brady, Ireland

Mr Stanford Harrison, Australia

Mr Alberto Fernandez Fernandez, Belgium

Mr Fredrik Norlund, Sweden

Mr Bas Heijs, The Netherlands

Dr Jan Horst Keppler, OECD Nuclear Energy Agency

International Energy Agency

Mr Aad van Bohemen

Mr Peter Fraser

Ms Sylvia Beyer

Ms Elena Merle-Beral

The review was co-ordinated by Sylvia Beyer with the invaluable assistance of Elena Merle-Beral who supported the review as consultant and prepared the chapters on climate, on energy efficiency and on renewables. The chapters on general energy policy, on electricity, and on technology research and development were drafted by Sylvia Beyer who also oversaw the entire report. The chapter on nuclear energy was drafted by Dr. Jan-Horst Keppler, OECD/NEA and the chapter on natural gas by Mr Peter Fraser, IEA head of gas, coal and power. The chapter on oil was prepared by Ms Maki Yamaguchi, IEA.

The report benefited from the guidance of the team leader Mr John Rampton and IEA head of energy policy and security division, Mr. Aad van Bohemen. Valuable insights and comments were provided by the review team members and the IEA staff, including Mr Enrique Gutierrez Tavarez, Ms Szilvia Doczi, Mr Carlos Fernandez, and Mr Jason Elliott.

Special thanks go to the IEA Secretariat with regard to the data, editing and publication. Importantly, the report has benefited from the support of timely and comprehensive data, including from the IEA energy statistics and energy balances, as prepared by Ms Selena Lee, Mr. Remi Gigoux, and Mr. Oskar Kvarnström.

Mr. Oskar Kvarnström and Mr. Bertrand Sadin ensured the preparation of the design of figures, maps and tables. Mr. John Ormiston carried out the editing of the report. The author thanks the IEA Communication and Digital Office (CDO), in particular Mr Jad Mouwad, Ms Astrid Dumond, Ms Isabelle Nonain-Semelin and Ms Therese Walsh who ensured the report's production and launch.

Organisations visited

Association for Decentralised Energy

Centrica

Centre for Sustainable Energy

Citizens Advice

Committee on Climate Change

Consumer and Market Authority

Department of Energy Business and Industrial Strategy

Department for Transport

EDF

Energy Technologies Institute

Energy Saving Trust

E3G

Green Alliance

Her Majesty's Treasury

National Grid

Ofgem

Oil and Gas Authority

Office for Low Emission Vehicles

Oxford Institute of Energy Studies

Renewable UK

UK Business Council for Sustainable Energy

UK Energy Research Centre

University College London

University of Cambridge

ANNEX B: Energy balances and key statistical data

Energy balances and key statistical data

Unit: Mtoe

SUPPLY		1973	1990	2000	2010	2015	2016	2017E
TOTAL PRODUCTION		**108.5**	**208.0**	**272.5**	**148.5**	**118.3**	**120.1**	**120.2**
Coal		75.9	53.6	18.7	10.8	5.1	2.5	1.8
Peat		-	-	-	-	-	-	-
Oil		0.6	95.2	131.7	65.5	47.0	49.3	48.3
Natural gas		24.4	40.9	97.6	49.8	35.0	35.8	36.0
Biofuels and waste[1]		-	0.6	1.9	5.0	8.2	9.1	9.9
Nuclear		7.3	17.1	22.2	16.2	18.3	18.7	18.3
Hydro		0.3	0.4	0.4	0.3	0.5	0.5	0.5
Wind		-	0.0	0.1	0.9	3.5	3.2	4.3
Geothermal		-	0.0	0.0	0.0	0.0	0.0	0.0
Solar/other[2]		-	0.0	0.0	0.0	0.7	0.9	1.0
TOTAL NET IMPORTS[3]		**107.7**	**-4.1**	**-52.9**	**49.2**	**59.3**	**54.2**	**52.8**
Coal	Exports	2.0	1.8	0.8	0.9	0.4	0.3	0.4
	Imports	1.1	10.3	15.2	16.9	14.9	6.3	6.2
	Net imports	-0.9	8.5	14.5	16.0	14.6	6.0	5.8
Oil	Exports	20.7	76.2	117.4	70.0	58.3	60.9	63.5
	Imports	136.7	65.2	70.6	80.9	85.1	86.0	89.1
	Int'l marine and aviation bunkers	-8.0	-8.9	-12.5	-13.5	-13.3	-13.6	-13.7
	Net imports	107.9	-19.9	-59.2	-2.6	13.5	11.5	12.0
Natural Gas	Exports	-	-	11.3	13.0	11.9	8.4	9.4
	Imports	0.7	6.2	2.0	46.9	38.3	40.8	40.5
	Net imports	0.7	6.2	-9.3	33.9	26.5	32.3	31.1
Electricity	Exports	0.0	0.0	0.0	0.4	0.2	0.2	0.3
	Imports	0.0	1.0	1.2	0.6	2.0	1.7	1.6
	Net imports	0.0	1.0	1.2	0.2	1.8	1.5	1.3
TOTAL STOCK CHANGES		**1.8**	**2.1**	**3.3**	**6.0**	**4.0**	**4.6**	**3.2**
TOTAL SUPPLY (TPES)[4]		**218.1**	**205.9**	**223.0**	**203.7**	**181.6**	**178.9**	**176.2**
Coal		76.4	63.1	36.5	31.0	23.9	11.9	9.7
Peat		-	-	-	-	-	-	-
Oil		108.9	76.4	73.2	63.6	60.1	60.7	60.6
Natural gas		25.1	47.2	87.4	84.8	61.7	69.4	68.0
Biofuels and waste[1]		-	0.6	1.9	6.6	11.1	12.1	12.5
Nuclear		7.3	17.1	22.2	16.2	18.3	18.7	18.3
Hydro		0.3	0.4	0.4	0.3	0.5	0.5	0.5
Wind		-	0.0	0.1	0.9	3.5	3.2	4.3
Geothermal		-	0.0	0.0	0.0	0.0	0.0	0.0
Solar/other[2]		-	0.0	0.0	0.0	0.7	0.9	1.0
Electricity trade[5]		0.0	1.0	1.2	0.2	1.8	1.5	1.3
Shares in TPES (%)								
Coal		*35.0*	*30.6*	*16.4*	*15.2*	*13.2*	*6.6*	*5.5*
Peat		-	-	-	-	-	-	-
Oil		*49.9*	*37.1*	*32.8*	*31.3*	*33.1*	*33.9*	*34.4*
Natural gas		*11.5*	*22.9*	*39.2*	*41.6*	*34.0*	*38.8*	*38.6*
Biofuels and waste[1]		-	*0.3*	*0.9*	*3.2*	*6.1*	*6.8*	*7.1*
Nuclear		*3.3*	*8.3*	*9.9*	*7.9*	*10.1*	*10.4*	*10.4*
Hydro		*0.2*	*0.2*	*0.2*	*0.2*	*0.3*	*0.3*	*0.3*
Wind		-	-	-	*0.4*	*1.9*	*1.8*	*2.4*
Geothermal		-	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*
Solar/other[2]		-	*0.0*	*0.0*	*0.0*	*0.4*	*0.5*	*0.6*
Electricity trade[5]		-	*0.5*	*0.5*	*0.1*	*1.0*	*0.8*	*0.7*

0 is negligible, - is nil, .. is not available, x is not applicable. Please note: rounding may cause totals to differ from the sum of the elements.

Unit: Mtoe

DEMAND							
FINAL CONSUMPTION	**1973**	**1990**	**2000**	**2010**	**2015**	**2016**	**2017E**
TFC	**143.2**	**138.2**	**150.7**	**138.0**	**126.0**	**128.2**	**..**
Coal	31.7	11.1	4.3	3.0	2.8	2.3	..
Peat	-	-	-	-	-	-	..
Oil	73.1	61.2	62.6	55.4	53.8	55.0	..
Natural gas	18.4	41.8	52.4	47.1	38.2	39.4	..
Biofuels and waste[1]	-	0.4	0.6	2.9	3.8	4.2	..
Geothermal	-	0.0	0.0	0.0	0.0	0.0	..
Solar/other[2]	-	0.0	0.0	0.0	0.1	0.1	..
Electricity	20.0	23.6	28.3	28.3	26.1	26.1	..
Heat	-	-	2.4	1.3	1.1	1.1	..
Shares in TFC (%)							
Coal	*22.1*	*8.0*	*2.9*	*2.2*	*2.2*	*1.8*	..
Peat	-	-	-	-	-	-	..
Oil	*51.0*	*44.3*	*41.5*	*40.2*	*42.7*	*42.9*	..
Natural gas	*12.8*	*30.2*	*34.8*	*34.1*	*30.3*	*30.8*	..
Biofuels and waste [1]	-	*0.3*	*0.4*	*2.1*	*3.0*	*3.3*	..
Geothermal	-	-	-	*0.0*	*0.0*	*0.0*	..
Solar/other [2]	-	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	..
Electricity	*14.0*	*17.1*	*18.8*	*20.5*	*20.7*	*20.4*	..
Heat	-	-	*1.6*	*0.9*	*0.9*	*0.9*	..
TOTAL INDUSTRY[6]	**64.6**	**43.0**	**45.5**	**33.8**	**30.7**	**30.4**	**..**
Coal	14.0	6.7	2.7	2.3	2.2	1.7	..
Peat	-	-	-	-	-	-	..
Oil	33.3	15.6	16.3	12.3	10.8	11.1	..
Natural gas	9.4	12.0	15.3	9.1	8.1	8.0	..
Biofuels and waste[1]	-	0.1	0.3	0.4	1.0	1.1	..
Geothermal	-	-	-	-	-	-	..
Solar/other[2]	-	-	-	-	-	-	..
Electricity	7.8	8.7	9.8	9.0	8.0	7.9	..
Heat	-	-	1.1	0.8	0.6	0.6	..
Shares in total industry (%)							
Coal	*21.7*	*15.5*	*6.0*	*6.7*	*7.3*	*5.6*	..
Peat	-	-	-	-	-	-	..
Oil	*51.5*	*36.3*	*35.8*	*36.3*	*35.2*	*36.4*	..
Natural gas	*14.6*	*27.8*	*33.6*	*26.8*	*26.4*	*26.2*	..
Biofuels and waste [1]	-	*0.2*	*0.6*	*1.1*	*3.1*	*3.8*	..
Geothermal	-	-	-	-	-	-	..
Solar/other [2]	-	-	-	-	-	-	..
Electricity	*12.1*	*20.1*	*21.6*	*26.6*	*26.1*	*26.0*	..
Heat	-	-	*2.4*	*2.4*	*2.0*	*2.0*	..
TRANSPORT[4]	**27.6**	**39.2**	**41.9**	**40.2**	**40.2**	**41.0**	**..**
OTHER[7]	**51.0**	**56.0**	**63.4**	**64.0**	**55.1**	**56.8**	**..**
Coal	17.6	4.4	1.6	0.8	0.6	0.6	..
Peat	-	-	-	-	-	-	..
Oil	12.4	6.9	5.2	4.5	4.2	4.3	..
Natural gas	9.0	29.8	37.2	38.0	30.1	31.5	..
Biofuels and waste[1]	-	0.3	0.3	1.3	1.9	2.1	..
Geothermal	-	0.0	0.0	0.0	0.0	0.0	..
Solar/other[2]	-	0.0	0.0	0.0	0.1	0.1	..
Electricity	12.0	14.5	17.8	18.9	17.7	17.8	..
Heat	-	-	1.3	0.4	0.5	0.5	..
Shares in other (%)							
Coal	*34.6*	*7.9*	*2.5*	*1.2*	*1.0*	*1.0*	..
Peat	-	-	-	-	-	-	..
Oil	*24.4*	*12.4*	*8.1*	*7.0*	*7.6*	*7.5*	..
Natural gas	*17.6*	*53.3*	*58.6*	*59.4*	*54.7*	*55.4*	..
Biofuels and waste [1]	-	*0.6*	*0.5*	*2.1*	*3.5*	*3.7*	..
Geothermal	-	-	-	*0.0*	*0.0*	*0.0*	..
Solar/other [2]	-	-	-	*0.1*	*0.1*	*0.1*	..
Electricity	*23.5*	*25.9*	*28.0*	*29.6*	*32.1*	*31.4*	..
Heat	-	-	*2.1*	*0.7*	*1.0*	*0.9*	..

Unit: Mtoe

DEMAND							
ENERGY TRANSFORMATION AND LOSSES	**1973**	**1990**	**2000**	**2010**	**2015**	**2016**	**2017E**
ELECTRICITY GENERATION[8]							
Input (Mtoe)	72.4	74.2	81.7	77.7	66.9	64.3	..
Output (Mtoe)	24.2	27.3	32.2	32.6	28.9	28.9	28.6
Output (TWh)	281.4	317.8	374.4	378.9	336.2	336.4	333.0
Output Shares (%)							
Coal	*62.1*	*65.0*	*32.7*	*28.7*	*22.9*	*9.4*	*7.0*
Peat	-	-	-	-	-	-	-
Oil	*25.6*	*10.9*	*2.3*	*1.3*	*0.6*	*0.5*	*0.7*
Natural gas	*1.0*	*1.6*	*39.6*	*46.4*	*29.7*	*42.6*	*40.0*
Biofuels and waste [1]	-	*0.2*	*1.2*	*3.6*	*9.8*	*10.4*	*11.1*
Nuclear	*10.0*	*20.7*	*22.7*	*16.4*	*20.9*	*21.3*	*21.1*
Hydro	*1.4*	*1.6*	*1.4*	*0.9*	*1.9*	*1.6*	*1.8*
Wind	-	-	*0.3*	*2.7*	*12.0*	*11.1*	*14.9*
Geothermal	-	-	-	-	-	-	-
Solar/other [2]	-	-	-	-	*2.2*	*3.1*	*3.4*
TOTAL LOSSES	**76.5**	**68.5**	**72.2**	**64.3**	**54.5**	**50.4**	**..**
of which:							
Electricity and heat generation[9]	48.2	46.9	47.1	43.7	36.5	34.0	..
Other transformation	11.0	5.1	5.6	3.5	3.0	2.4	..
Own use and transmission/distribution losses[10]	17.3	16.4	19.5	17.0	14.9	14.0	..
Statistical Differences	**-1.7**	**-0.7**	**0.1**	**1.4**	**1.1**	**0.3**	**..**
INDICATORS	**1973**	**1990**	**2000**	**2010**	**2015**	**2016**	**2017E**
GDP (billion 2010 USD)	1147.63	1642.51	2095.21	2441.17	2705.25	2757.62	2806.90
Population (millions)	56.22	57.24	58.89	62.76	65.11	65.65	66.05
TPES/GDP (toe/1000 USD)[11]	0.19	0.13	0.11	0.08	0.07	0.06	0.06
Energy production/TPES	0.50	1.01	1.22	0.73	0.65	0.67	0.68
Per capita TPES (toe/capita)	3.88	3.60	3.79	3.25	2.79	2.73	2.67
Oil supply/GDP (toe/1000 USD)[11]	0.09	0.05	0.03	0.03	0.02	0.02	0.02
TFC/GDP (toe/1000 USD)[11]	0.12	0.08	0.07	0.06	0.05	0.05	..
Per capita TFC (toe/capita)	2.55	2.41	2.56	2.20	1.93	1.95	..
CO_2 emissions from fuel combustion ($MtCO_2$)[12]	634.1	549.3	520.4	477.0	389.8	371.1	..
CO_2 emissions from bunkers ($MtCO_2$)[12]	25.2	27.0	37.7	40.9	40.2	41.1	..
GROWTH RATES (% per year)	**73-90**	**90-00**	**00-10**	**10-14**	**14-15**	**15-16**	**16-17**
TPES	-0.3	0.8	-0.9	-3.0	0.9	-1.5	-1.5
Coal	-1.1	-5.3	-1.6	-0.7	-20.7	-50.4	-18.4
Peat	-	-	-	-	-	-	-
Oil	-2.1	-0.4	-1.4	-2.2	3.1	1.1	-0.2
Natural gas	3.8	6.4	-0.3	-8.3	2.9	12.5	-2.1
Biofuels and waste[1]	-	11.9	13.1	9.8	15.8	9.3	3.6
Nuclear	5.2	2.6	-3.1	0.6	10.3	2.0	-1.9
Hydro	1.8	-0.2	-3.4	13.1	7.1	-14.4	10.1
Wind	-	55.2	27.0	32.8	26.2	-7.3	32.7
Geothermal	-	-	-	-	-	-	-
Solar/other[2]	-	1.0	14.3	75.5	75.9	35.3	9.7
TFC	-0.2	0.9	-0.9	-2.9	2.5	1.8	..
Electricity consumption	1.0	1.8	-0.0	-2.0	0.2	0.1	..
Energy production	3.9	2.7	-5.9	-7.7	9.6	1.5	0.1
Net oil imports	..	..	..	..	-19.4	-15.2	4.4
GDP	2.1	2.5	1.5	2.0	2.3	1.9	1.8
TPES/GDP	-2.4	-1.6	-2.4	-4.9	-1.5	-3.3	-3.2
TFC/GDP	-2.3	-1.6	-2.4	-4.8	0.2	-0.2	..

0 is negligible, - is nil, .. is not available, x is not applicable. Please note: rounding may cause totals to differ from the sum of the elements.

Footnotes to energy balances and key statistical data

1. Biofuels and waste comprises solid biofuels, liquid biofuels, biogases, industrial waste, and municipal waste. Data are often based on partial surveys and may not be comparable between countries.
2. Other includes solar thermal, tide, and wave.
3. In addition to coal, oil, natural gas, and electricity, total net imports also includes solid and liquid biofuels.
4. Excludes international marine bunkers and international aviation bunkers.
5. Total supply of electricity represents the net trade. A negative number in the share of TPES indicates that exports are greater than imports.
6. Industry includes non-energy use.
7. Other includes residential, commercial and public services, agriculture/forestry, fishing, and other non-specified.
8. Inputs to electricity generation include inputs to electricity, co-generation, and heat plants. Output refers only to electricity generation.
9. Losses that arise in the production of electricity and heat at the main activity producer utilities and autoproducers. For non-fossil-fuel electricity generation, theoretical losses are shown based on the plant efficiencies of approximately 33% for nuclear and 100% for hydro, wind, tide, and solar photovoltaic.
10. Data on “losses” for forecast years often include large statistical differences that cover differences between expected supply and demand and mostly do not reflect real expectations on transformation gains and losses.
11. Toe per thousand US dollars at 2010 prices and exchange rates.
12. “CO_2 emissions from fuel combustion” was estimated using the IPCC Tier I Sectoral Approach from the *2006 IPCC Guidelines.* In accordance with the IPCC methodology, emissions from international marine and aviation bunkers are not included in the national totals. Projected emissions for oil and gas are derived by calculating the ratio of emissions to energy use for 2013 and applying this factor to forecast energy supply. Projected emissions for coal are based on product-specific supply projections and are calculated using the IPCC/OECD emission factors and methodology.

ANNEX C: International Energy Agency "Shared Goals"

The member countries* of the International Energy Agency (IEA) seek to create conditions in which the energy sectors of their economies can make the fullest possible contribution to sustainable economic development and to the well-being of their people and of the environment. In formulating energy policies, the establishment of free and open markets is a fundamental point of departure, though energy security and environmental protection need to be given particular emphasis by governments. IEA countries recognise the significance of increasing global interdependence in energy. They therefore seek to promote the effective operation of international energy markets and encourage dialogue with all participants. In order to secure their objectives, member countries therefore aim to create a policy framework consistent with the following goals:

1. Diversity, efficiency, and flexibility within the energy sector are basic conditions for longer-term energy security: the fuels used within and across sectors and the sources of those fuels should be as diverse as practicable. Non-fossil fuels, particularly nuclear and hydro power, make a substantial contribution to the energy supply diversity of IEA countries as a group.

2. Energy systems should have **the ability to respond promptly and flexibly to energy emergencies.** In some cases this requires collective mechanisms and action: IEA countries co-operate through the Agency in responding jointly to oil supply emergencies.

3. The environmentally sustainable provision and use of energy are central to the achievement of these shared goals. Decision makers should seek to minimise the adverse environmental impacts of energy activities, just as environmental decisions should take account of the energy consequences. Government interventions should respect the Polluter Pays Principle where practicable.

4. More environmentally acceptable energy sources need to be encouraged and developed. Clean and efficient use of fossil fuels is essential. The development of economic non-fossil sources is also a priority. A number of IEA member countries wish to retain and improve the nuclear option for the future, at the highest available safety standards, because nuclear energy does not emit carbon dioxide. Renewable sources will also have an increasingly important contribution to make.

5. Improved energy efficiency can promote both environmental protection and energy security in a cost-effective manner. There are significant opportunities for greater energy efficiency at all stages of the energy cycle from production to consumption. Strong efforts by governments and all energy users are needed to realise these opportunities.

6. Continued **research, development, and market deployment of new and improved energy technologies** make a critical contribution to achieving the objectives outlined above. Energy technology policies should complement broader energy policies. International co-operation in the development and dissemination of energy technologies, including industry participation and co-operation with non-member countries, should be encouraged.

7. Undistorted energy prices enable markets to work efficiently. Energy prices should not be held artificially below the costs of supply to promote social or industrial goals. To the extent necessary and practicable, the environmental costs of energy production and use should be reflected in prices.

8. Free and open trade and a secure framework for investment contribute to efficient energy markets and energy security. Distortions to energy trade and investment should be avoided.

9. Co-operation among all energy market participants helps to improve information and understanding, and encourages the development of efficient, environmentally acceptable, and flexible energy systems and markets worldwide. These are needed to help promote the investment, trade. and confidence necessary to achieve global energy security and environmental objectives.

(The Shared Goals were adopted by IEA Ministers at the meeting of 4 June 1993 Paris, France.)

* Australia, Austria, Belgium, Canada, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Japan, Korea, Luxembourg, Mexico, the Netherlands, New Zealand, Norway, Poland, Portugal, the Slovak Republic, Spain, Sweden, Switzerland, Turkey, the United Kingdom, the United States.

ANNEX D: Glossary and list of abbreviations

In this report, abbreviations and acronyms are substituted for a number of terms used within the International Energy Agency. While these terms generally have been written out on first mention, this glossary provides a quick and central reference for the abbreviations used.

Acronyms and abbreviations

ASC	Adaptation Sub-Committee
ASHP	air-source heat pump
BAU	business as usual
BBL	Balgzand Bacton Leiding Company
BEIS	Department of Business, Energy and Industrial Strategy
capex	capital expenditure
CCA	Climate Change Agreement
CCC	Committee on Climate Change
CCL	Climate Change Levy
CCRA	Climate Change Risk Assessment
CCS	carbon capture and storage
CCUS	carbon capture, usage, and storage
CEM	Clean Energy Ministerial
CFD	contract for difference
CLH-PS	CLH Pipeline System
CM	capacity market
CMA	Competition and Markets Authority
CPS	Carbon Price Support
CRC	Carbon Reduction Commitment
CSE	Central Stocking Entity
CWW	composite weather variable
Defra	Department for Environment, Food and Rural Affairs
DFID	Department for International Development
DFT	Department for Transport

DNO	distribution network operator
DSO	distribution system operator
DSR	demand-side response
ECJ	European Court of Justice
EED	Energy Efficiency Directive
EINA	Energy Innovation Needs Assessment
EMR	Electricity Market Reform
ENTSO-E	European Network of Transmission System Operators for Electricity
EOR	enhanced oil recovery
EPBD	Energy Performance of Buildings Directive
EPC	Energy Performance Certificate
EPR	evolutionary power reactor
EPS	emissions performance standard
ErP	Energy-related Products
ERA-NET	European Research Area Network
ESO	electricity system operator
ESOS	Energy Savings Opportunity Scheme
ETYS	Electricity Ten Year Statement
EV	electric vehicle
FID	final investment decision
FIT	feed-in tariff
GB	Great Britain
GBP	Great Britain pounds
GDP	gross domestic product
GHG	greenhouse gas
GPSS	government Pipeline and Storage System
HAW	higher activity waste
HMG	Her Majesty's government
HMT	Her Majesty's Treasury

HNIP	Heat Networks Investment Project
HPC	Hinkley Point C
IAEA	International Atomic Energy Agency
IDR	in-depth review
IEA	International Energy Agency
IEEA	Industrial Energy Efficiency Accelerator
IMO	International Maritime Organization
I-SEM	Integrated Single Electricity Market
IUK	Interconnector (UK) Limited
JET	Joint European Torus
KPI	key performance indicator
LCCC	Low Carbon Contracts Company
LCF	levy control framework
LCICG	Low Carbon Innovation Coordination Group
LNF	liquefied natural gas
LPA	local planning authority
LTO	long-term operations
LULUCF	land use, land use change, and forestry
MER	maximisation of the economic recovery
MI	Mission Innovation
MOU	memorandum of understanding
NAP	National Adaptation Plan
NBP	National Balancing Point
NCA	Nuclear Cooperation Agreement
NCC	Natural Capital Committee
NDA	Nuclear Decommissioning Authority
NEP-F	National Emergency Plan for Fuel
NETS	National Electricity Transmission System
NG	National Grid

NGG	National Grid Gas
NPPF	National Planning Policy Framework
NPS	National Policy Statement
NSIP	nationally significant infrastructure project
OCGT	open cycle gas turbines
ODA	Overseas Development Aid
Ofgem	Office of Gas and Electricity Markets
OFTO	offshore transmission owner
OGA	Oil and Gas Authority
OLEV	Office for Low Emission Vehicles
opex	operational expenditure
OWIC	Offshore Wind Industry Council
PPM	prepayment meter
PPP	purchase power parity
PTL	Premier Transmission Limited
RAB	regulated asset base
R&D	research and development
RAV	Regulatory asset value
RD&D	research, development, and demonstration
RED	Renewable Energy Directive
REGO	Renewable Energy Guarantees of Origin
RES	renewable energy source
RHI	Renewable Heat Incentive
RO	renewables obligation
ROC	Renewables Obligation Certificate
RSC	Regional Security Coordinator
RSP	reserve scarcity price
RTFO	Renewable Transport Fuel Obligation
SAFED	Safe and Fuel Efficient Driving

SAP	system average price
SEM	single electricity market
SET	Strategic Energy Technology
SMR	small modular reactor
STOR	short-term operating reserve
TCP	Technology Collaboration Programme
TCP	total carbon price
TFC	total final consumption
TINA	Technology Innovation Needs Assessment
TNUoS	transmission network use of system
Totex	total expenditure
TPA	third-party access
TPES	total primary energy supply
ULEV	ultra-low emission vehicle
UNFCCC	United Nations Framework Convention on Climate Change
UR	Utility Regulator
USD	United States Dollars
VAT	value-added tax
VRE	variable renewable energy
WEF	World Economic Forum

Units of measure

bcm	billion cubic metres
bcm/yr	billion cubic metres per year
GJ/m^2	gigajoules per square metre
GW	gigawatt
GWh	gigawatt hour
gCO_2/km	grammes of carbon dioxide per kilometre

gCO_2/kWh	grammes of carbon dioxide per kilowatt-hour
kb/d	kilobarrels per day
$kgCO_2$	kilogrammes of carbon dioxide
km	kilometre
kV	kilovolt
kW/yr	kilowatts per year
L	litre
Mb/d	million barrels per day
mcm	million cubic metres
mcm/d	million cubic metres per day
Mt	million tonnes
Mt/yr	million tonnes per year
Mtoe	million tonnes of oil-equivalent
MW	megawatt
MWh	megawatt hour
MW_{th}	megawatt thermal
tCO_2	tonne of carbon dioxide
toe	tonnes of oil-equivalent
TV	television
TWh	terrawatt hour

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ENERGY POLICIES OF IEA COUNTRIES

United Kingdom

2019 Review

The International Energy Agency (IEA) regularly conducts in-depth peer reviews of the energy policies of its member countries, a process that supports energy policy development and encourages the exchange of international best practices and experiences.

The United Kingdom is a global leader in decarbonisation, both in terms of actual emissions reductions and ambitions set out in five-year carbon budgets. The carbon price floor has supported coal-to-gas switching, which combined with a record investment in offshore wind and solar PV, is transforming the UK power sector.

By 2030, wind and solar are expected to reach above 50%, more than in any other country. Solutions for flexible electricity markets and technologies need to be scaled up. Coal and nuclear power capacity is going to retire and new nuclear faces a weak outlook, the contribution of natural gas to meet peak demand is likely to increase. The UK has been able to stabilise production from the North Sea. Given its long term decline, however, oil & gas imports are critical. Maintaining open energy trade with the Continent and the world has to remain a top priority.

The UK Clean Growth Strategy puts energy technology and innovation at the centre of its decarbonisation policy. The IEA underlines that the country's offshore expertise is a strong basis for innovative technologies, such as carbon capture, utilisation and storage (CCUS) and also hydrogen, along with improving energy efficiency.

In this report, the IEA provides recommendations to help the country guide the transformation of the UK energy sector and to meet its ambitious targets.