

Onshore Oil and Gas

This factsheet provides an overview of onshore oil and gas supply in the UK. It forms part of a series on economically important minerals that are extracted in Britain and is primarily intended to inform the land use planning process. It is not a statement of planning policy or guidance; nor does it imply Government approval of any existing or potential planning application in the UK administration. March 2011.

Hydrocarbons, comprising petroleum (oil and natural gas liquids) and gas, are fossil fuels that occur concentrated in nature as economic accumulations trapped in structures and reservoir rocks beneath the Earth's surface. They are principally valued as sources of energy and presently provide around two-thirds of the world's primary energy supply. They are also important chemical feedstocks. Oil and gas are non-renewable resources and our use and dependence on them has increased to the extent that concerns exist about how long they will last. We now consume four barrels of known reserves for every new barrel discovered and some suggest that 90% of the original recoverable oil has been discovered and of that 50% has been produced. Currently, improved technology in the oil and gas industry means that each year we are able to produce more oil from existing fields around the world. Although this will not continue to be the case, alternative sources, such as oil shales, may be available globally to bridge the gap developing between remaining conventional resources and demand.

This factsheet primarily considers onshore oil and gas. Offshore production is briefly mentioned in order to put the much lower level of onshore production into context and to emphasise the enormous contribution which oil and gas have made to the UK economy over

the past 40 years. Because exploration and production of oil and gas from 'unconventional' sources (such as methane from coals, shale gas, underground coal gasification and oil shale) are likely to have significantly different land use planning impacts to 'conventional' onshore oil and gas, these energy sources are covered in a separate 'Alternative Fossil Fuels' mineral planning factsheet. Issues related to storage of natural gas underground are covered in a separate mineral planning factsheet on Underground Storage.

Petroleum ('rock oil') is, after water, the second most abundant liquid on Earth and, along with gas, is found trapped in porous and permeable reservoir rocks. Oil may seep to the surface where it mostly evaporates, leaving behind bitumen, a tarry residue that has been used for thousands of years as a waterproofing agent, for plumbing, boat building, brick bonding and road construction.

Oil is derived from mainly fine-grained, organic-rich (>2-4% total organic carbon) argillaceous sedimentary rocks (mudstones and shales), known as source rocks. On burial, temperatures and pressures increase and hydrocarbons are generated from the source rocks; first, liquids (oil) and, then, successively wet (containing natural gas liquids) and dry gas (methane). Once generated, hydrocarbons can, in processes driven by buoyancy, pressure and concentration gradients, migrate through the pore spaces and minute fractures in rocks. If on the migration pathway suitably porous and permeable reservoir rocks occur, which are sealed by impermeable cap rocks in favourable trapping configurations, then economic accumulations of oil and gas can arise. Potential source rocks occur in many areas of the UK, including perhaps the best known, the Kimmeridge Clay, offshore in the North Sea and which extends across southern England to the south coast of England. The Kimmeridge Clay has provided the UK with major oil and gas reserves that have been exploited since the early 1970s. Commercial hydrocarbon accumulations derived from older sources are also known in a number of regions onshore and these have been exploited since the early 1900s but most from 1939 onwards.

**Kimmeridge Oilfield,
Dorset**



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Market

The UK economy is highly dependent on oil and gas as primary sources of energy and they play an important role in every area of our lives. Today, between 85 and 90% of the UK's energy needs are met by fossil fuels. Natural gas, in particular, is used to generate electricity, and petroleum products derived from oil (petrol, diesel and kerosene) are essential fuels for transport on land, sea and in the air. Oil and gas are also used for domestic heating and are important process fuels in industry. Less obvious are the millions of products that are made from the chemical processing of oil and gas. Indeed, it is almost impossible to find any synthetic item where petroleum has not had any part in the process of its manufacture.

Supply

Prior to the first oil being discovered at Hardstoft in east Derbyshire in 1919, Britain had an important oil shale industry in the Midland Valley of Scotland, which was established in 1851 and continued until 1962. Peak production was during the First World War.

The systematic search for onshore oil began in 1918, following concerns about overseas supply disruptions during the First World War. Modest oil fields were discovered in a number of regions onshore in Britain and they made important contributions to supply, particularly those in the East Midlands during the Second World War. However, it is the significant oil and gas reserves that have been discovered in the offshore areas, most notably the North Sea, since the mid 1960s that have proved of huge economic significance to Britain.

Onshore exploration in the United Kingdom increased significantly from the early 1980s following a period during which drilling activity had declined to its lowest level since the early 1950s. The increase in activity was attributable, at least in part to the introduction in mid-1980 of revised arrangements for the issue of production licences and in part to the increase in world oil prices which took place in 1979.

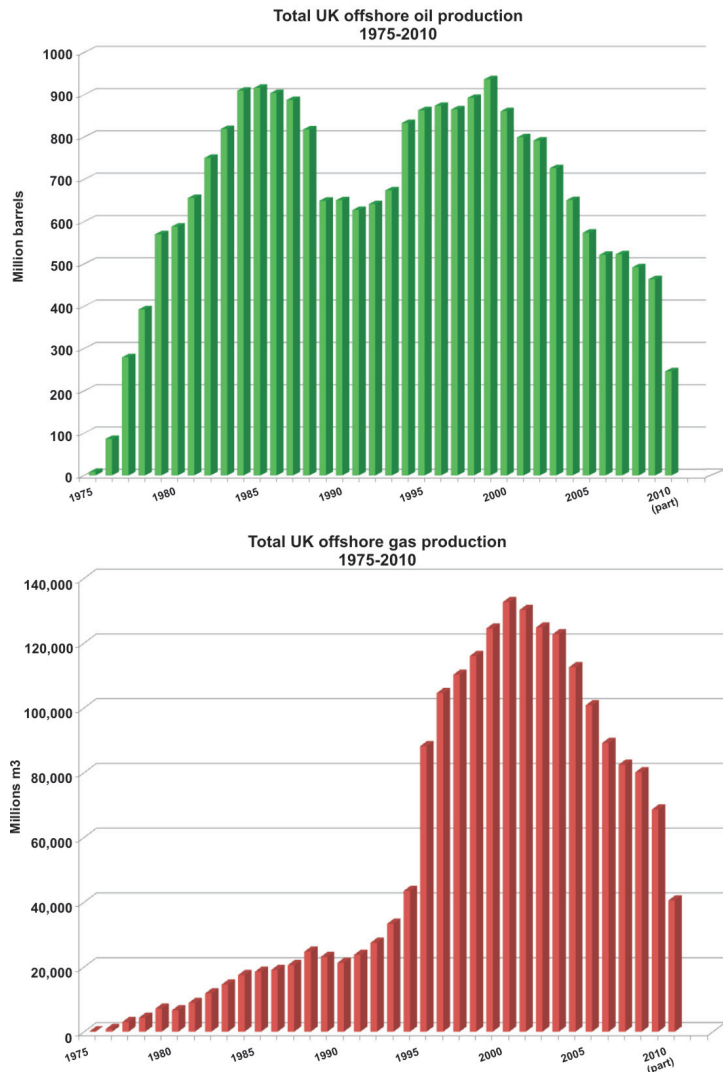


Figure 1 UK offshore oil and gas production, 1975 – 2010 (part) (including natural gas liquids)
Source: DECC

Following the discovery of oil and gas in the North Sea and the rapid build up in production around the UK Continental Shelf thereafter, the UK has been largely self-sufficient in these minerals since the early 1980s. This will change markedly over the next few decades. Production of oil, gas liquids and liquid products from the UK continental shelf area peaked at around 137 million tonnes (1027.5 million barrels) in 1999 when the UK was a major exporter of oil and gas. Crude oil production at that time was 936 mbbbls, since when production has been in general decline (Figure 1). Offshore gas produc-

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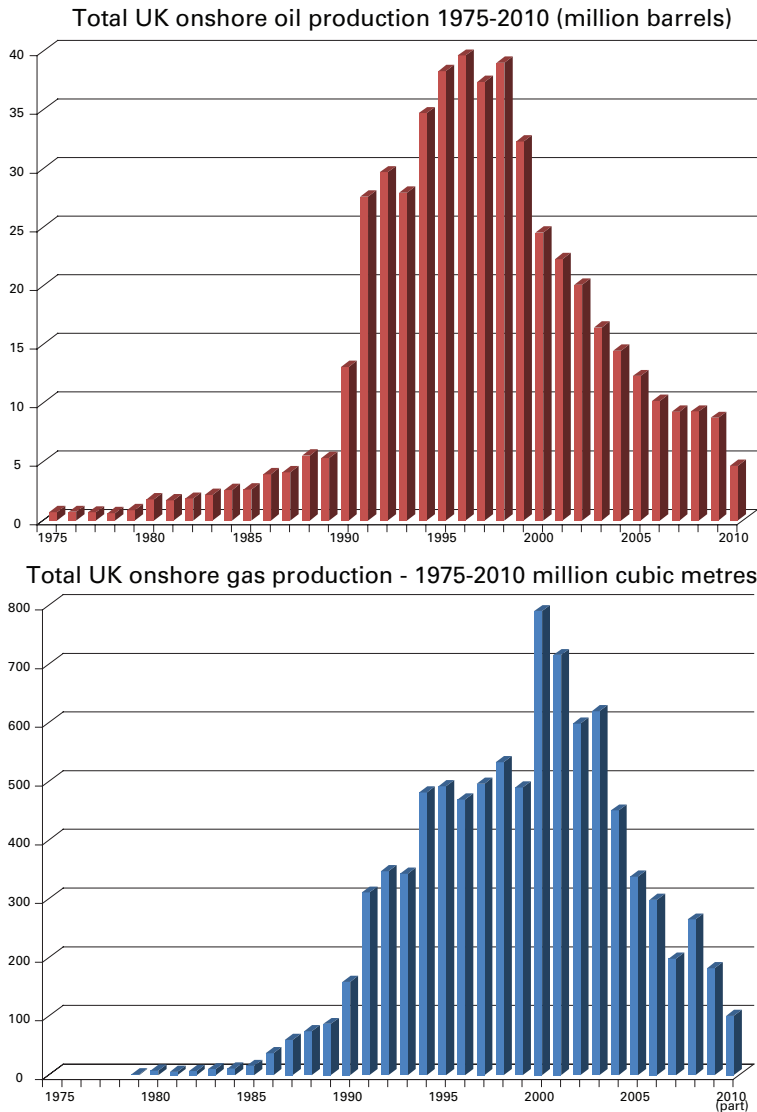


Figure 2 UK onshore oil and gas production, 1979–2010 (part). Source: BGS, DECC.

Note: This represents the gas production figures from the DTI for dry gas and associated gas for each onshore field, where available. (http://www.og.dti.gov.uk/pprs/full_production.htm). As such there may be natural gas liquids included.

tion is also in decline (Figure 1) and after 30 years of self-sufficiency this period of surplus is now at an end; the UK became a net importer of gas in 2004, with imports likely to account for as much as 90% of our needs by 2020. The UK is also expected to become a net importer

of oil during 2010. These issues are outlined below.

Government figures show that production of indigenous oil, gas liquids and liquid products (from both offshore and onshore) stood at about 72 Mt (540 mbbbls) in 2008. Total gas production in 2008 stood at 68 bcm. Clearly offshore figures dominate those of the onshore area, with offshore crude oil production in 2008 totalling about 65.5 Mt (Figure 1; 491.3 mbbbls), whilst onshore the total was about 1.2 Mt (Figure 2: 9.3 mbbbls).

Cumulative UK oil production (including condensate, gas liquids and liquefied products) stood at 3315 million tonnes and gas production at 2225 billion cubic metres (bcm) at end 2008. To end October 2009, total production of onshore oil since 1919, has been about 69.2 million tonnes (around 519 million barrels) representing about 2% of total offshore oil production since 1975 of around 3 123 million tonnes (23 420 million barrels). Production peaked in the period 1996-1998 (Figure 2). Onshore gas production (including associated gas) is much smaller totalling about 9 bcm. Peak natural gas production onshore was almost 800 million m³ in 2000 (Figure 2), representing about 0.4% of total UK production.

The Wessex Basin with its large Wytch Farm oilfield in Dorset dominates onshore oil production (Figure 3a). Discovered in 1973, Wytch Farm has estimated reserves of 500 million barrels of oil. It is the largest onshore oilfield in Europe and ranks in the top 10 UK oilfields, including those offshore. Output from this field dwarfs production from the other onshore fields. Peak onshore oil production was some 5.3 million tonnes (39.8 million barrels) in 1996, of which some 4.7 million tonnes (35.3 million barrels) was from Wytch Farm. Excluding Wytch Farm, the East Midlands province is the most productive.

A similar picture emerges for gas production (Figure 3b), where onshore production is again dominated by the Wessex Basin Wytch Farm field with 5716 million m³. Excluding Wytch Farm, the East Midlands province is the most, with a total gas and associated gas production

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of 2 685 million m³. There is also important production from gasfields in NE England (842 million m³) and gas plus associated gas production from the oil and gasfields in the Weald (1 590 million m³).

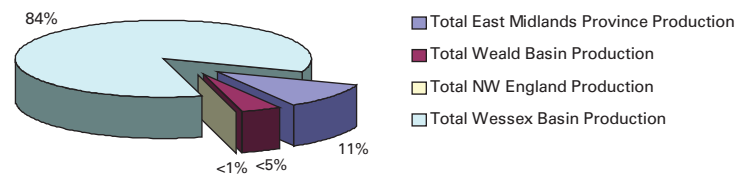
Oil exploration has continued around the UK with much success, but with the exception of Wytch Farm, onshore oil and gasfields are small by offshore standards. However, the capital expenditure required to develop them is also much smaller and they continue to provide economically attractive targets. They have made, and continue to make, a modest contribution to Britain's oil and gas requirements. Given the current high price of oil and gas, continuing activities onshore may be expected. DECC figures to the end of 2008, indicate that maximum UK oil reserves (including onshore fields) were estimated to be 1.13 billion tonnes of which only 0.4 billion tonnes was proven (greater than 90% chance of being produced). At the end of 2008, remaining gas reserves were estimated at 907 bcm, with proven reserves at 292 bcm.

Trade

Government figures published yearly (through the DUKES Energy reports) provide information on the production, import and export of petroleum (primary oils) and gas products in Britain. The UK's trade in fuels was dominated by imports until exports grew rapidly in the mid-1970s as production from the North Sea became established. The UK achieved a trade surplus in 1981, which, with the exception of 1989 when a small deficit was recorded as a result of the Piper Alpha disaster and the resulting safety works required, was sustained until 2004. The amount of surplus has varied, dipping in 1998–1999 and 2001 with the fall in the price of crude oil. Although in volume terms the UK became a net importer of fuels in 2004, in financial terms, the UK became a net importer of fuels in 2005, with a deficit on the balance of payments of £2.7 billion, compared to a surplus of £0.3 billion in 2004.

The UK has remained a net importer of fuels in both volume and financial terms since 2004 and in 2008 this balance of payments defi-

a) Total UK onshore oil production to end Oct 2010



b) Total UK onshore gas production to end Oct 2010

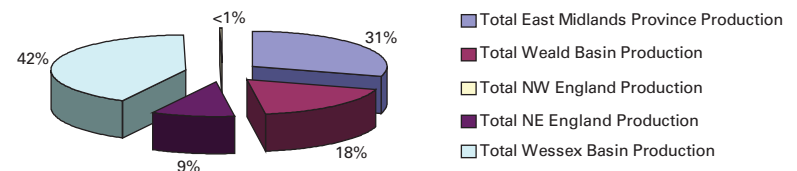


Figure 3 Total onshore oil (a) and gas (b) production by region to end October 2009.

Source: BGS (based on DTI and other published sources).

Note: This represents the gas production figures from the DTI for dry gas and associated gas for each onshore field, where available. (http://www.og.dti.gov.uk/pprs/full_production.htm). As such there may be natural gas liquids included

cit measured £12.9 billion. The UK's trading position for all fuels is clearly dominated by crude oil and petroleum products, reflected in a deficit for 2008 of £5.6 billion compared to a surplus of £0.9 billion in 2004. However, in 2008 the deficit doubled as the UK imported greater volumes of gas and the price of crude oil jumped from an average of \$70 per barrel in 2007 to a record of \$147 per barrel in 2008. Figures show oil prices fell back from the highs of mid 2008 to \$40–50 per barrel at the start of 2009, before commencing a steady rise during 2009 to reach around \$80 per barrel by the start of 2010.

Indigenous production will continue to decline, the result of which will be a further widening of the gap between exports and imports. Based upon proven and probable reserve estimates, Government (DECC) figures indicate that the

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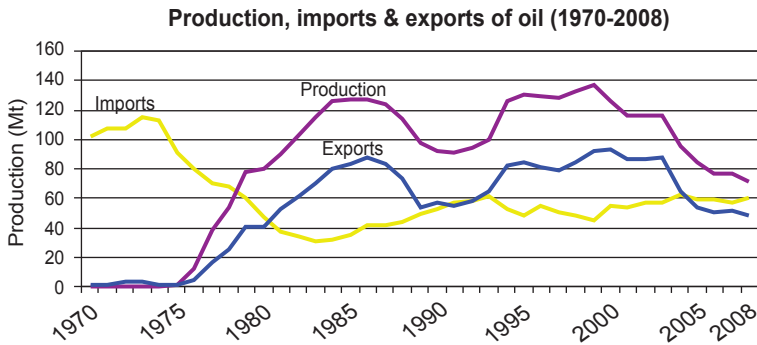


Figure 4 Production, imports and exports of primary oils between 1970 and 2008.

Source: DECC, Digest of UK Energy Statistics (DUKES report for 2009).

UK will be a modest net oil importer by 2010 and a much larger importer by 2020.

Between 1997 and 2003 the UK was a net exporter of natural gas, with a peak in production reached in 2000 (Figure 5). However, the major mature gasfields have shown an increasing decline in production and limited opportunities to find new, significant fields means that the UK once again became a net importer of gas in 2004, with imports having increased markedly since then. In 2005 total imports of gas accounted for nearly 10% of gas used. This rose sharply in 2008, as imports accounted for 26% of total natural gas supply. If the current trend continues, early Government forecasts of imports reaching 90% of consumption by 2020 may have to be revised to sometime earlier than that.

Imports of natural gas are provided by major new pipelines from the Norwegian sector of the

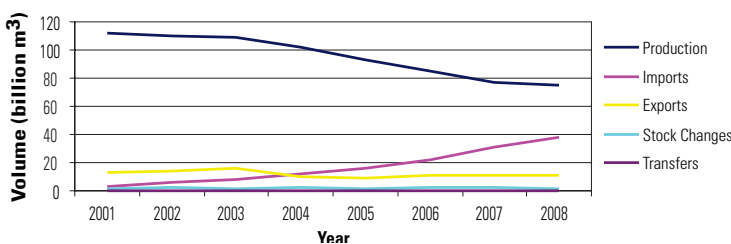


Figure 5 UK production, import and export figures for natural gas between 2001 and 2008.

Source: DECC (2009).

North Sea and from Balgzand in the Netherlands (December 2006) into Bacton on the east coast. In November 2005 the capacity of the Bacton-Zeebrugge interconnector also arriving into Bacton was almost doubled.

In July 2005, imports of liquefied natural gas (LNG) commenced at the Isle of Grain import facility. This was the first time LNG had been imported to the UK since the early 1980s.

Consumption

Oil and gas are the principal sources of energy consumed in the UK, with natural gas having become the most important source of energy in 1996 (Figure 6). The UK imports crude oil for various commercial, manufacturing and energy needs.

Deliveries of petroleum products to the UK markets in 2008, including those used by the UK refining industry as fuels within the refining process and all other uses totalled 76 Mt (570 mbbls). The total amount of oil products used by industry was declining in the mid-1990s as industry moved away from using oil as an energy source, although consumption increased again in the late 1990s to around 2004, before falling back (Figure 6). Electricity generators switched to natural gas fired power stations from that of coal- and oil-based generation during the 'dash for gas' in the mid-late 1990s. In 2008, petroleum products accounted for 33% and gas nearly 42% of the primary fuel for energy use.

Per capita consumption of crude oil and gas at around 1.3 tonnes and 1.6 tonnes (oil equivalent), respectively, is the highest for all minerals except primary aggregates. Gas was traditionally used for the domestic, industrial and commercial markets but since the early 1990s electricity generation has dominated growth in consumption and caused a rapid growth in the use of gas: as electricity generators switched from coal to gas fired power stations. There has been a continued increase from gas fired power stations between 2000 (39%) to 2008 (46%), largely replacing generation from nuclear and solid fuel sources. Electricity generation from oil is minor, having remained constant at around 1–2%.

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Natural gas offers higher generation efficiency and lower carbon dioxide emissions than conventional coal technology. In 2005 natural gas accounted for 39% of the primary fuel used in electricity generation, which by 2008 had risen to 46% (Figure 7). Figure 13 illustrates the share of gas consumption by main market sector. In 2008, 34% of natural gas demand was for electricity generation, whilst about 37% of natural gas demand was to households and public administration (including schools and hospitals). Industry consumed about 12%, with non-energy use (chemical feedstocks etc.) having accounted for about 1% of total gas demand.

Whilst onshore oil production, and particularly gas, is small there will be a ready market and continuing need for these minerals for the foreseeable future.

Economic importance

Oil and gas play a central role in the UK economy and the Government's energy policy is to ensure secure, diverse and sustainable supplies. The UK is a major producer of oil and gas, the total value of which was £36.2 billion in 2008, although the major proportion of this was from offshore fields. Onshore oil and gas production makes a small, but important, contribution to supply with the additional advantage of proximity to demand. The value of onshore oil and gas production was estimated at over £650 million in 2008. Of this some 90% was oil, (including natural gas liquids), mainly obtained from the Wytch Farm oilfield in Dorset.

The continued decline in indigenous primary oil production means the gap between exports and imports will continue to widen. However, primary oil exports will continue to make significant contributions to the UK economy. The estimated value of oil reserves stood at around £177.9 billion in 2008, up on the value in 2006, reflecting higher crude oil prices. The value of gas reserves stood at around £68 billion in 2008, down on 2006 values of £69.4 billion, but considerably up on the 1998 valuation of £25.4 billion.

Inland consumption of primary fuels and equivalents for energy use 1970-2008

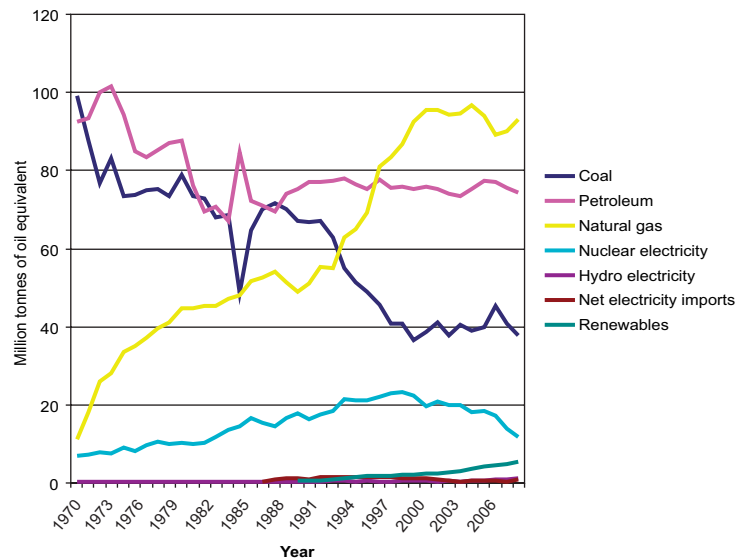


Figure 6 Inland consumption of primary fuels and equivalents for energy use in the period 1970–2008.

Source: DECC, Digest of UK Energy Statistics (DUKES report for 2009).

Structure of the industry

Major oil companies have, for many years, explored for and produced oil and gas onshore. However, since the 1980s with escalating costs and the smaller discoveries, they have gradually relinquished assets to smaller, more focussed independent operators who now dominate onshore exploration. These include

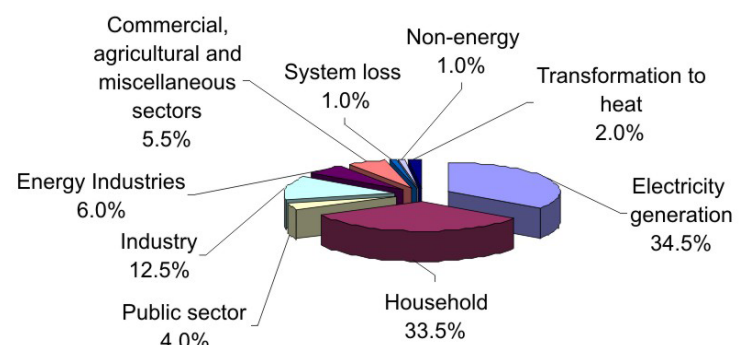


Figure 7 Gas consumption by main sector in 2008.

Source: DECC, Digest of UK Energy Statistics (DUKES report for 2009).

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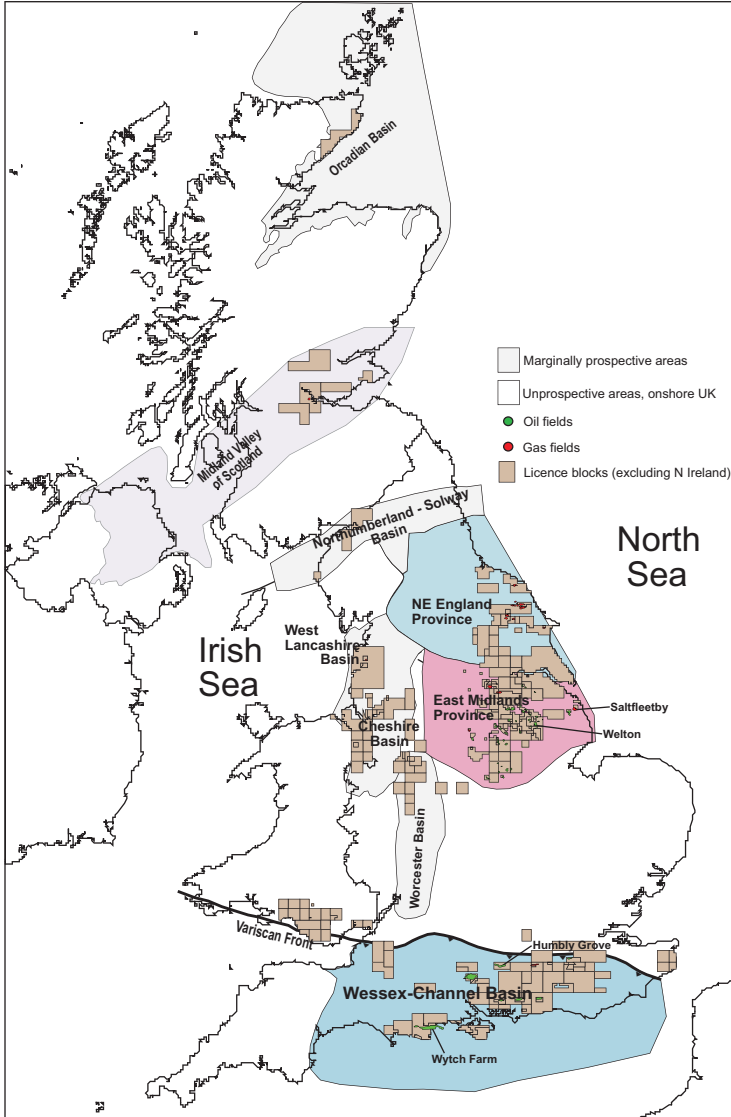


Figure 8 *Prospective onshore sedimentary basins, illustrating significant oil and gas fields and discoveries. Licence areas are as of January 2010 and also show areas of Coalbed Methane prospectivity.*

Note: licence blocks not shown in Northern Ireland. Source: BGS and DECC

Europa Oil & Gas, Rathlin Energy (UK) Ltd, Star Energy, Warwick Energy, Northern Petroleum and Egdon Resources who have developed large licence holdings in the various prospective areas onshore. A number of the produc-

ing oilfields (e.g. Gainsborough/Beckingham and Welton) have been sold by the major oil companies to smaller independent operators. BP, as the operator of the Wytch Farm and Kimmeridge Bay oilfields, is the only major left onshore.

The United Kingdom Onshore Operators Group (UKOOG) is the trade organisation for companies exploring for and producing crude oil and natural gas onshore in the United Kingdom.

Resources

Evidence of oil, both at surface and in mines and boreholes, is known in many areas of Britain. However, oil and gas have only been discovered and produced in commercial quantities from specific sedimentary basins onshore. These are where the required reservoir rocks and source rocks that gained adequate maturity were deposited and where trapping structures now exist (Figure 8). Large areas of the UK are not prospective for oil and gas due to the absence or lack of one or more of these. The productive basins have been explored for about 100 years and are now at a mature stage of exploration. Nevertheless, they continue to attract interest and large areas are licensed for exploration (Figure 8). With improving exploration technology modest onshore discoveries continue to be made.

The age of mature source and reservoir rocks, and the type of hydrocarbons found (oil or gas) varies, the most productive defining a number of 'provinces' or producing areas (Table 1). Many of these provinces are not entirely onshore, with the Wessex and Weald basins extending offshore into the English Channel. Similarly, the West Lancashire Basin is the eastern, onshore margin of the more extensive East Irish Sea Basin, and the East Midlands and Cleveland Basin link to the Southern North Sea Gas Basin. In Northern Ireland prospective Carboniferous and Permo-Triassic sequences occur beneath the Antrim basalts in the north east of the province. Here exploration continues but no commercial discoveries have, to date, been made onshore, although shows have been encountered in the near offshore areas.

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Province	Typical hydrocarbon occurrence	Typical Reservoirs	Source(s)	Trap type	Examples
Wessex-Channel Basin	Oil and gas	Bridport Sands, Great Oolite (Jurassic), Sherwood Sandstone Group (Triassic)	Lower Lias (clays Jurassic)	Tilted fault blocks & Palaeogene inversion anticlines	Oil: Wytch Farm, Kimmeridge, Humbly Grove, Stockbridge, Wareham Gas: Albury
East Midlands	Oil and gas	Silesian sandstones & fractured Dinantian limestones (Carboniferous)	Silesian (Carboniferous) mudstones and coals	Variscan anticlines and stratigraphic traps	Oil: Eakring, Welton, Rempstone, Scampton, Gainsborough Gas: Hatfield Moors and Hatfield West, Trumfleet, Saltfleetby
Yorkshire/NE England	Gas	Permian limestones (e.g. Upper Magnesian Limestones)	Silesian (Carboniferous) mudstones and coal	Mesozoic folds	Malton, Marishes, Lockton, Eskdale
NW England	Oil and gas	Sherwood Sandstone Group (Triassic)	Silesian (Carboniferous) mudstones and coals	Variscan anticlines, Stratigraphic – superficial deposits trapping oil	Oil: Formby Gas: Elswick
Midland Valley Scotland	Oil and gas	Silesian sandstones (Carboniferous)	Silesian (Carboniferous) mudstones and coals	Variscan anticlines	Oil: Dalkeith, Gas: Cousland

Table 1 Summary of the main hydrocarbon province characteristics and significant discoveries onshore UK.

Major oil and gas fields have been discovered and produced from the eastern parts of the Irish Sea but many of these are approaching depletion and some are being considered for gas storage purposes, e.g. the Bains gas field (Figure 8).

Midland Valley of Scotland

In 1937, Anglo American discovered the small Midlothian oilfield, which for a few years produced small amounts that were refined at Purfleet in Essex. Within a few months, D'Arcy Exploration, the forerunner of BP, made a gas discovery at Cousland along the same

structural trend as Dalkeith. BP later returned to the site and for a time produced gas for local use.

North West England

The Formby Oilfield was discovered by D'Arcy Exploration in 1939. The occurrence of oil had long been known in the vicinity, but the oilfield proved difficult to locate, being sealed by superficial deposits. The oilfield, which probably results from seepage of oil from a deeper accumulation, produced 10 200 tonnes (almost 76 500 barrels) of oil before being shut down in 1965. The only other success in the region was

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by British Gas with the discovery, in 1990, of the still operating Elswick Gasfield.

East Midlands Province

The East Midland oil province comprises a series of major Carboniferous rift basins, within which sequences containing important source and reservoir rocks were deposited during Namurian and Westphalian (late Carboniferous) times. Early exploration led to the oil discovery at Kelham in the 1920s, after which exploration continued into the 1930s as the need to ensure oil supplies during the Second World War grew. In June 1939 BP discovered the Eakring Oilfield, confirming the East Midlands as a major oil province. However, wartime censorship meant that no announcement was made until September 1944.

Historically, the East Midlands province, comprising Lincolnshire, Nottinghamshire and the northern part of Leicestershire, has been one of the most prospective areas for onshore oil and gas in Britain. It is an area that has been subjected to only minor folding or tilting and faulting in post-Mesozoic times, such that hydrocarbon accumulations emplaced in post-Carboniferous times have not been greatly disturbed.

Since 1939, many important discoveries have been and continue to be made, including Gainsborough/Beckingham, Welton, Saltfleetby and Keddington. However, many of the older fields such as Eakring, Bothamsall, Egman-ton and Kelham Hills are now shut down due to exhaustion of recoverable reserves and increasing water production. One or two oil discoveries have yet to be developed, including those of Broughton and Brigg. The current trend is for small focussed operators to identify smaller satellite structures to the main producing fields. Consequently large parts of the East Midlands are licensed. Cumulative output of oil in the East Midlands is some 8.6 million tonnes with the cumulative output from individual fields being in the range from a few thousand tonnes up to about 2.4 million tonnes. Total gas production is about 2.7 bcm.

The Hatfield Moors Gasfield, near Doncaster, is the first onshore hydrocarbons field to become

depleted and its use changed to that of a gas storage facility. The field was converted to storage operations in 2000.

Wessex-Channel (including the Weald) Basin

This prospective basin covers the Weald and Wessex areas in southern Britain, across which, oil and gas occurrences have long been known. Prospective sequences also extend offshore beneath the English Channel. A number of oil seeps have been documented inland, but most occur along the Dorset coast, from near Osmington in Weymouth Bay to Durlston Head and include the famous Mupe Bay oil seep and the occurrences of gas bubbling on the seabed between Durlston Head and Anvil Point. Many oil and gas seepages are also known from East Sussex, the first discovery of which was in a water well being excavated in 1836. Similar discoveries led to the formation of a company in 1902 to develop and supply the gas to local markets at Heathfield, Polegate and Eastbourne.

These oil and gas seepages and occurrences provided the early impetus for exploration in the area. Though results were initially disappointing, the Kimmeridge Oilfield was discovered in 1959 and is still producing today. Continuing exploration led to the discovery of the giant Wytch Farm Oilfield in the early 1970s. Production from this field has dominated onshore oil output. Ten other oil and gasfields have subsequently been discovered in the Wessex-Channel Basin.

Cumulative output of oil in the Wessex-Channel Basin province is some 61.5 million tonnes, with the contributions of individual fields being in the range from a few thousand tonnes to that of the giant Wytch Farm Field (57.3 million tonnes). Total gas production is about 5.4 bcm, again dominated by production from Wytch Farm (3.7 bcm).

The Wessex-Channel Basin province contains the second onshore hydrocarbons field to become depleted and its use changed to that of a gas storage facility: the Humbly Grove Oilfield. The field was converted to storage operations in 2004, beginning storage in 2005. Other fields, such as Albury, are now depleting rap-

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idly and are being considered for underground gas storage purposes.

North East England (including the Cleveland Basin)

In 1937 BP and ICI drilled at Eskdale and tested gas from the Permian Upper Magnesian Limestone. The field was developed in 1960 and the gas fed into the town gas system in the Whitby area until it was shut down in 1967. Subsequently, a number of other gasfields have been discovered along an E-W structural trend. The gas originates from Carboniferous (Westphalian) Coal Measures and has been trapped in fractured Permian limestones to create the now closed Eskdale and Lockton gasfields and the still producing Malton, Kirby Misperton, Marshes and Pickering gasfields.

Total gas production from the NE England region is about 14.3 million cubic metres.

The Caythorpe Gasfield is now depleted and, following a Public Inquiry, the operators (Warwick Energy) gained planning permission to convert it to gas storage purposes.

Reserves

DTI estimates are that at the end of 2009 total UK proven reserves of oil stood at 533 million tonnes (3998 million barrels). Of this the contribution from onshore reserves was approximately 15.2 million tonnes (113.8 million barrels) or less than 3% of the total. Table 2 shows the remaining

recoverable reserves in those onshore fields for which data are available. However, it should be noted that the output of some onshore fields has been much more than originally assessed.

Exploration and extraction

Onshore oil and gas are found in reservoir rocks at depths generally between 800 and 1200 m and are extracted through boreholes. Some reservoirs may be at shallower depths, for example, 300–400 m below sea level at Hatfield Moors in South Yorkshire.

Hydrocarbon exploration utilizes the highly sophisticated geophysical methods to detect and determine the extent of likely deposits. The main tool used by exploration companies to assess prospective areas is reflection seismic surveying. This technique images subsurface strata and structures and identifies those likely to entrap oil and/ or gas. It works on the principle of sending a sound wave into the ground, which is reflected back at major rock boundaries and recorded by geophones at the surface. Onshore, seismic information is acquired as long 'lines', generally along roads (but they can cross fields) that form an interlocking grid of data. Sound waves are generated using vehicle-mounted vibration pads (a method commonly known as 'vibroseis' - Figure 9) and their reflections from the subsurface are collected by strategically-placed cable-linked geophones. Although the time spent and disturbance at one spot is minimal (survey vehicles will cover

Oil Province	Remaining recoverable reserves (barrels)	Remaining recoverable reserves (tonnes)
Wyth Farm	70 247 825	9 366 377
Wessex Basin, excluding Wyth Farm	68 437	9 125
Weald Basin	11 293 460	1 505 795
East Midlands	21 927 470	2 923 663
North West	N/A	N/A
Total:	103 537 193	13 804 959

Table 2 Estimated remaining recoverable onshore reserves by producing area at end 2009.

Note: this table only reflects the data for those fields with published initial reserves estimates.

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Figure 9 Vehicle mounted vibration pads ('vibroiseis') are generally used for onshore seismic surveys for oil and gas.

several kilometres in one day), survey lines are required to avoid buildings and underground infrastructure.

Following acquisition, the seismic reflection data are processed and time slices representing the subsurface geology are produced. These images are interpreted to produce maps of the subsurface layers, which are depth-converted and provide information on of the sub-surface geology from which large scale features (leads/prospects) with potential as hydrocarbon traps may be identified. Further, more detailed seismic surveys may be needed before the prospect is drilled to ultimately prove the presence (or not) of oil and gas.

If this process identifies structures which may contain commercial quantities of hydrocarbons,

an exploration well is drilled in an attempt to conclusively determine the presence or absence of oil or gas. Oil drilling rigs are generally capable of drilling through several thousand metres of rock. They require a power source to rotate the drill and drive the pumps needed to circulate drilling mud (slurry) through the drill bit and well casing to cool and remove the rock cuttings while a well is drilled. Hoists in the rig can lift hundreds of tons of pipe. Onshore drilling is a short lived but intensive activity which may carry on 24 hours per day.

If an exploration well encounters significant hydrocarbon and if, following further testing, a commercial appraisal is successfully completed, then a development may move into production. This may involve drilling additional wells. Various processes are used to prolong the productive life of an oilfield and production in the UK.

Primary recovery occurs in two stages: 1) the oil flows to the surface through natural reservoir pressure and 2) following initial flow and after the natural pressure is depleted, oil is pumped to the surface often using the familiar beam pumping units, commonly referred to as 'nodding donkeys'. About 10% of the reservoir's original oil in place (OOIP) will be extracted at this stage.

Secondary (enhanced) recovery refers to simple water flood to displace and drive out remaining oil, or reservoir pressure maintenance through re-injection of natural gas often produced at the same time as the oil. Water or gas is injected as a continuous force to the reservoir formation to maintain reservoir pressures (and thus drive). Many oilfields now routinely inject sour gas (containing a proportion of H₂S) back into the reservoir to enhance oil recovery. A growing option is the injection of gases such as nitrogen and CO₂. These dissolve in the oil, lowering its viscosity and increasing the mobility. This stage may increase oil recovery to 20% of the OOIP.

Elsewhere in the world, a third (Tertiary) stage of enhanced oil recovery may be carried out, offering the prospect of recovering 30–60% of the OOIP. This is more expensive and less con-

ventional techniques are employed, including thermal recovery (steam injection), chemical injection to increase the effectiveness of water flood or the use of detergents.

Processing

Crude oil is essentially a mixture of hydrocarbons with varying molecular weights and differing from one another in structure and properties. These various species are separated into groups, or fractions, by a process of distillation called oil refining. The oil is first heated to a vapour, then passed upward through a tower containing trays at various levels. The vapours are very hot at the bottom, but become cooler as they rise, so that different fractions condense in the trays at different heights. The lighter the fraction the higher it condenses. In an average crude oil the fractions, beginning with the lightest, are: (1) dissolved gases, (2) petroleum ether, (3) gasoline, (4) kerosene, (5) gas oil, (6) lubricating oils, (7) fuel oils, and (8) asphalt.

Further breaking down of the larger heavier molecules of the heavier fractions to produce lighter fractions can be achieved in a process called 'cracking', whereby these fractions are subjected to higher temperatures and pressures or a chemical catalyst.

Catalytic reforming is an important refining process where a catalyst (generally platinum or a platinum-rhenium mix) is used to generate high octane gasoline blending components (reformates) from low octane naphthas (e.g. parafins and olefins).

At the end of 2008 nine major and three minor refineries were in operation in the UK. The UK's crude oil refining (distillation) capacity stands at approximately 91 million tonnes (682.5 million barrels) per year, somewhat higher than the country's consumption. Total UK reforming capacity at end 2008 was 14.3 million tonnes (107.3 million barrels), while cracking and conversion capacity stood at 37 million tonnes (277.5 million barrels). About 80% of UK output by weight is in the form of lighter, higher value products, such as petrol, DERV and jet kerosene.

Most natural gas requires very little processing prior to use. However, in some cases components called natural gas liquids, such as propane, are extracted from the gas before it is transported or delivered to the consumer. Some natural gases (sour gas) contain hydrogen sulphide, which has to be removed before it can be transported and used.

By-products

Although a wide range of products may be produced during the oil refining process, there are no by-products of oil and gas production in the UK. If sour gas were encountered, the hydrogen sulphide would have to be removed giving rise to sulphur, potentially an important chemical feedstock.

Alternatives and recycling

Alternative fuels are available for electricity generation, the most important in the UK being coal, nuclear power and renewable energy sources, such as hydroelectricity and wind power. However, natural gas is a favoured fuel for electricity generation because it has a lower sulphur content than coal and produces lower carbon dioxide emissions per unit of electricity produced. It is prudent to assume that Britain will continue to be dependent on oil and gas as its main sources of primary energy for the foreseeable future. There are few currently commercial alternatives to petroleum-derived products for transportation although the development of hybrid and electric vehicles is advancing rapidly.

Alternative fossil fuels, sometimes also known as 'unconventional hydrocarbons' may present a viable partial replacement for the natural gas from 'conventional' onshore reservoirs described elsewhere in this factsheet. These alternatives fall into three distinct types. The first is methane from coals including gas recovered from active and abandoned mines, as well as methane recovered from undisturbed coal seams (usually known as coalbed methane). Gas from these sources is already produced on a modest scale in the UK and exploration is ongoing for further prospects. The second unconventional source is shale gas, which

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is natural gas recovered from mudrocks and shales which have previously been considered too impermeable to allow economic recovery of gas. Although there is not yet any production of shale gas in the UK, there is some exploration activity. The third unconventional source of gas involves combustion of underground coal seams in situ to produce synthetic gas ('syngas'). This process is usually known as 'underground coal gasification' (UCG). There are currently no UCG operations in the UK. These alternative gas sources are covered in a separate 'Alternative Fossil Fuels' Mineral Planning Factsheet.

With time, oil and gas fields are depleted and reservoir pressures decrease as hydrocarbons are removed and less of the pore space is occupied by hydrocarbons. To maintain reservoir pressures, water and gases, including natural gas and CO₂ can be injected to aid oil recovery. With the need to capture and safely store greenhouse gases such as CO₂, depleted oil and gas fields could be used to store significant quantities in the future (see Mineral Planning Factsheet on 'Underground Storage'). Depleting oil and gas fields are also increasingly being considered for the storage of natural gas.

Effects of economic instruments

There are no fiscal measures that are aimed specifically at onshore oil and gas production.

Transport issues

Oil is generally pumped to the surface for short-term storage and is then transported via lorry, rail or, as in the case of Wytch Farm, pipeline to refineries in the UK. In some places oil produced at small satellite fields is piped or taken by road tanker to gathering stations for onward transfer to refineries by road or rail.

Gas is more readily transported and used. It may be used directly on site to generate electricity for the National Grid or piped to a remote generating station. The gas from the major onshore gas discovery at Saltfleetby is taken by pipeline to Theddlethorpe and thence into the National Transmission Sys-

tem (NTS), which supplies gas direct to users and storage facilities around the country via pipeline.

Regulation

Licensing of oil and gas exploration and development

The Petroleum Act 1998 (the '1998 Act') vests all rights and ownership of the petroleum resources (oil and gas) of Great Britain and the United Kingdom territorial waters in the Crown. The Secretary of State for Trade and Industry grants licences to persons that confer exclusive rights to 'search and bore for and get' these petroleum resources. DECC (formerly DTI) has a fairly regular timetable of offshore licensing rounds and generally one onshore licensing round per year. Licences are awarded to those bids promising to optimise the exploitation of the UK's petroleum resources.

The main objectives of the licensing regime are to secure the comprehensive exploration and appraisal of UK oil and gas resources and the economic development of discovered reserves. The rights granted by landward licences do not include any rights of access, and the onus is upon the licensee to obtain all the relevant authorisations and planning permissions from the respective authorities and landowners.

As a result of a long history of legislation several types of onshore licence exist. To simplify things, the DTI in 1996 commenced the issue of Petroleum Exploration and Development (PEDL) Licences at the 8th Licensing Round. These carry a three-term lifetime: a six-year Initial Term allows completion of an agreed Work Programme, which is a precondition of entry into the five-year Second Term. Successful completion and approval of a development plan is a precondition of entry to the Third Term for production, which is granted for a period of 20 years, although the Secretary of State has the discretion to extend this period if production is continuing.

Following the announcement of a new round of licensing offers, applications are made for a PEDL over unlicensed areas ('blocks') which correspond to the 10 km by 10 km Ordnance

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Survey grid. Many licences cover more than one 'block'.

Licencees are entitled to surrender a Licence, or part of the acreage covered by it, at any time after the Initial Term and the Work Programme have been completed, with a minimum relinquishment required at the end of the Initial Term.

Northern Ireland issues its own licences to cover its onshore area and these are granted by the Department of Enterprise, Trade and Investment, Energy Division.

When issuing licences EU Member States are now required to follow strict rules laid down in 1994 (*Hydrocarbons Licensing Directive 94/22/EC*). These rules were implemented in the UK in 1995 by means of the Statutory Instrument *Hydrocarbons Licensing Directive Regulations 1995 (Nos 1434)*.

Planning issues

National policy

In England, planning policy for land-based exploration, appraisal, development and extraction of oil and gas is set out in Mineral Policy Statement 1: Annex 4. Onshore oil and gas in England. In Scotland, planning policy for onshore oil and gas is set out in Scottish Planning Policy. Mineral Planning Policy Wales sets out the planning framework for onshore oil and gas in Wales.

Relationship with environmental designations

A number of the main onshore hydrocarbon provinces, and notably the Wessex and Weald provinces, are coincident with major environmental designations including National Parks and AONBs. The Wytch Farm oilfield development facilities are wholly located within the Dorset Area of Outstanding Natural Beauty (AONB) and the oilfield underlies areas designated as Heritage Coast, as Ramsar sites and as Special Areas of Conservation (SAC) and Special Protection Areas (SPA) as well as other national and local designations. Under some circumstances, deviation well drilling can enable recovery of oil/ gas at a considerable distance from the wellhead. This sometimes allows extraction sites (the wellhead) and associ-

ated works (water injection facilities, railheads, gathering stations) to be moved, within limits, to less sensitive locations.

Exploration by seismic investigation

Exploration for oil and gas almost always begins with seismic investigations to identify 'prospective' geological structures which may contain oil and/ or gas. This is a temporary activity and generally has very limited environmental effects. Most MPAs regard such work as either 'not development' or as permitted development. However, for such types of surveys, Government require that a Petroleum Operation Notice (PON) form (14b: Notification of intention to carry out onshore (landward) geophysical surveys) is submitted and proposals should also be discussed with the MPA and relevant statutory agencies.

Exploration drilling

If seismic surveys identify geological structures which are prospective, the only way to firmly establish if oil or gas is present is to drill a borehole. Oil and gas exploration drilling is a major undertaking which requires planning permission. Applications for consent to drill exploration, appraisal, and development wells also requires completion of the PON4 form through the DECC WONS (Well Operations Notification System). Specific issues associated with drilling may include visual intrusion, noise, lighting, traffic on local roads and the round-the-clock nature of the operations. Potential pollution from drilling fluids and any oil finds needs to be mitigated by adequate pollution prevention facilities on site, although no UK productive oilfield has ever encountered oil under sufficient pressure to raise concerns about a major pollution event during exploration drilling. An exploration borehole site may require an area of around 1 hectare. Historically, an average of one in ten exploration wells will prove hydrocarbons and perhaps only one in thirty will find commercially viable accumulations. Thus, even where hydrocarbons are found, development may not necessarily follow.

Duration of exploration activity

Exploration drilling operations are generally of quite short duration (less than one month), although work to prepare the site beforehand

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and restore after drilling has ceased may extend this time period significantly. If hydrocarbons are found in economic quantities, then additional appraisal wells may be necessary to delineate the extent of the accumulation. It may be possible to sink these wells from the existing exploration site using deviated drilling techniques, although outlying appraisal well sites may also be required. These activities are likely to extend the duration of activity at the sites in question.

Location and scale of production development

Production operations will generally use existing exploration well sites. Some of the planning issues associated with production may have been resolved as a result of the previous permitting process for exploration drilling. Under some circumstances, deviation well drilling can enable recovery of oil/gas at a considerable distance from the wellhead. This sometimes allows extraction sites and associated works to be moved, within limits, to less sensitive locations (see above). Issues relating to noise, lighting and traffic are similar to those from more standard industrial developments. Pollution control measures will be required to mitigate the potential impacts of oil spillage.

Storage and transport

Small fields may require storage facilities on site, with road tankers transporting the product to refineries. Larger fields may require additional wellhead sites linked by pipelines. A gathering station, storage tanks and transport links may be necessary where a number of well sites are developed in a locality or to deal with the products from a number of fields and, if of sufficient size, pipelines or a railhead may be required to transport the product.

Further information

Planning and minerals. Minerals Policy Statement 1, Annex 4. Oil and gas in England. Department for Communities and Local Government. November 2006. <http://www.communities.gov.uk/documents/planningandbuilding/pdf/152993.pdf>

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The Department for Energy and Climate Change (formerly DTI) website contains background and detailed information on UK onshore oil and gas <https://www.og.decc.gov.uk/information/onshore.htm>

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Mineral Planning Factsheets for a range of other minerals produced in Britain are available for download from www.mineralsUK.com

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