Office for National Statistics

Statistical bulletin

Scottish natural capital: Ecosystem Service Accounts, 2019

The Scottish natural capital Ecosystem Service Accounts, highlighting the value and benefits of Scotland's natural assets. These are Experimental Statistics.

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1 . Executive summary

This article presents 10 service accounts, containing estimates of the quantity and value of services being supplied by Scottish natural capital.

These services are:

- agricultural biomass
- fish capture
- timber
- water abstraction
- mineral production
- oil and gas production
- renewable energy generation
- carbon sequestration
- air pollutant removal
- recreation

This article uses the term “ecosystem service” throughout, which generally refers to living (biotic) components of the Earth, which provide services to humanity. However, non-living (abiotic) components, such as oil and gas used for energy, are also included in this release. A summary of the main trends is presented in this article, but more information can be found in the datasets accompanying this release.

2 . Main points

- In 2015, the partial asset value of Scottish natural capital was estimated to be £273 billion, 34% of the UK asset valuation.
- A quarter of the asset value was attributable to non-material benefits not directly captured in gross domestic product.
- In 2017, oil and gas production in Scotland more than halved from 1998 levels.
- Fish capture in Scottish waters rose by over two-thirds between 2003 and 2016.
- Scottish timber production nearly doubled from 1997 to 2017.
- During 2017, water abstraction for public water supply in Scotland fell to its lowest level in the series history (2002 to 2017), partly due to less leakage.
- In 2017, five times as much energy was produced from renewable sources in Scotland than was produced in 2000.
- Renewable sources contributed 52% of Scottish electricity generation in 2017, up from 12% in 2004.
- The removal of PM2.5 from the atmosphere by Scottish vegetation led to overall avoided health damage costs of £52.3 million during 2017.
- Between 2009 and 2017, annual outdoor recreation time spent per person was 56 hours (65%) higher in Scotland than the UK average.
- Average spend per visit on outdoor recreation in Scotland was £1.14 between 2009 and 2017, which was 43% lower than the UK (£1.99).

3 . Collaboration

This article was produced for the Scottish Government by the Office for National Statistics. The article is available from both the Office for National Statistics and the Scottish Government. Office for National Statistics natural capital accounts are produced in partnership with the Department for Environment, Food and Rural Affairs (Defra). Further details about the natural capital accounting project are also available.

4 . Introduction

Nature provides the basic goods and services that make human life possible: the food we eat, the water we drink and the plant materials we use for fuel, building materials and medicine. The natural world also provides less visible services such as climate regulation, the natural flood defences provided by forests, removal of air pollutants by vegetation, and the pollination of crops by insects. Then there is the inspiration we take from wildlife and the natural environment.

This article includes natural capital assets, the flows of services and the values of those services. These terms help us to think logically about what aspects of the natural world we are measuring and how they impact on people.

Natural capital assets are the things that persist long-term such as a mountain or a fish population. From those assets people receive a flow of services such as recreational hikes on the mountain and fish captured for consumption. Finally, we can value the benefit to society of those services by estimating what the hikers spent to enable them to walk over the mountain or the profit to the fishermen of bringing the fish into the market. Applying this logic consistently across assets and services enables us to start building accounts of the value provided by nature.

The benefits we receive from nature are predominantly hidden, partial or missing from the nation's balance sheet. However, by recognising nature as a form of capital and developing accounts of natural capital's contribution to the economy and our well-being, decision-makers can better include the environment in future policy planning.

The development of natural capital accounts has been flagged by the Natural Capital Committee and the UK National Ecosystem Assessment as a fundamental activity that is necessary if natural capital is to be mainstreamed in decision-making.

There has also been strong international momentum to develop natural capital accounts. The UN System of Environmental-Economic Accounting (SEEA) is the main source of technical guidance and sharing of experiences, the principles of which these accounts are built upon. The World Bank's wealth accounting WAVES project is looking to implement ecosystem accounting in a range of partner countries. In 2010 at Nagoya, 193 countries agreed to a strategic target to incorporate the values of biodiversity into national accounting and reporting systems by 2020 (subsequently referred to in the Sustainable Development Goals).

In 2011, the Department for Environment, Food and Rural Affairs (Defra) committed to working with the Office for National Statistics (ONS) to measure the value of UK natural capital (see Natural Environment White Paper, June 2011). Since then, the ONS has collaborated with Defra to develop innovative methods to measure this strand of economic statistics, with an objective of including UK natural capital estimates in the UK Environmental Accounts by 2020.

Natural capital accounts include stock accounts of specific habitats and flow accounts of services. Both physical (non-monetary) accounts and monetary valuations are presented as a time series to monitor change over time. Monetary valuations of natural capital begin to reveal the value of benefits provided by nature.

Where available, estimates are presented between the period 1997 to 2017 and all monetary valuations are given in 2017 prices deflated using the HM Treasury June 2018 GDP deflators. Valuations were developed under the principle of comparability with the 1997 to 2015 UK Ecosystem Service Accounts and consistency between individual ecosystem services. It is recognised that the UK accounts remain experimental and future UK publications will be subject to methodological improvements over time. Ecosystem service valuations offer comparative analysis across services whereas physical flows provide information about the changes over time independent of price changes.

The services are presented by type, which include provisioning, regulatory and cultural. Types of service are defined at the beginning of each section.

All estimates are experimental and are subject to adjustment and improvement as the natural capital accounts are developed. A number of ecosystem services are not being measured in this article so the monetary accounts should therefore be interpreted as a partial or minimum value of Scottish natural capital.

5 . Provisioning services

Food, water, and materials produced by nature and consumed by society are known as provisioning services.

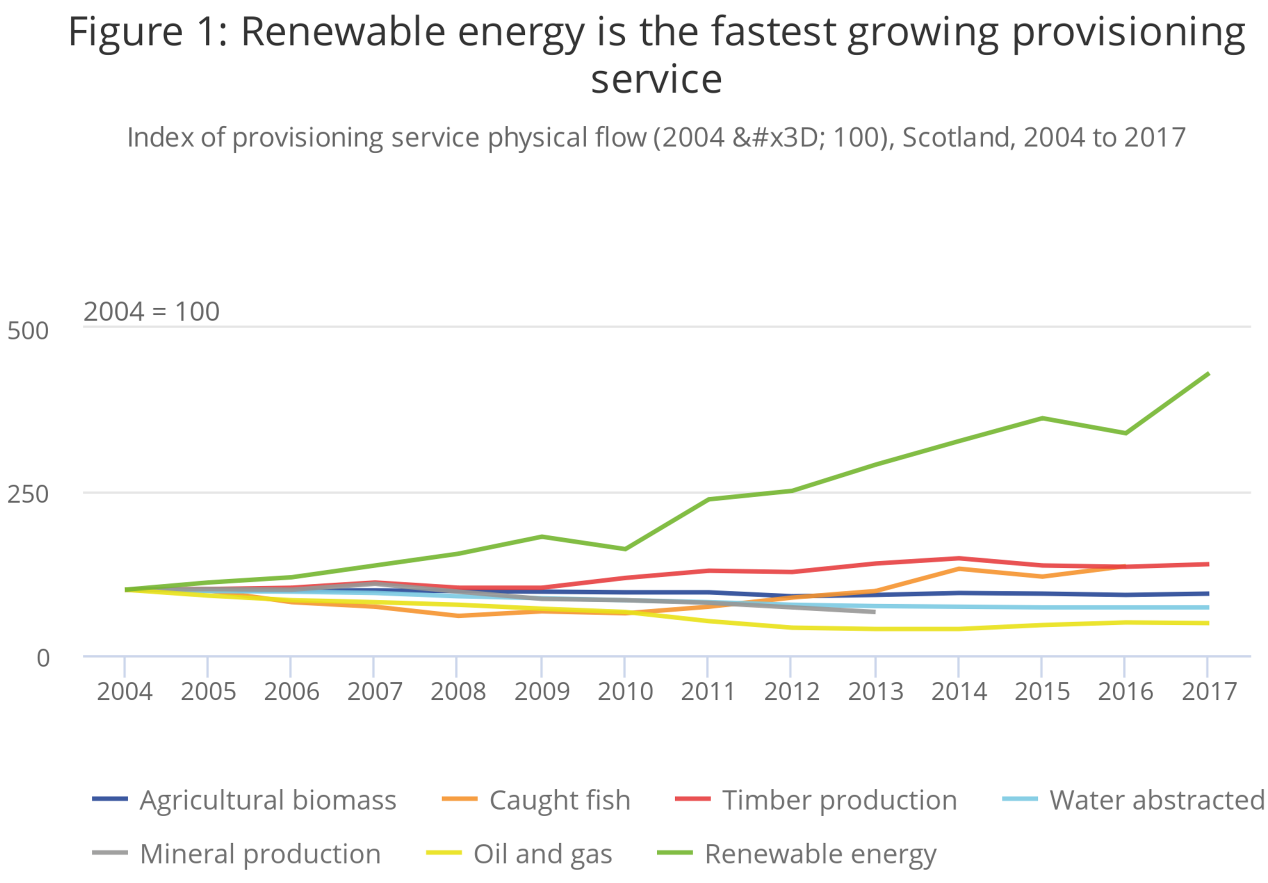
Provisioning services currently included in the Scottish Ecosystem Accounts are:

- agricultural biomass
- fish caught
- timber
- water abstraction
- minerals
- oil and gas
- renewable energy

Figure 1 presents an index of the physical flows of these services.

Figure 1: Renewable energy is the fastest growing provisioning service

Index of provisioning service physical flow (2004 = 100), Scotland, 2004 to 2017

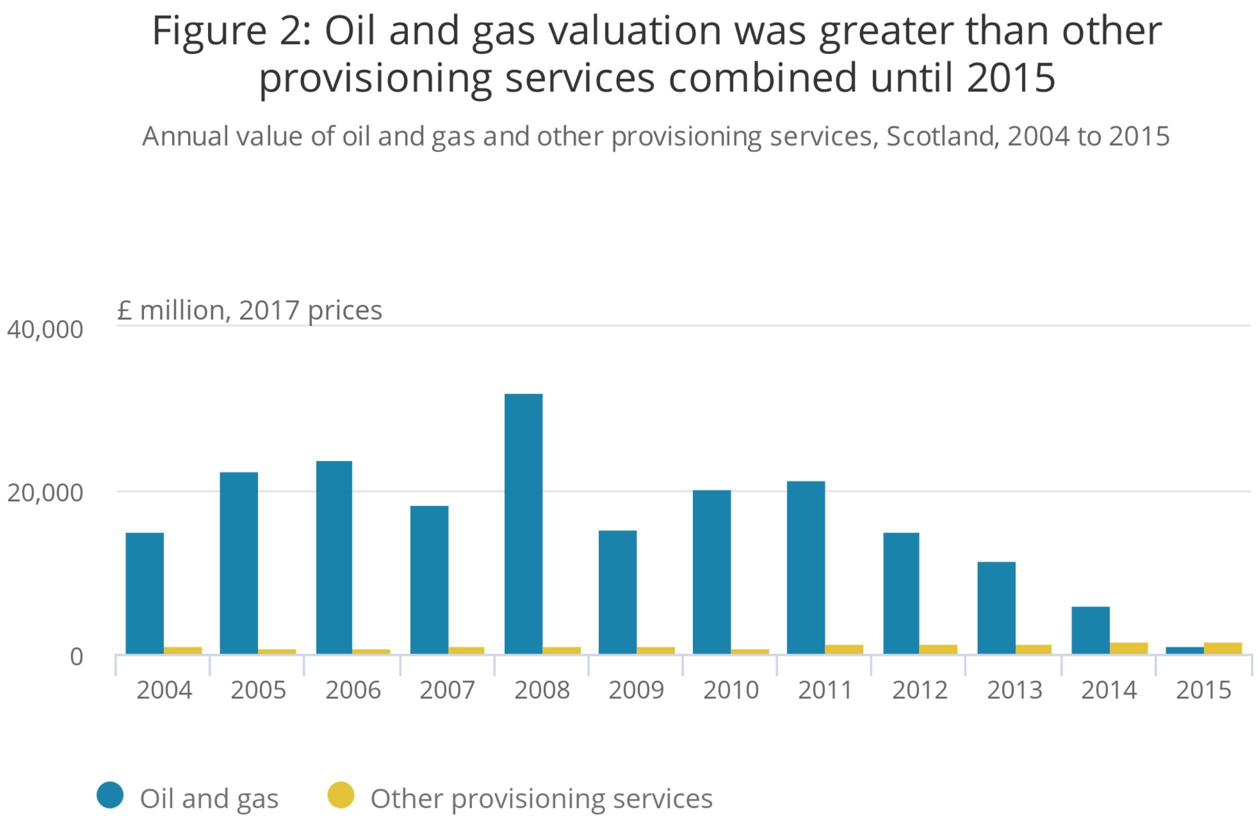


Source: Office for National Statistics, Scottish Government, European Commission: Scientific, Technical and Economic Committee for Fisheries, Forestry Commission and Scottish Water

Figure 2 and Figure 3 show a time series of the annual valuation for the provisioning services. In 2004, oil and gas represented 92.8% of the provisioning service valuation. This decreased to 41.5% in 2015.

Figure 2: Oil and gas valuation was greater than other provisioning services combined until 2015

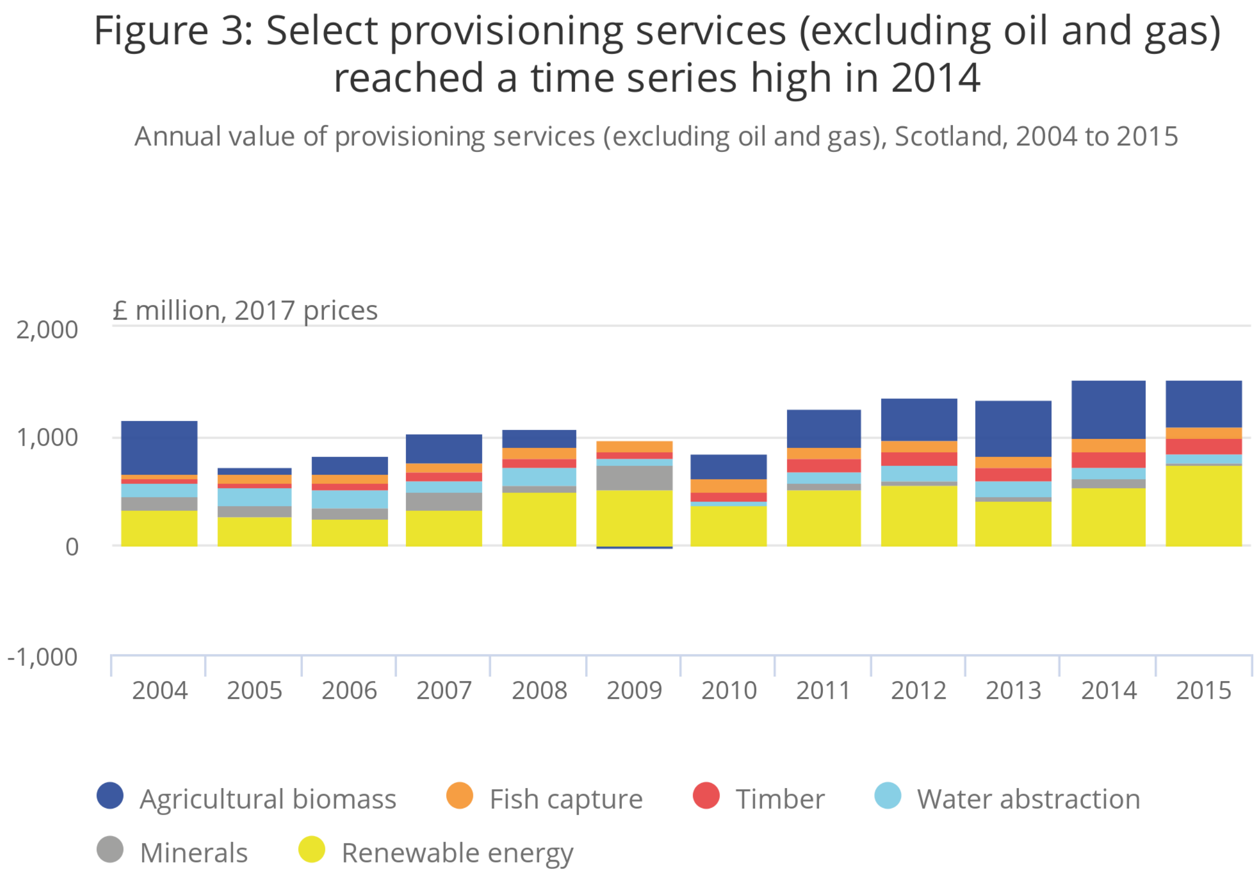
Annual value of oil and gas and other provisioning services, Scotland, 2004 to 2015



Source: Office for National Statistics, Scottish Government, European Commission: Scientific, Technical and Economic Committee for Fisheries, Forestry Commission and Scottish Water

Figure 3: Select provisioning services (excluding oil and gas) reached a time series high in 2014

Annual value of provisioning services (excluding oil and gas), Scotland, 2004 to 2015



Source: Office for National Statistics, Scottish Government, European Commission: Scientific, Technical and Economic Committee for Fisheries, Forestry Commission and Scottish Water

Notes:

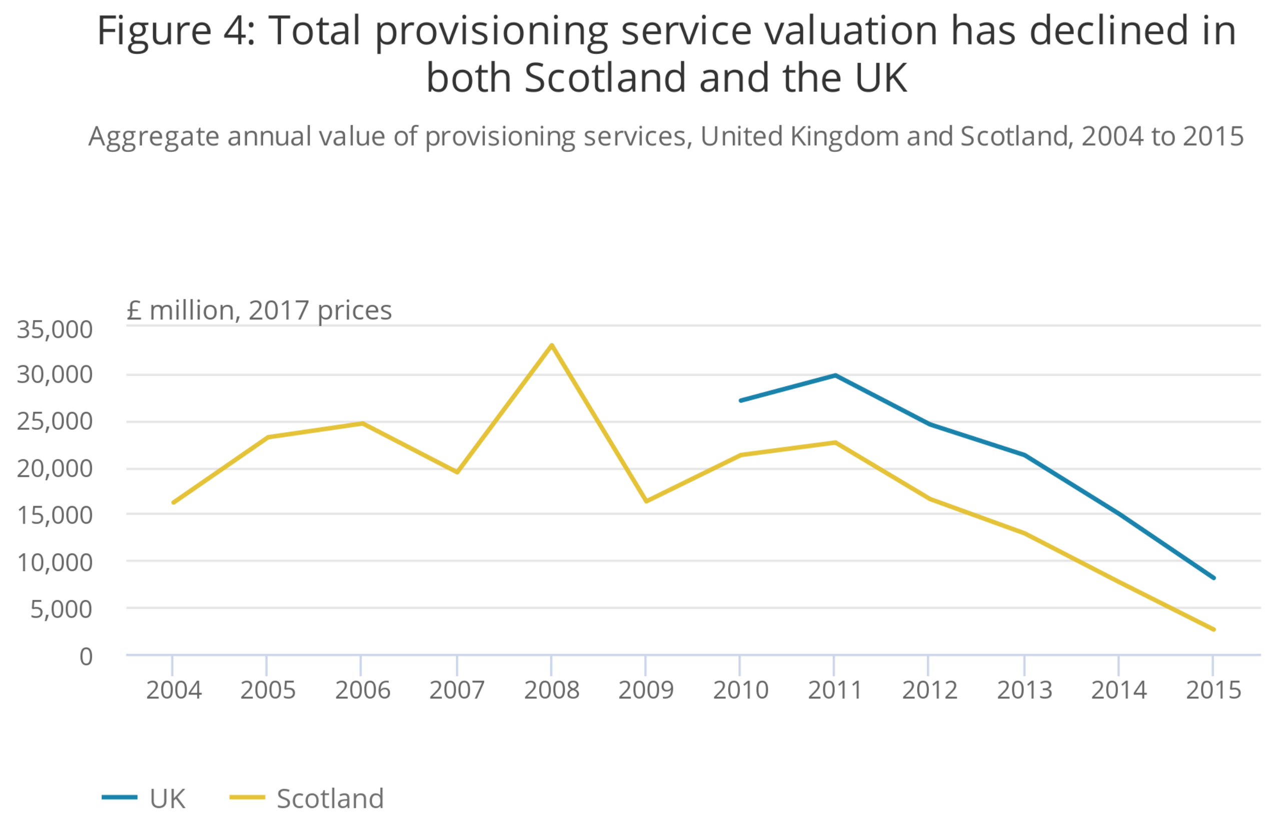
1. Where an annual service valuation is zero or negative it does not appear in the chart.

The total value of provisioning services in Scotland has decreased 87.8% between 2010 and 2015, compared with the value of services for the UK as a whole, which decreased 75.9% for the same period (see Figure 4).

This decrease has primarily been driven by the declining valuation of the oil and gas service, resulting from declining production, which decreased in Scotland and the UK by 94.7% and 94.6% respectively between 2010 and 2015. The decline in the valuation of oil and gas over this period can be attributed to falling income, due to production and general price decline, and increasing costs.

Figure 4: Total provisioning service valuation has declined in both Scotland and the UK

Aggregate annual value of provisioning services, United Kingdom and Scotland, 2004 to 2015



Source: Office for National Statistics and Scottish Government

Agricultural biomass

Farmed animals are not included in these estimates as they are seen as produced rather than natural assets, instead the grass and feed that livestock eat are regarded as ecosystem services and so are included.

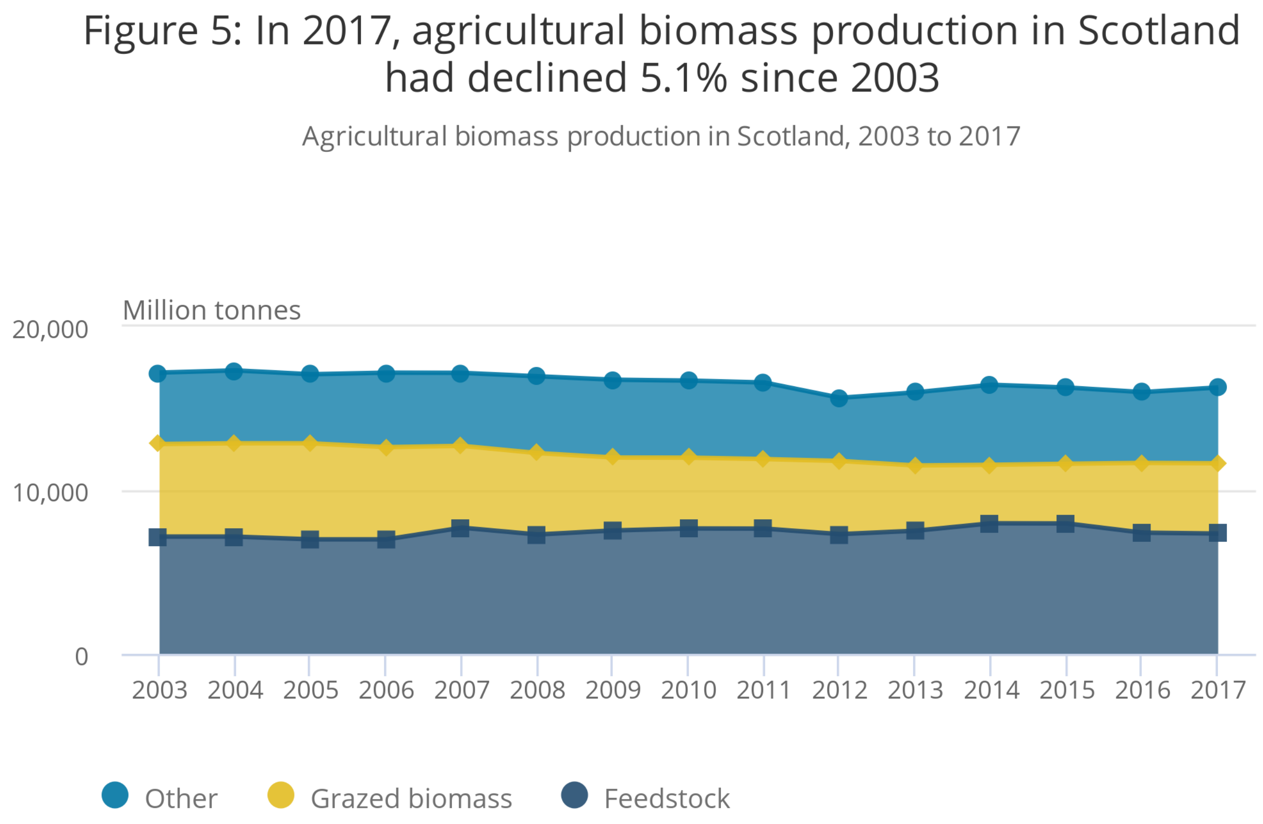
Agricultural biomass relates to the value of crops, fodder and grazed biomass provided to support agricultural production in Scotland. The overall volume of agricultural biomass produced in Scotland decreased from 17.20 million tonnes in 2003 to 16.32 million tonnes in 2017, equivalent to a 5.1% reduction.

This was primarily caused by a fall in the production of grazed biomass (animals consuming from the land), which dropped by 31.9% between the years 2003 and 2017. Looking at the results from the Scottish Agriculture Census , livestock in Scotland (cattle, sheep, pigs) declined over the period 2006 to 2016, which caused a fall in grazed biomass.

Agricultural biomass has generally declined year-on-year since 2003 (see Figure 5), with increases observed in 2013, 2014 and the latest year 2017. All elements of agricultural biomass rose in 2017, except for fruit and feedstock, which declined slightly.

Figure 5: In 2017, agricultural biomass production in Scotland had declined 5.1% since 2003

Agricultural biomass production in Scotland, 2003 to 2017



Source: Office for National Statistics and Scottish Government

Notes:

1. "Other" includes: spring barley, winter barley, wheat, oats, carrots, turnips and swedes, brussel sprouts, peas, other vegetables, raspberries, strawberries, other fruit, oilseed rape and potatoes.

The major two components that made up total agricultural biomass in Scotland throughout the time series were the production of feedstock (animal feed) and grazed biomass. From 2003 to 2017, the production of feedstock represented between 41% and 49% of total agricultural biomass and grazed biomass made up between 22% and 34%. The percentage of agricultural biomass in Scotland related to livestock feed (feedstock and grazed biomass combined) in 2017 was 71.3%.

The valuation of the agricultural biomass provisioning service fluctuated between 1998 and 2015, with peaks in 2004 and 2014 in line with production highs. The average valuation of agricultural biomass provisioning service over the time series was £283.8 million.

Scottish and UK agricultural biomass trends have been broadly similar, with both displaying a dip in 2012 and recent production increases during 2017. The fall in the production of agricultural biomass in 2012 may be attributed to exceptionally high rainfall.

The proportion of the UK's agricultural biomass that is made in Scotland fluctuated between 15% and 17% between the years 2003 and 2017. Overall, the proportion has declined from 16.2% in 2003 to 15.4% in 2017. The proportion of UK feedstock grown in Scotland has declined since 1998 from a high of 37% to a low of 24% in 2017 making this one of the main drivers behind the decline in the proportion of UK agricultural biomass from Scotland.

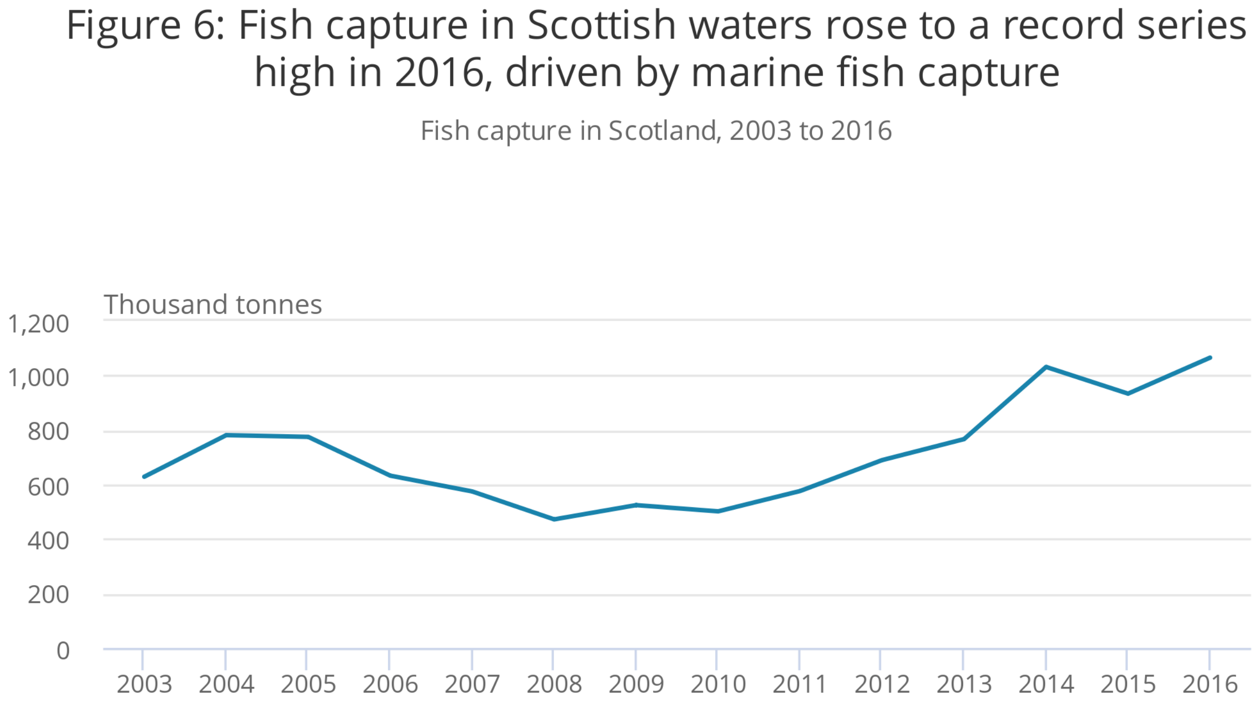
Fish capture

In 2016, fish capture in Scottish waters was over two-thirds higher than in 2003

Fish capture in Scottish waters has increased 70% since 2003 from 628.2 thousand tonnes to 1,065.2 thousand tonnes in 2016 (see Figure 6). This is primarily due to an increase in marine fish capture, which represents the clear majority of total fish capture (over 99%). Aquaculture or farmed fish, like farmed livestock have been removed from estimates as farmed fish are viewed as a produced asset and not a natural asset.

Figure 6: Fish capture in Scottish waters rose to a record series high in 2016, driven by marine fish capture

Fish capture in Scotland, 2003 to 2016



Source: European Commission: Scientific, Technical and Economic Committee for Fisheries

The largest annual increases in fish capture in Scottish waters occurred in the more recent years, with 2014 seeing an annual expansion of nearly 35% and 2016 observing an increase of 14%.

Whilst marine fish capture from Scottish vessels and landings into Scottish ports also increased in recent years it should be noted that both marine fish capture from Scottish vessels and landings into Scottish ports may not necessarily be fish captured exclusively in the Scottish exclusive economic zone (EEZ) and may come from other waters.

In 2016, of all fish caught by Scottish vessels, 84.3% (381.2 thousand tonnes) was caught in Scottish waters; this has risen from 75.7% (276.2 thousand tonnes) in 2012. Despite more Scottish vessels fishing in Scottish waters their proportional contribution to total fish capture in Scottish waters has decreased from 50.9% in 2008 to 35.9% in 2016.

Total marine fish captured in the UK EEZ followed a similar trend to those captured in Scottish EEZ between the years 2003 and 2016. This is not surprising, as fish capture in Scottish waters makes up a large proportion of all fish capture in the UK EEZ, with the proportion increasing from 60% in 2003 to 77% in 2016.

This can also be seen when comparing fishing fleets, as Scottish vessels represented around 60% of all marine fish capture from UK vessels between the years 2012 and 2016, and landings into Scottish ports made up over two-thirds of total landings into the UK.

The annual value of fish capture in Scottish waters fluctuated between the years 1998 and 2015. The annual value reached a low of £55.73 million in 2004 and a peak of £128.72 million in 2010.

Despite Scottish marine fish capture making up a large proportion of UK marine fish capture, the Scottish annual value makes up less than half of the value of UK fish capture. Looking at the UK Sea Fisheries Statistics 2017 report (PDF, 22.5MB), this may be because important elements of the Scottish fleet are engaged in several fisheries that are high volume but lower priced, such as herring and mackerel caught in the North Sea and West of Scotland waters. The Scottish fish capture provisioning service valuation should be interpreted as a minimum valuation as it excludes fish capture in Scottish waters not represented in Scottish national accounts. Please see the methodology Section 9 for further details.

Timber

Scottish timber production has almost doubled in the last 20 years

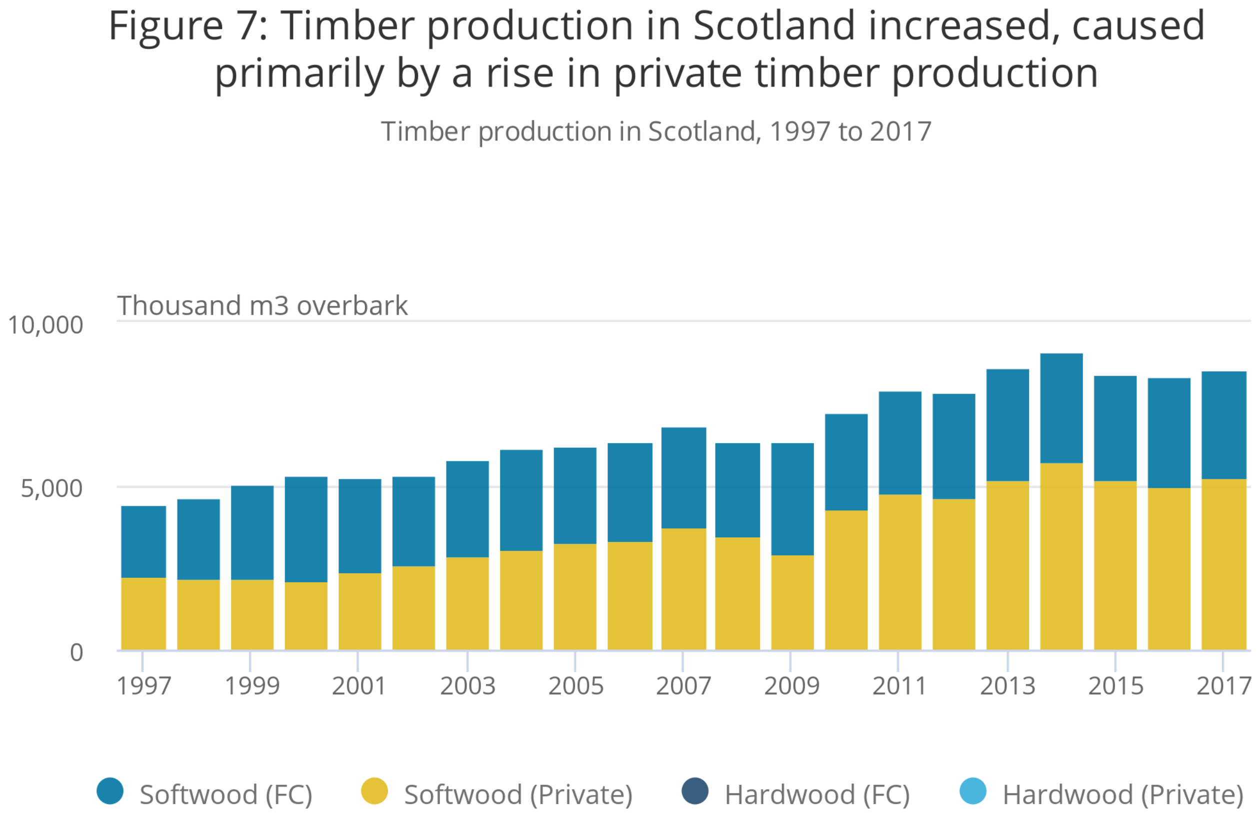
Timber production in Scotland increased 91% between 1997 and 2017, with 8.55 million cubic metres (m3) overbark standing[1] of timber being removed in 2017 compared with 4.47 million m3 in 1997 (see Figure 7).

Scottish timber production has generally increased year-on-year, albeit with slight falls during the downturn in 2008 to 2009 and recently in 2015 to 2016. Despite remaining below the 2014 peak, timber production in 2017 rose to the highest level seen in three years, driven primarily by an increase in private sector production.

During the years 1997 to 2000, timber production came predominantly from the public forestry estate. However, from 2000 onwards private sector timber production was generally greater than public sector timber production and was the main factor behind the trend seen in the data since 2000. This change is primarily due to differences in the age structure and timing of timber production between woodlands on the public and private forest estates.

Figure 7: Timber production in Scotland increased, caused primarily by a rise in private timber production

Timber production in Scotland, 1997 to 2017



Source: Forestry Commission

Notes:

1. FC stands for Forestry Commission.

2. Hardwood - broadleaved trees such as oak, birch and beech. Softwood - coniferous trees such as spruce, pine and larch.

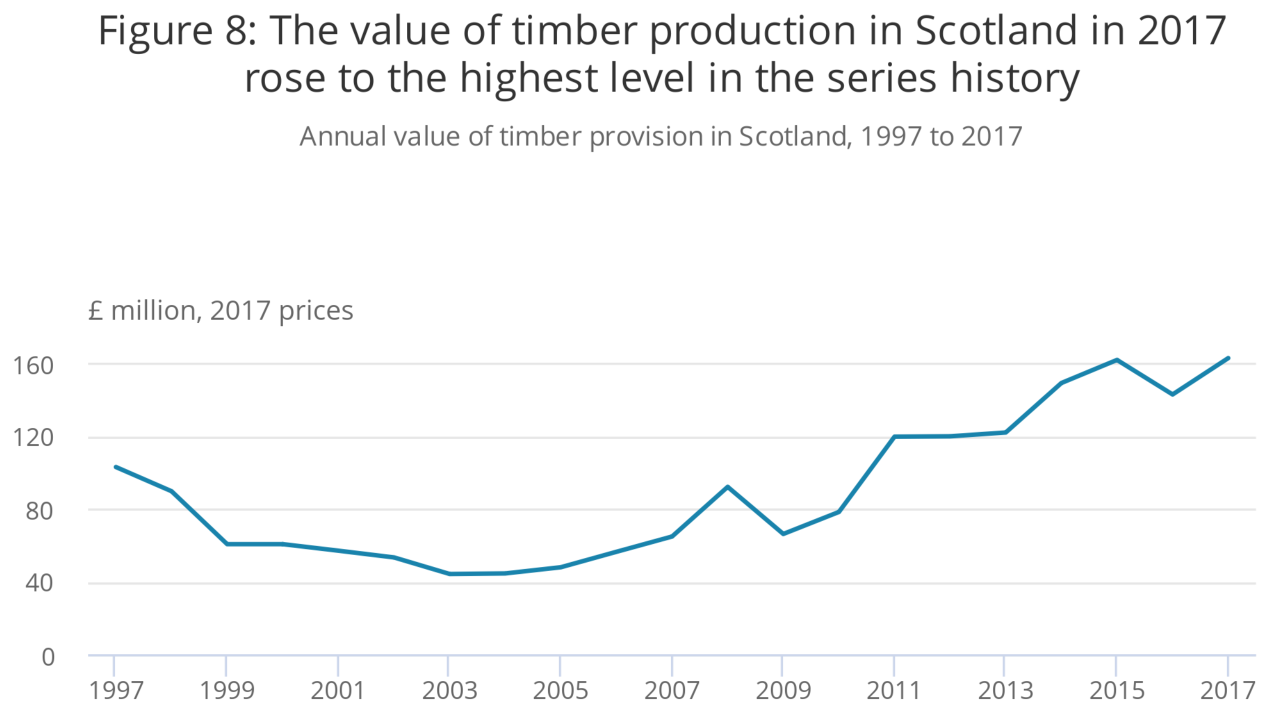
3. Hardwood production is proportionally much smaller than softwood production meaning it is difficult to see in this chart. Clicking on the softwood production key elements will remove them from the chart enabling you to see changes in hardwood production.

In 2017, the value of Scottish timber production rose to £162.78 million, the highest since the series started in 1985. This was caused by increases in both stumpage prices and timber production. The stumpage price is the price paid per standing tree for the right to harvest timber from a given area.

Annual timber values generally declined year-on-year between the years 1997 to 2003 due to a steady fall in stumpage prices. In 2004, annual values rose and continued to increase until 2009, where the annual value of timber fell to £66.14 million. However, this was short-lived as the annual value of timber increased in 2010 and continued to increase until 2015 (see Figure 8).

Figure 8: The value of timber production in Scotland in 2017 rose to the highest level in the series history

Annual value of timber provision in Scotland, 1997 to 2017



Source: Office for National Statistics and Forestry Commission

Scotland's timber production made up 60% of the UK's total timber production in 2017. Since 1997, the proportion of UK timber production from Scotland has generally increased year-on-year. Looking at woodland area and planting data published by the Forestry Commission this is not surprising as Scotland represents 66% of UK conifer (softwood) woodland area and the extent of Scottish woodland has been increasing at a faster rate than that of both England and Wales since 1998. According to data published in the Forest Research Forestry Statistics 2018, between the years 1998 to 2018, woodland area in Scotland has increased 11% while woodland areas in both England and Wales have expanded by only 5% and 3% respectively.

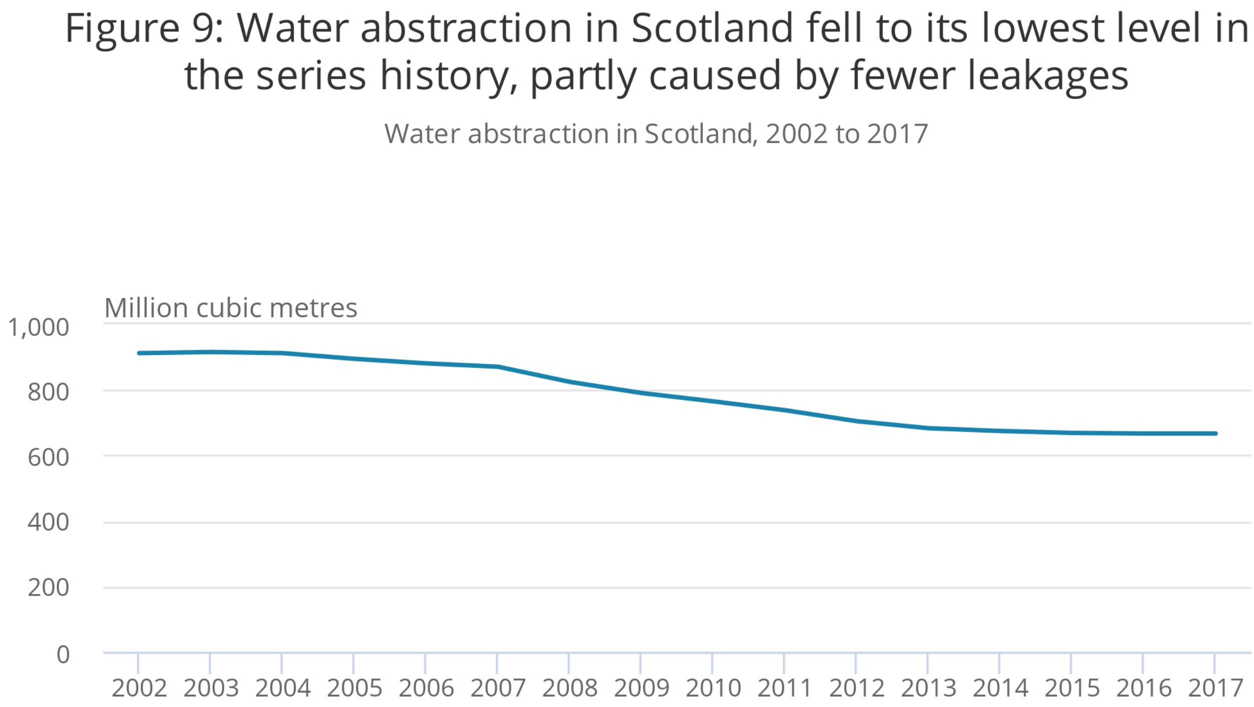
Water abstraction

Volume of Scottish water being abstracted for public water supply is falling due to less leakage

In Scotland, water abstraction (extracting water from natural sources) for public water supply by Scottish Water declined between the years 2002 and 2017, from 912 million m3 to 666 million m3 respectively (see Figure 9). This was despite both domestic consumption and operational use (fire service use, waste water treatment works, the distribution network and so on) demand increasing and was due to a reduction in the amount of water that was lost through leakages. This was reduced by nearly 50% from 413 million m3 in 2002 to 204 million m3 in 2017: meaning less water was abstracted despite the rise in demand.

Figure 9: Water abstraction in Scotland fell to its lowest level in the series history, partly caused by fewer leakages

Water abstraction in Scotland, 2002 to 2017



Source: Scottish Water

The value of water abstraction fluctuated throughout the time series, with a peak of £165.11 million in 2006 and a low of £63.68 million in 2016. As with the UK Ecosystem Service Accounts, the valuation of water does not include significant uses, particularly in Scotland, such as drinks manufacturing and hydroelectric power.

With a similar trend to Scotland, water abstraction for public water supply in the UK also declined over the period 2002 to 2015, albeit at a slightly slower pace. Scottish water abstraction for public water supply made up between 11% and 10% of UK water abstraction.

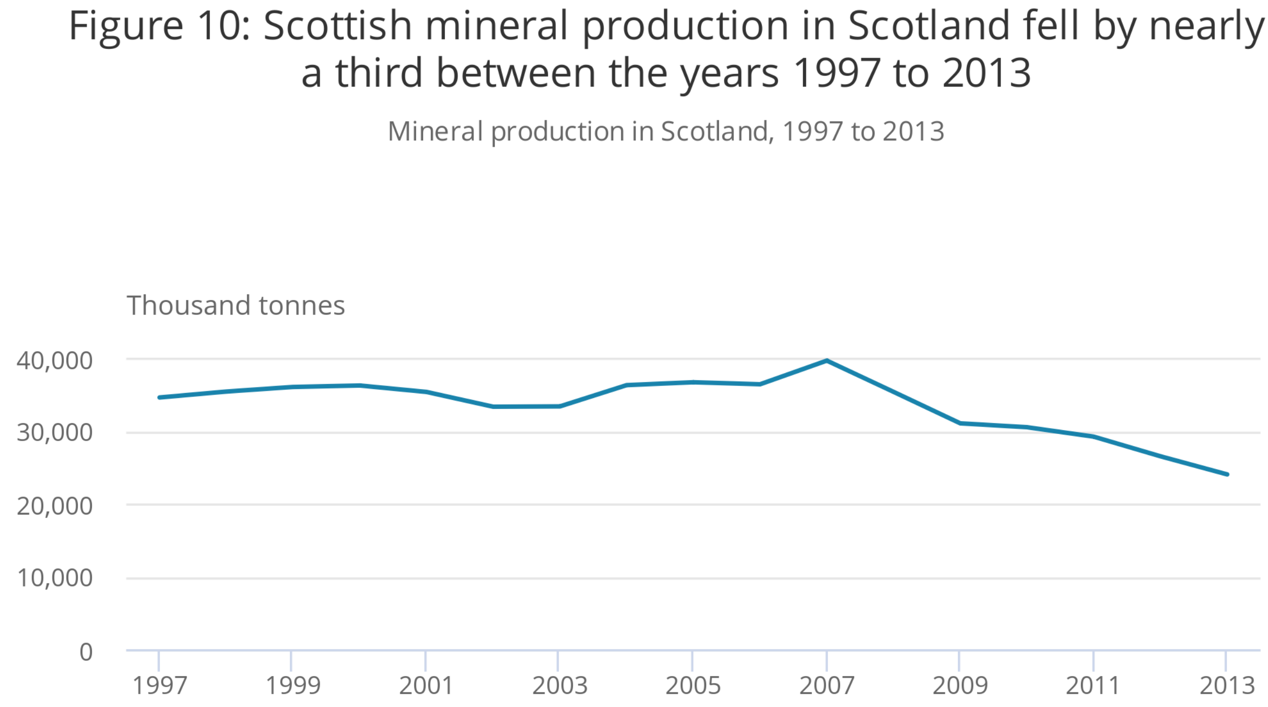
Minerals

Scottish minerals production declined to the lowest level in the series history during 2013

Mineral production in Scotland decreased 30.6%, from 34,599 thousand tonnes in 1997 to 24,026 thousand tonnes in 2013 (see Figure 10). Mineral production includes clay and shale, igneous rock, limestone and dolomite, sand and gravel, sandstone, barytes, fireclay, peat, silica sand, and talc.

Figure 10: Scottish mineral production in Scotland fell by nearly a third between the years 1997 to 2013

Mineral production in Scotland, 1997 to 2013



Source: British Geological Survey

Notes:

1. Data are only available up to 2013.

The decline in mineral production in Scotland can be mainly attributed to falls in the production of minerals used in the foundations for roads and buildings such as sand and gravel, and igneous rock, which declined by 50.4% and 21.3% respectively between the years 1997 to 2013.

The annual valuation of the mineral production abiotic provisioning service in Scotland has decreased, with fluctuation, by £60.2 million since 1998 (67.2%) to £29.4 million in 2015. Fluctuation has largely been driven by fluctuation in the gross operating surplus of the mining and quarrying industry in Scotland. The annual value peaked in 2009 with a valuation of £211.1 million but has since declined by 86.1% to £29.4 million in 2015. This trend is reflected in the asset valuation.

Between 1997 and 2013, a 30.6% decline in mineral production in Scotland has been a contributing factor of mineral production decline in the UK, which decreased 9.9% over the same period. In 1997, Scotland represented 15.8% (34,599.0 thousand tonnes) of UK mineral production (219,091.8 thousand tonnes). In 2013, this had decreased to 12.2% (24,026.0 thousand tonnes) of UK mineral production (197,434.7 thousand tonnes).

Unstable valuations of the mineral production abiotic provisioning service and years of negative gross operating surplus for the minerals industry in the UK National Accounts do not lend well to valuation comparisons between the UK and Scotland. Data inputs and methods will be reviewed in future accounts.

Oil and gas

Section 9 provides details on the methodology used to estimate the value of oil and gas production. This is a “resource rent” approach, which estimates the surplus remaining to the extractor after all costs and normal returns have been taken into account. This is closely related to profitability, which explains why the fall in value over recent years during a period of increasing production is significantly greater than the relative decline in the oil price and hence revenues.

Resource rent is different from an intrinsic measure of value such as the wholesale price determined by the market, which is in effect the willingness to pay for a good and therefore the value placed on it by the consumer, or the value it provides to the economy in terms of economic output (that is, gross value added). Resource rent does not value, as benefits, government receipts, employment, supply chain activity or energy security.

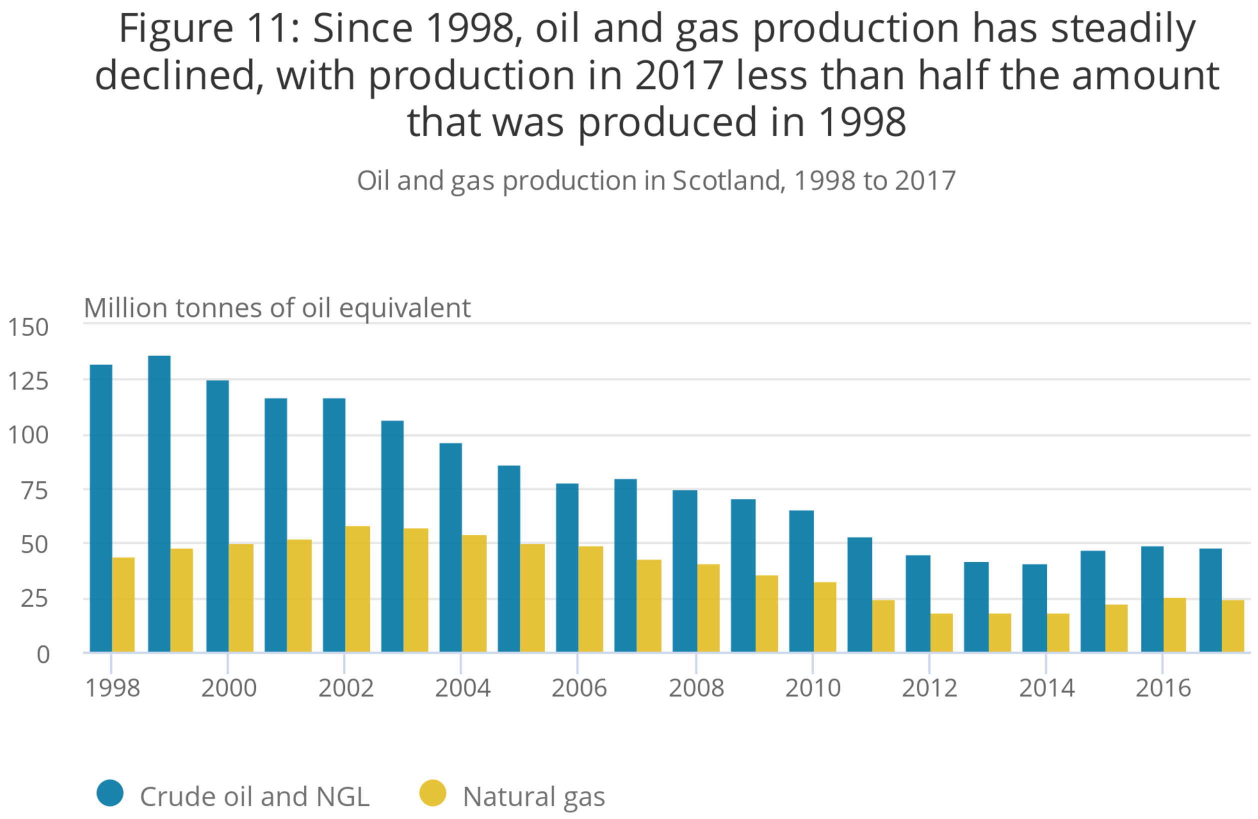
Oil and gas production in Scotland during 2017 has more than halved since 1998

In 2017, combined oil and gas production in Scotland was 73.7 million tonnes of oil equivalent, decreasing 58.3% from 1998 levels (176.6 million tonnes of oil equivalent). Over the time series the production of oil has decreased 83.7 million tonnes (63.2%) and gas production decreased 19.3 million tonnes of oil equivalent (43.7%). Contrasting to the long-term declining trend, since 2013, combined oil and gas production has grown 22.8%, with marginal decline between 2016 and 2017 (see Figure 11).

Between 1998 and 2017, combined production peaked in 1999 at 185.2 million tonnes of oil equivalent. Oil production reached a peak of 136.9 million tonnes in 1999 and gas production peaked at 58.8 million tonnes of oil equivalent in 2002.

Figure 11: Since 1998, oil and gas production has steadily declined, with production in 2017 less than half the amount that was produced in 1998

Oil and gas production in Scotland, 1998 to 2017



Source: Scottish Government

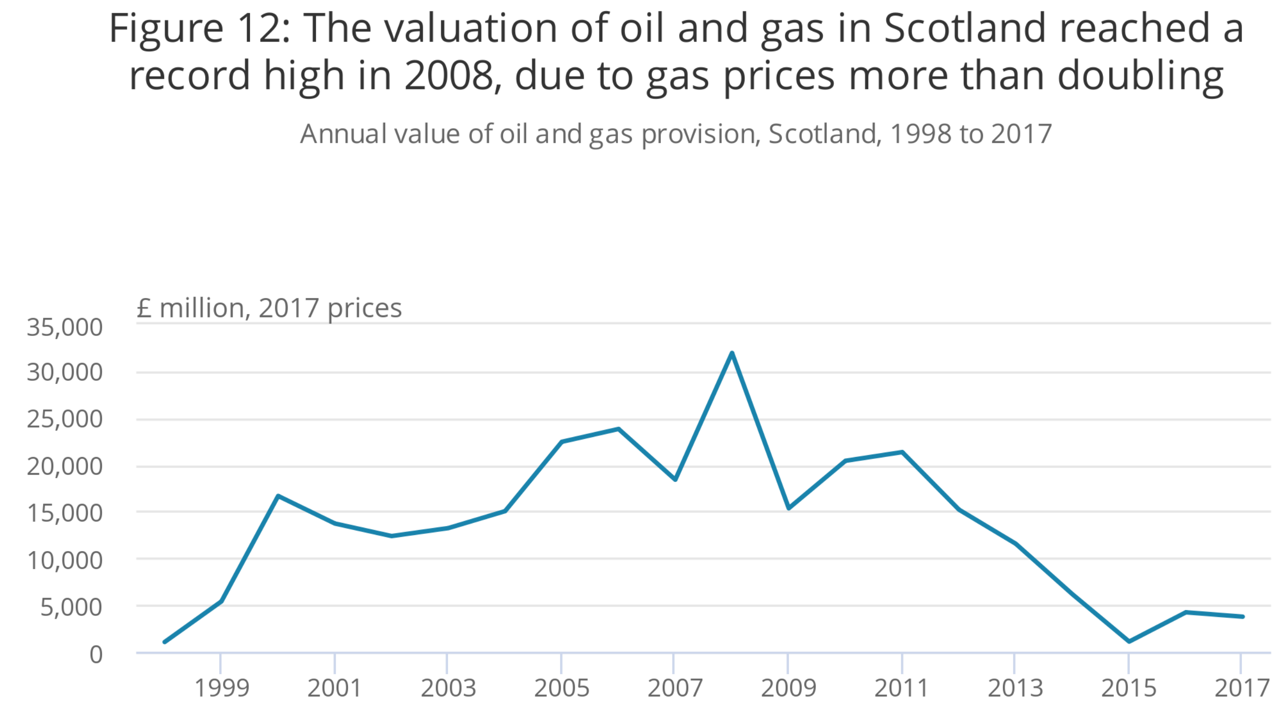
In 2017, Scottish combined production of oil and gas represented 81.0% of the UK overall oil and gas production. This was 6 percentage points higher than in 1998 (75.0%). This increasing proportional contribution occurs across the production of crude oil, natural gas liquid (NGL) and natural gas. In 2017, Scottish crude oil and NGL production represented 95.7% of UK production and natural gas production represented 62.3% of UK production.

The annual valuation of oil and gas abiotic provisioning in Scotland has fluctuated, driven largely by price changes and production trends (see Figure 12). The largest year-on-year real price increases were seen from 1999 to 2000 (63.5% for oil and 80.2% for gas) and 2007 to 2008 (43.3% for oil and 101.8% for gas), which saw gas prices more than double. These spikes are reflected in the annual valuation.

More recently, the annual value fell to a new series low in 2015 of £1,078.2 million despite production picking up. The fall in the annual value in 2015 was primarily due to a sharp decline in both oil and gas prices, which saw the lowest prices in 11 and 6 years respectively.

Figure 12: The valuation of oil and gas in Scotland reached a record high in 2008, due to gas prices more than doubling

Annual value of oil and gas provision, Scotland, 1998 to 2017



Source: Office for National Statistics and Scottish Government

The UK annual value of oil and gas followed a similar trend to Scotland, with the annual value in Scotland making up a large proportion of the UK figure. Both the Scottish and UK oil and gas calculations use the same price bases for oil and gas.

Renewable energy

In 2017, five times as much energy was produced from renewable sources in Scotland than was produced in 2000

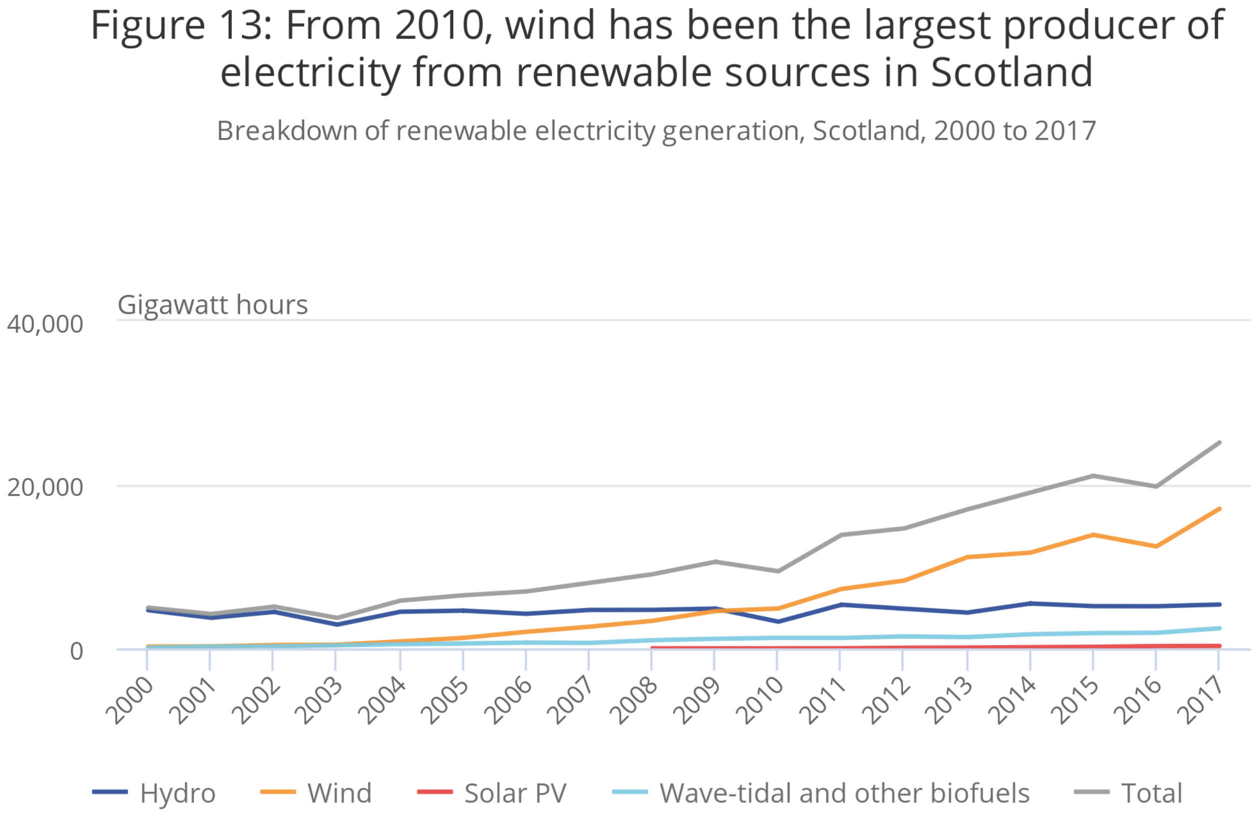
Electricity generation from renewable sources in Scotland has increased dramatically since 2000 and by 2017 was over five times larger. National and international incentives, including the EU Renewable Energy Directive and Renewable Obligation (RO) target, have helped contribute towards the increase.

Most years have seen increases except 2003, 2010 and 2016. The 2016 decrease is attributable to a wind generation decline of 10.2%, due to a 10.9% reduction in average wind speeds. This is reflected in the wind generation load factor, a measure of generation efficiency being the utilisation of total generation capacity, which also decreased from 29.2% to 23.4% between 2015 and 2016.

The make-up of electricity generation from renewables in Scotland has changed since 2000 when hydropower represented 93.8% of production. Despite hydropower generation staying relatively stable over the time series, in 2017, it represented only 21.3% of renewable production. The relative decline of hydropower is due to generation increases in other renewables, most notably wind power, which was 78.7 times larger in 2017 compared with 2000, overtaking hydropower in 2010. Scottish wind generation peaked in 2017 (see Figure 13), representing 67.8% of the electricity generated from renewables.

Figure 13: From 2010, wind has been the largest producer of electricity from renewable sources in Scotland

Breakdown of renewable electricity generation, Scotland, 2000 to 2017



Source: Scottish Government and Department for Business, Energy and Industrial Strategy (Dukes)

Notes:

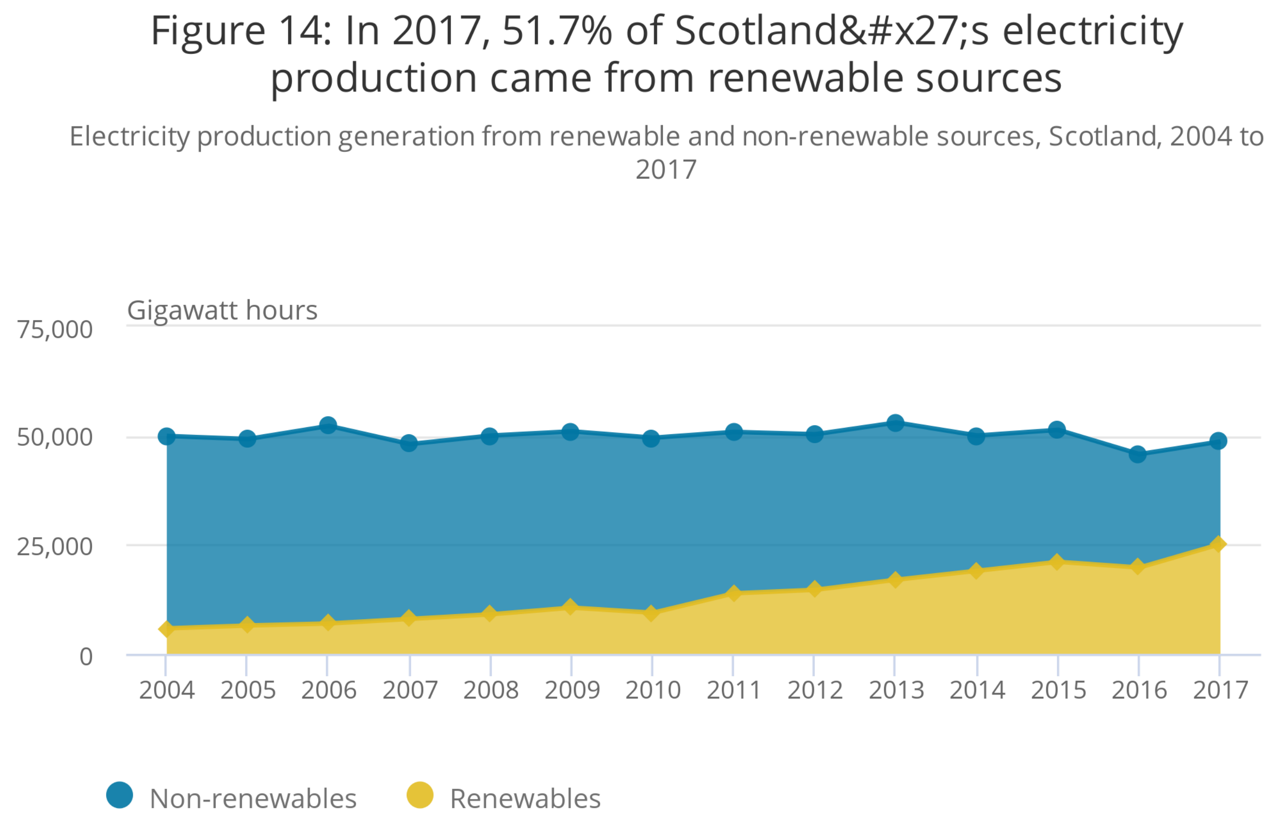
1. Wave-tidal and biofuels includes: landfill gas, sewage gas, other biofuels and wave/tidal.

2. Figures may not sum due to rounding.

In 2004, electricity generated from the renewable sector accounted for 11.7% or 5,832.2 gigawatt hours (GWh) of the total electricity generated from all sources (49,937.0 GWh) in Scotland. Whilst total generation has remained relatively stable, between 2004 and 2017, the proportional contribution of renewables has generally increased year-on-year to a high of 51.7% in 2017 or 25,165.9 GWh as shown in Figure 14.

Figure 14: In 2017, 51.7% of Scotland's electricity production came from renewable sources

Electricity production generation from renewable and non-renewable sources, Scotland, 2004 to 2017



Source: Scottish Government and Department for Business, Energy and Industrial Strategy (Dukes)

Notes:

1. Non-renewable includes: coal, oil, gas, nuclear, other thermal, hydro pumped storage and non-biodegradable wastes.

2. Renewables include: hydro, wind, wave/tidal, landfill gas, sewage gas, other biofuels and solar PV.

The monetary estimates are gross value added only and not resource rent calculations, therefore are over-estimates. The estimated gross value added of electricity generation from renewable sources in Scotland has fluctuated across the time series but overall has increased 120.5%, from £338.3 million in 2004 to a peak of £746.1 million in 2015.

In 2017, the Scottish renewable sector generated 25,165.9 GWh or 25.3% of UK renewable generation, down from 50.1% (4,971.6 GWh) in 2000. Scotland has consistently represented around 90% of UK hydropower generation. Despite Scotland’s fivefold increase in renewable electricity production its decreasing contribution to UK renewable generation is due to faster growth of renewables in England, most notably in the bioenergy sector.

Scotland’s contribution to the UK’s renewables gross value added was 64.9% in 2010 and has declined year-on-year since, to 20.3% in 2015. This declining trend follows that of the Scottish contribution to UK renewable generation.

Notes for: Provisioning services

1. Cubic metres (m3) overbark standing relates to the volume of timber including the bark and before being felled.

6 . Regulating services

As well as tangible provisioning services, natural assets in Scotland provide a number of typically intangible regulating services, such as cleaning the air, sequestering carbon and regulating water flows to prevent flooding.

This section presents two such ecosystem services that are classed as regulating ecosystem services: carbon sequestration and air pollutant removal from vegetation.

The pollutants covered in pollution removal are:

- PM2.5
- PM10
- nitrogen dioxide (NO_2)
- ground-level ozone (O_3)
- ammonia (NH_3)
- sulphur dioxide (SO_2)
- PM2.5 is a component of PM10.

Air pollution leads to respiratory diseases in humans and the risk of those diseases for a population can be estimated based on the levels of pollution and the health costs of that disease.

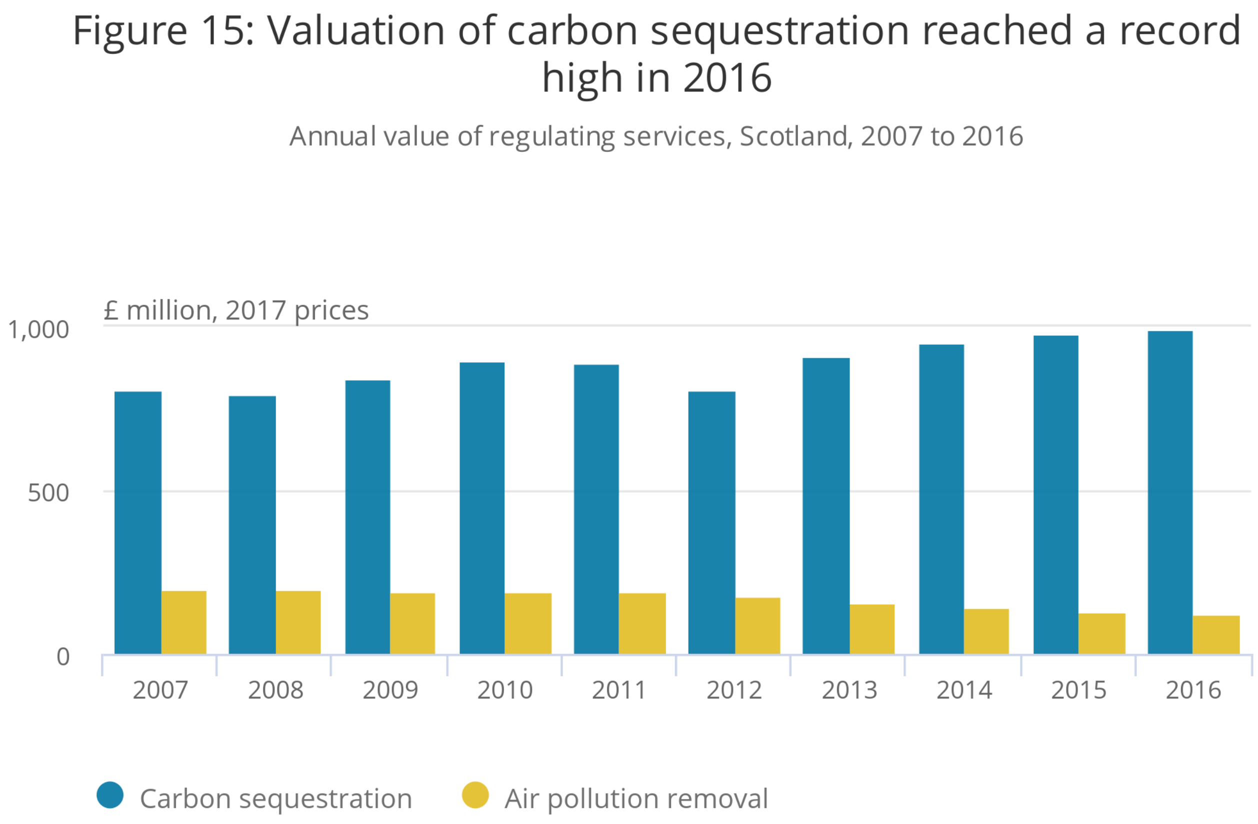
Interrelating biological processes underpin both carbon sequestration and air pollution removal. Underpinning carbon sequestration and air pollution removal trends are the emissions levels that are available to be removed.

Please note the valuation methods used differ; carbon sequestration valuation is a removal cost and air pollution removal valuation is a societal cost. To put it another way we are valuing the cost of avoiding damage (for carbon) and the cost of treating damage that has already happened (for air pollution). Air pollution removal valuation does not consider the cost of abatement and carbon sequestration valuation does not consider the global societal impacts of carbon dioxide.

Although, over the time series, carbon sequestration removes on average 37 times more tonnes than air pollution removal, the valuation of air pollution removal was on average 3.5 times greater per tonne. In 2016, carbon sequestration was 15.5 million tonnes and air pollution removal was 0.4 million tonnes, valued at £995.7 million and £61.8 million respectively (see Figure 15).

Figure 15: Valuation of carbon sequestration reached a record high in 2016

Annual value of regulating services, Scotland, 2007 to 2016



Source: Office for National Statistics, Centre for Ecology and Hydrology and National Emissions Inventory

Both carbon sequestration and air pollution removal are cross-cutting ecosystem services, which are provided by a range of broad habitats, although woodland is the primary supplier in both cases. Analysis of these two services are covered in more depth in the following sections.

Carbon sequestration

Due to data constraints, values related to carbon sequestration by marine ecosystems, including those intertidal areas such as coastal margins, are not included in current estimates. As a result, annual flow values related to carbon sequestration services are likely to be an underestimate.

Carbon sequestration in Scotland has increased gradually since 1998

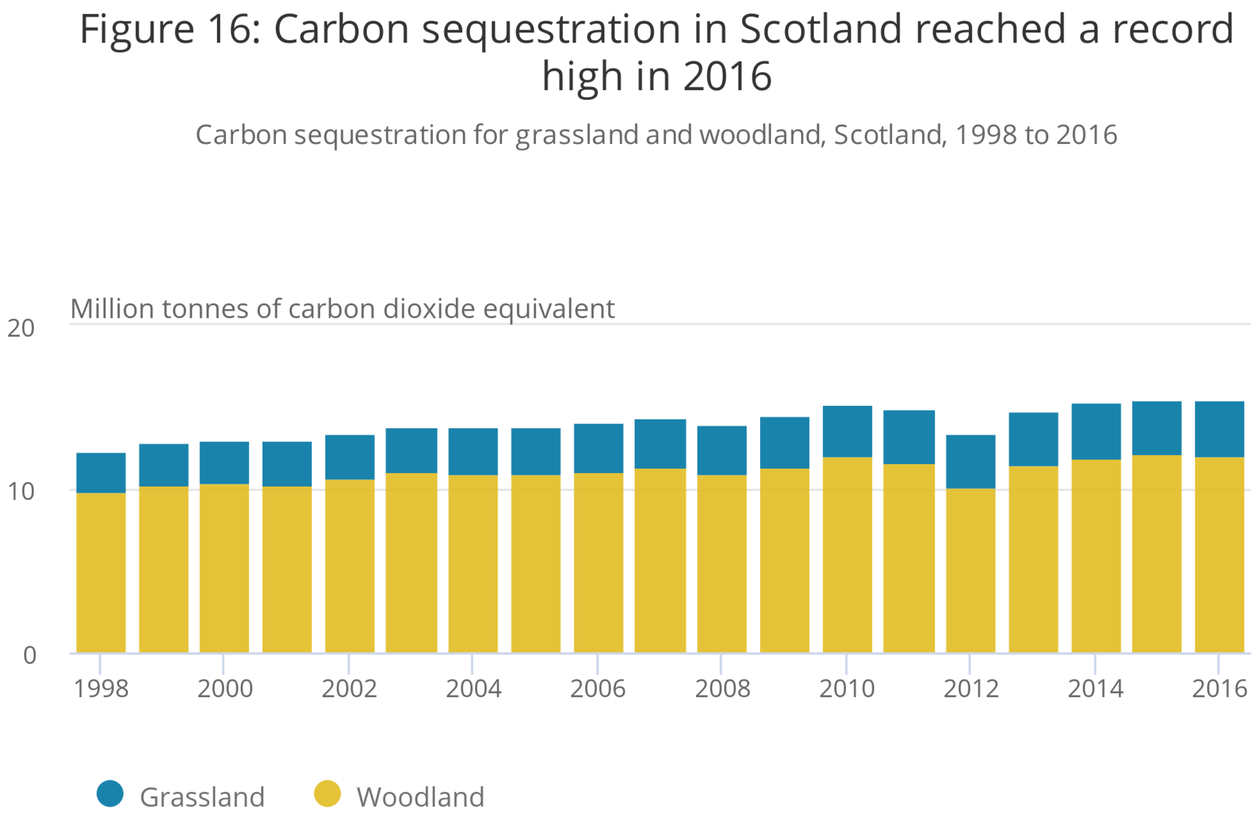
Overall the estimated carbon sequestration for Scotland has increased 26.0% from 12.3 million tonnes of carbon dioxide equivalent (MtCO2e) in 1998 to 15.5 MtCO2e in 2016, which is the highest figure on record.

From 1998, carbon sequestration increased steadily year-on-year, reaching a high in 2010 (15.2 MtCO2e) before declining for two consecutive years to 13.4 MtCO2e in 2012. After 2012, carbon sequestration rose, reaching a series high in 2016 of 15.5 MtCO2e (see Figure 16). These trends are largely driven by changes in the age structure of woodland, due to annual felling and planting, as younger trees will sequester less carbon.

Carbon sequestration occurs almost entirely in woodland and grassland, 78.0% and 22.0% respectively. Meanwhile, cropland and wetlands contributed a maximum of 0.2% towards the overall carbon sequestration in Scotland.

Figure 16: Carbon sequestration in Scotland reached a record high in 2016

Carbon sequestration for grassland and woodland, Scotland, 1998 to 2016



Source: Office for National Statistics and National Atmospheric Emissions Inventory (NAEI)

Projected Scottish carbon sequestration is estimated to decline to 8.7 MtCO2e in 2050. This reduction is due to the projected decline of carbon sequestration in woodland whilst projected grassland carbon sequestration shows small increases.

The regulating service of carbon sequestration valuation has increased 60.5% from £604.4 million in 1998 to £995.7 million in 2016. This trend has been driven both by increases in sequestration and steady increases in the non-traded price of carbon (1.5% annual growth over this period), which is projected by the Department for Business, Energy and Industrial Strategy (BEIS) to keep increasing in real terms until around 2080. In 2016, the carbon sequestration regulating service was valued at £776.2 million for woodland and £219.3 million for grassland.

Despite decreasing carbon sequestration, the annual valuation is projected to grow, driven by increases in carbon cost, to £1,969.2 million; £1,068.3 for woodland and £900.9 million for grassland.

As with Scotland, the UK’s carbon sequestration has fluctuated since 1998 but peaked in 2015 at 34.5 MtCO2e before falling back to 34.4 MtCO2e in 2016.

In 1998, Scotland represented 40.9% of overall UK carbon sequestration. This proportion has steadily increased to 45.1% in 2016. In 2016, Scotland represented over half (50.4% or 12.1 MtCO2e) of UK woodland carbon sequestration (24.0 MtCO2e), growing from 46.6% in 1998. In 2016, Scotland also represented more of the UK grassland carbon sequestration than it did in 1998, growing from 27.5% to 32.8%. As Scotland and the UK share the same non-traded cost of carbon, annual valuations reflect their physical flow relationship.

Air pollutant removal by vegetation

Avoided health damage costs in Scotland decline due to a reduction in the absorption of the most harmful air pollutants

Air pollutant removal data have been modelled for 2007, 2011, 2015 and 2030. Between these years linear interpolation has been used as an estimation of pollution removal. As with all methods, this method is under review.

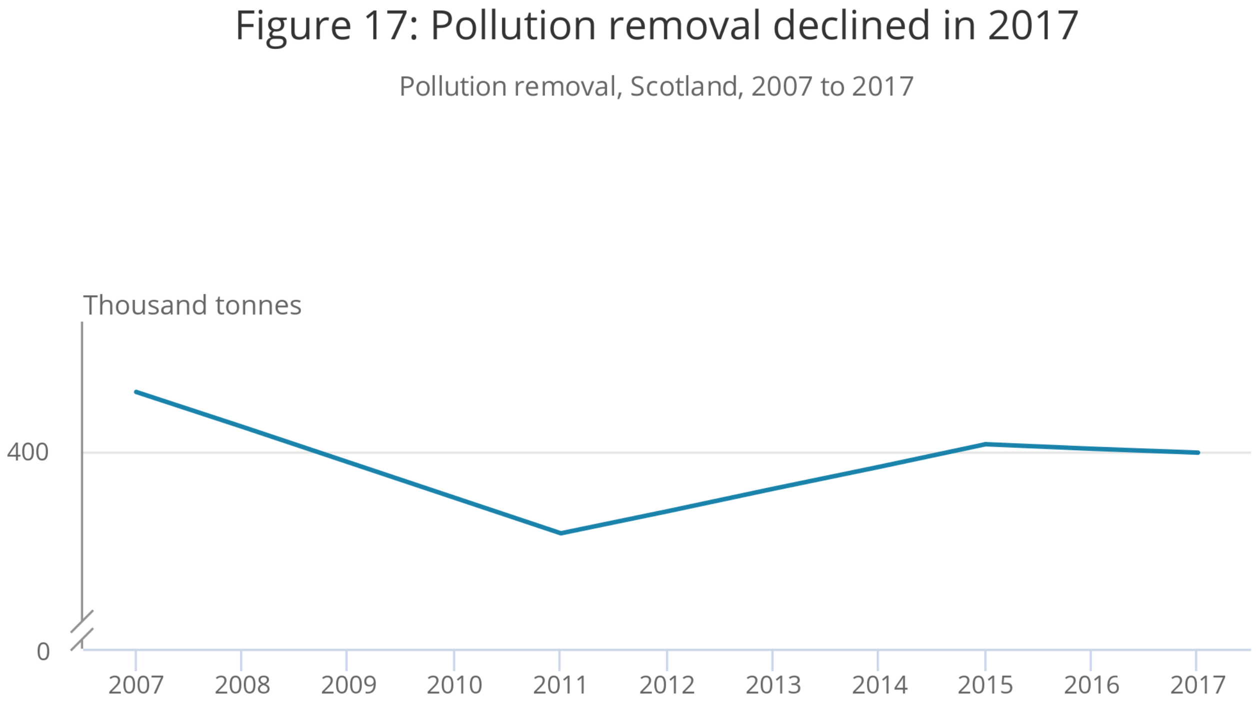
The pollutants covered are PM2.5, PM10, nitrogen dioxide (NO2), ground-level ozone (O3), ammonia (NH3) and sulphur dioxide (SO2).

Between the years 2007 to 2017, pollution removal in Scotland decreased 2.3% from 409.2 thousand tonnes to 399.7 thousand tonnes (see Figure 17). Much of this decline is accounted for by a reduction in air pollution removed by woodland, which fell by 4.2% between the years 2007 and 2017. This declining trend is largely due to less pollution being emitted into the atmosphere for vegetation to remove, rather than a reflection of changing condition, extent or species mix of vegetation.

Pollution removed in Scotland fell to 387.2 thousand tonnes in 2011 and this was primarily due to a fall in ground level ozone pollution removal across all habitats, particularly the woodland habitat. After 2011, overall pollution removal increased, peaking in 2015 to 401.0 thousand tonnes, before falling for two consecutive years.

Figure 17: Pollution removal declined in 2017

Pollution removal, Scotland, 2007 to 2017

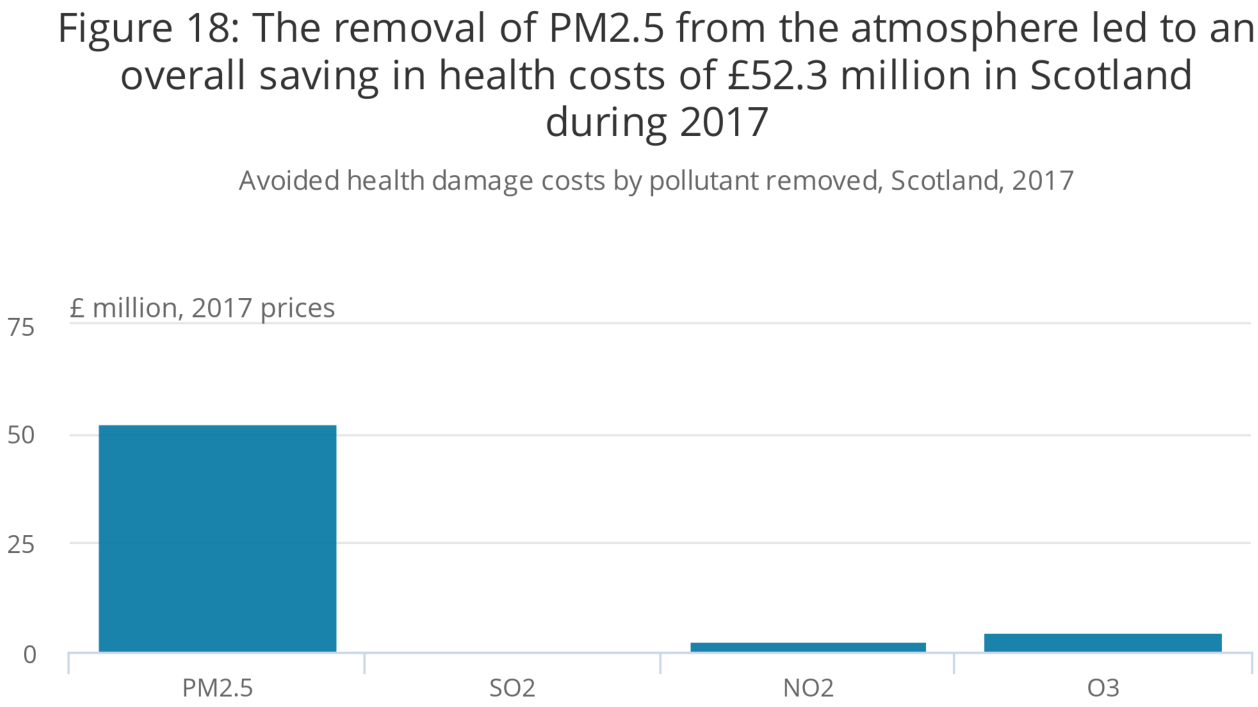


Source: Office for National Statistics and Centre for Ecology and Hydrology

Ground-level ozone (O3) represented the majority of total pollution removal (over 90%) from 2007 to 2017. However, the most harmful pollutant is PM2.5 (fine particulate matter with a diameter of less than 2.5 micrometres, or 3% of the diameter of a human hair), which can bypass the nose and throat to penetrate deep into the lungs, leading to potentially serious health effects and healthcare costs. This can be seen in Figure 18, with the removal of PM2.5 accounting for 88% (£52.3 million) of all avoided healthcare damage costs in 2017.

Figure 18: The removal of PM2.5 from the atmosphere led to an overall saving in health costs of £52.3 million in Scotland during 2017

Avoided health damage costs by pollutant removed, Scotland, 2017

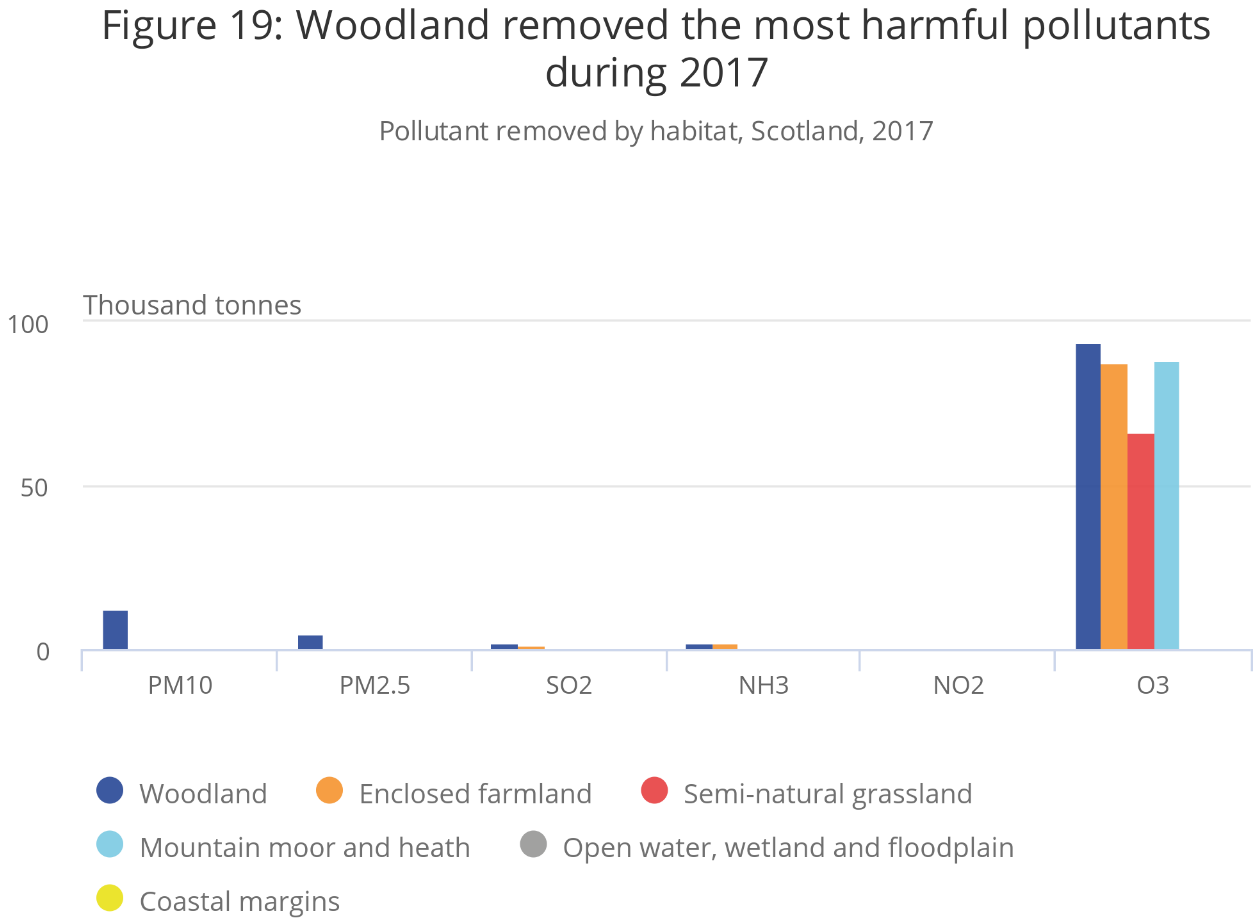


Source: Office for National Statistics and Centre for Ecology and Hydrology

It should be noted that absolute pollution removal of all pollutants is largely ground-level ozone (O3) (91.9%) removal. Between the years 2007 to 2017, whilst other habitats provided significant contributions to ground-level ozone (O3) removal, woodland removed the majority (average of 84%) of the most harmful pollutant of PM2.5 (see Figure 19).

Figure 19: Woodland removed the most harmful pollutants during 2017

Pollutant removed by habitat, Scotland, 2017



Source: Office for National Statistics and Centre for Ecology and Hydrology

Notes:

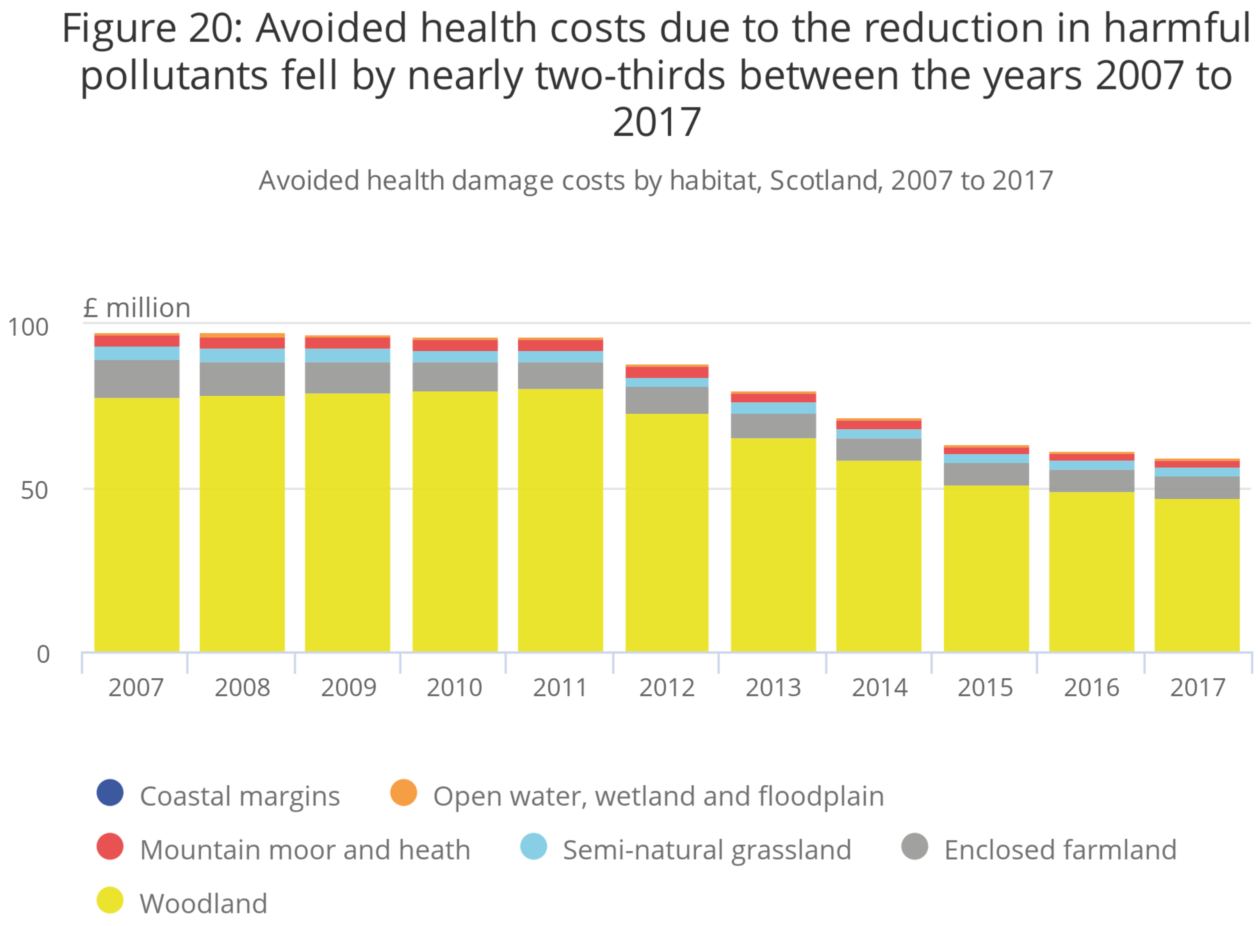
1. PM2.5 is a component of PM10.

The pollution removal regulating service is valued through avoided health damage cost modelling, detailed in Section 9 of this publication. The annual valuation of pollution removal for all habitats declined by 39% between the years 2007 and 2017, from £98.0 million to £59.6 million (see Figure 20). As noted earlier, this declining trend is largely due to less pollution being emitted into the atmosphere.

Woodland makes up the majority of avoided health damage costs due to woodland removing the majority of the most harmful pollutant (PM2.5) (see Figure 20). However, the removal of PM2.5 by woodland has fallen by 28% between the years 2007 and 2017. Therefore, the fall in the annual value can be attributed to the fall in the amount of PM2.5 removed by woodland.

Figure 20: Avoided health costs due to the reduction in harmful pollutants fell by nearly two-thirds between the years 2007 to 2017

Avoided health damage costs by habitat, Scotland, 2007 to 2017



Source: Office for National Statistics and Centre for Ecology and Hydrology

Despite habitats in Scotland removing on average 29% of the UK's most harmful pollutants (PM2.5) over the time series, Scotland only made up on average 6% of the UK annual valuation from air pollutant removal. One reason behind this difference is the lower relative population, including large areas of low population density of Scotland, meaning there will be fewer avoided health damage costs from the removal of PM2.5.

Pollution removal in Scotland followed a similar trend to the UK, with the amount of pollution removal dipping in 2011 before increasing again in 2015. This is partly due to pollution removal in Scotland making up around one-third of total air pollution removed in the UK between the years 2007 and 2017. Out of the six habitats reviewed, mountain moorland and heath (MMH) in Scotland accounted for around three-quarters of all air pollution removed by this habitat in the UK. This is not surprising as the majority of the UK's MMH habitat is in Scotland.

7 . Cultural services

This section presents the cultural service of nature providing recreational opportunities. Other cultural services are also provided by natural capital in Scotland, such as aesthetic appreciation and heritage value. These additional cultural service accounts are not yet developed and further work is needed to clarify where non-recreational cultural services are truly additional to what is accounted for under recreational services.

Outdoor recreation

The recreation estimates were produced using the Scottish Recreation Survey (ScRS), which ran between 2003 and 2012. Spending and time per visit estimates beyond 2012 were fixed at 2012 levels and multiplied by visit numbers from the Scotland's People and Nature Survey (SPANS), which ran in 2013 to 2014 and 2017 to 2018. Time periods presented alter throughout this section in accordance with data availability.

Currently, habitat breakdowns of recreation are provided up to 2012 but we will seek to fully incorporate SPANS data for more timely estimates in the future. More information on the surveys and methods used are available in Section 9 of this article.

The UK estimates of recreation are scaled from the Monitor of Engagement with the Natural Environment Survey (MENE) to represent the UK population. Therefore, since UK estimates did not include Scottish, Welsh, or Northern Ireland surveys, comparisons between Scottish and UK values are, in effect, comparisons with inflated English trends. We will seek to fully incorporate additional surveys, such as ScRS and SPANS, in future UK estimations of outdoor recreation.

It is worth noting that these surveys focus on short day-trips from home and miss out potentially large amounts of spending on outdoor activity from domestic tourism, which future reports will include.

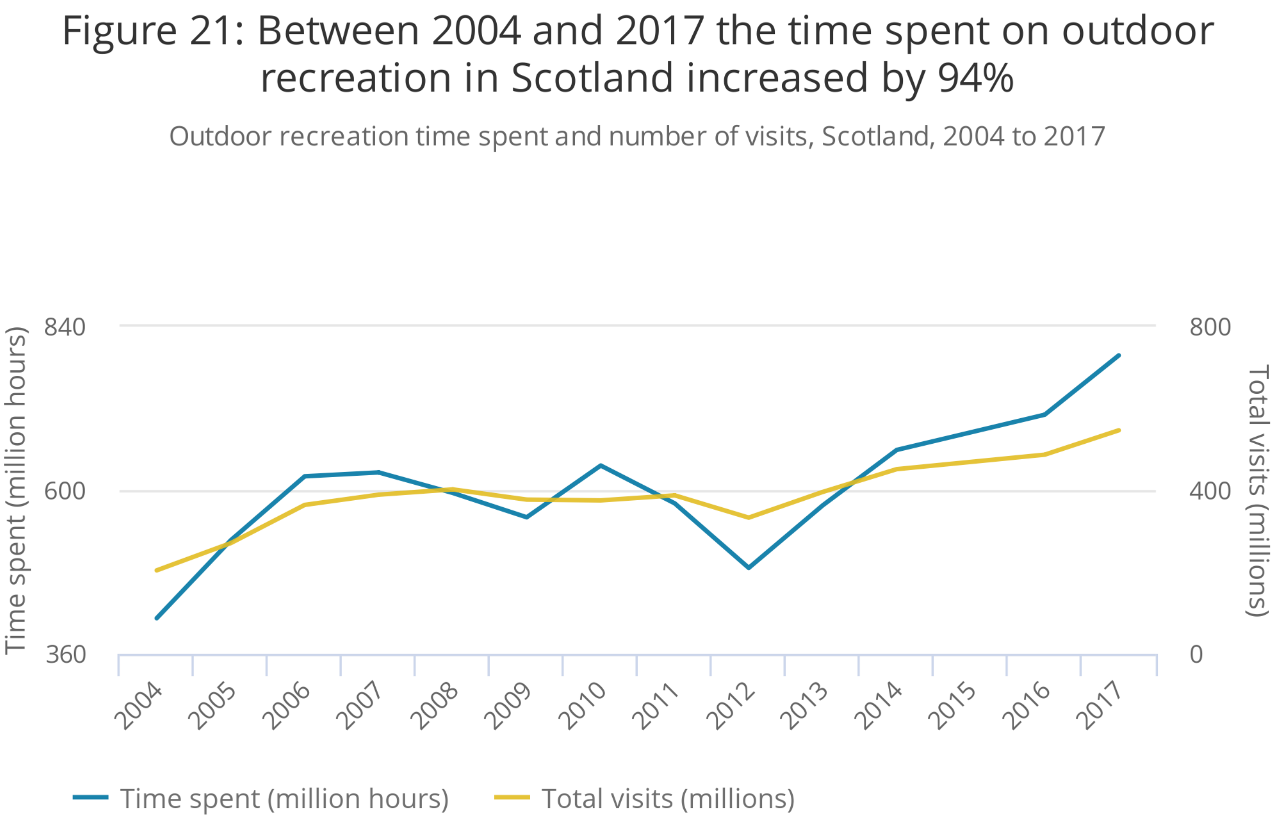
Between 2004 and 2017, time spent on Scottish outdoor recreation (excluding travel time) increased 94%, from 412 million hours to 798 million hours respectively. This trend was driven by visitor numbers, which increased 168%, from 204 million visits to 547 million visits over the same period. Average time spent per visit during this period decreased from 2 hours in 2004 to 1 hour and 28 minutes in 2012.

Figure 21 shows two periods in which outdoor recreation increased consistently: 2004 to 2007 (time spent increased 52% and visit numbers increased 91%) and 2012 to 2017. In 2008, despite increasing visitor numbers, time spent dropped 5% to 596 million hours due to average time spent per visit decreasing by 8 minutes.

Time spent on outdoor recreation increased to a high of 798 million hours in 2017. This is likely to be a conservative estimate as we used the, relatively low, 2012 ScRS average time spent per visit with SPANS visitor numbers. There were 214 million more Scottish visits to the outdoors in 2017 than 2012.

Figure 21: Between 2004 and 2017 the time spent on outdoor recreation in Scotland increased by 94%

Outdoor recreation time spent and number of visits, Scotland, 2004 to 2017



Source: Office for National Statistics and Scottish National Heritage

Comparing Scotland with overall UK figures, Scotland accounted for 13% of estimated UK time spent in outdoor recreation during 2017. The average person in Scotland took 121 outdoor recreation visits in 2017, 46% higher than the UK average of 83.

The average time spent per visit is similar across the UK (4 minutes longer in Scotland in 2017), but Scotland's greater per head visit frequency leads to an average time spent per adult (over 16 years old) on outdoor recreation 62 hours higher in Scotland than the UK average (177 hours and 115 hours respectively). Across the available comparable time series (2009 to 2017), time spent per head on outdoor recreation in Scotland was consistently higher than the UK, averaging 142 hours and 86 hours respectively. Scottish adults on average spent 65% more time on outdoor recreation than the UK average (2009 to 2017).

In Scotland, outdoor activities in cities and towns (urban) were the most common between 2004 and 2012 (37% of time spent, or 182 million hours), followed by the beach (listed as coastal margins 17%), then woodland (14%).

The 2000s saw Scotland move towards a “little and often” approach to outdoor recreation. Across all habitats (but farmland), visit length shortened but increased in number. For most habitats the increasing number of visits outweighed declining visit times to drive growth in overall time spent outdoors. Woodland and lochs (including reservoirs) were the exception to the general trend as the only habitats with a net decline in total time spent between 2004 and 2012.

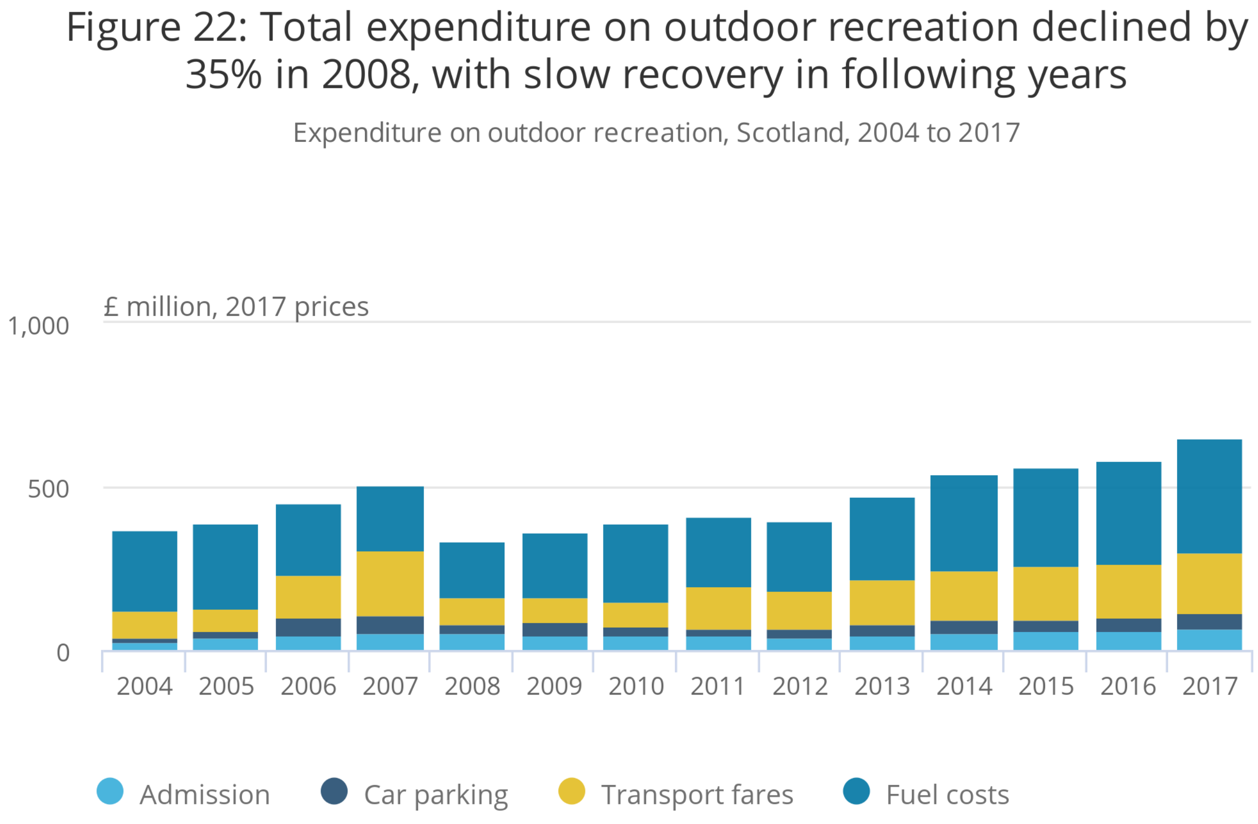
The Scottish population lingered longest when visiting inland lochs (average 2 hours and 59 minutes for a visit, 2004 to 2012). Loch visits were 79% longer than the average (1 hour and 40 minutes). Visits (and other activities) in the mountains and moors were almost as long as lochs, with an average time spent per visit of 2 hours and 42 minutes (61% higher than the average 2004 to 2012).

Like Scotland, in the UK between 2009 and 2012, visits to urban outdoor areas represented the largest proportion of overall time spent (41%). Scottish visitors remained longer in woodlands, farms, and towns and cities (urban) than the average UK visitor between 2009 and 2012 (78%, 34% and 25% more time spent per visit on average respectively). A trip to the beach took similar amounts of time across the UK, with only 1 minute extra spent in Scotland than in the UK average (1 hour and 59 minutes Scotland and 1 hour and 58 minutes UK for coastal margins).

Between 2004 and 2017, spending on outdoor recreation in Scotland increased 75% from £372.5 million to £652 million. This is due to increases in visit numbers, noted in the SPANS dataset, with spend per visit fixed at 2012 levels.

Figure 22: Total expenditure on outdoor recreation declined by 35% in 2008, with slow recovery in following years

Expenditure on outdoor recreation, Scotland, 2004 to 2017



Source: Office for National Statistics and Scottish Natural Heritage

Figure 22 shows, for the years in which we can directly observe spending (2004 to 2012), consistent increases up to 2007 are followed by a clear drop then a comparatively slower recovery. Between 2004 and 2007, spending on outdoor recreation increased (36%), peaking at £507 million in 2007. In 2008 a £0.43 (35%) drop in average expenditure per visit drove overall expenditure decline. After 2008, with increasing visit numbers, expenditure recovered back to approximate 2004 levels before 2012 but still with a lower spend per visit.

Before 2007, an increasing percentage of visitors spent nothing on a trip – up from 63% in 2004 to 72% in 2007, despite 2007 representing a total spending high point. Across the sample, on average, 71% of outdoor recreation visits were enjoyed for free. Interestingly the proportion of visits where nothing was spent fell from 72% in 2007 to 68% in 2008 as total spend fell. The 33% (£169 million) decrease in spending in 2008 also happened despite an increase in visit numbers.

The main drive of the fall was in public transport spending (transport fares), down £117 million (negative 59%). Car parking also fell by £28 million (negative 48%) while fuel costs only dropped by 12% (£4 million). On average over the time series, visitors, who did spend money, spent 54% of it on fuel, followed by transport fares (28%), admissions (11%), then car parking (8%).

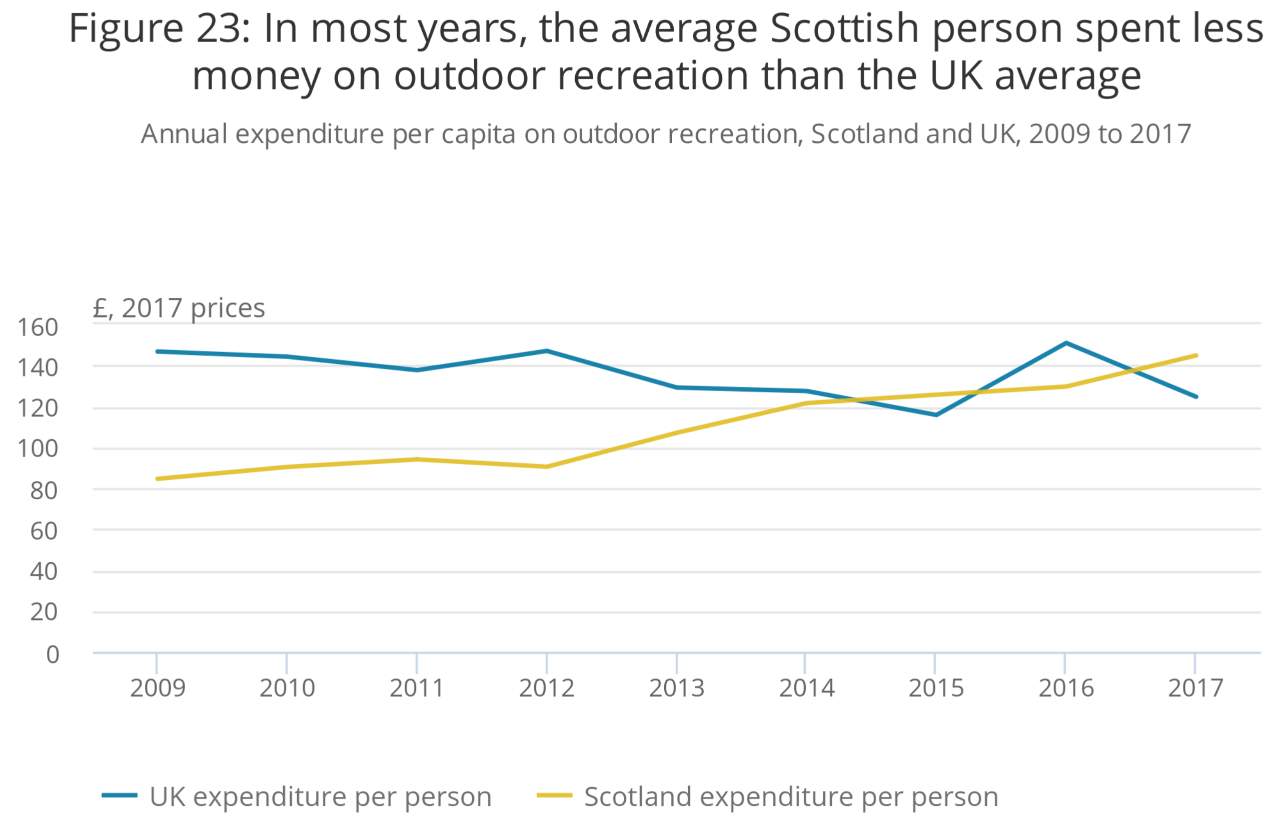
In 2017, UK outdoor recreation was valued at £6,670 million; Scottish visits are estimated at 10% of this (£653 million). Between 2009 and 2017, the value of UK recreation decreased 10% from £7,410 million. In this same period, the value of Scottish outdoor recreation is estimated to have increased 79% from £365 million in 2009 to £652 million in 2017.

Average spend per visit on outdoor recreation in Scotland was £1.07 between 2009 and 2012, which was 75% lower than the UK (£2.27). In the UK expenditure per visit decreased 31% from £2.18 in 2009 to £1.50 in 2017. However, in Scotland expenditure per visit increased 24%, from £0.97 in 2009 to £1.19 in 2012.

Figures 23 and 24 show that Scotland spends more time in the outdoors but less on each trip. For most of the time series the lower per trip spending in Scotland meant the average person spent less on outdoor recreation. Based upon spend per visit in 2012, by 2017 the average person in Scotland spent more each year (£177) than the UK average (£115), driven largely by the higher numbers of visits per person.

Figure 23: In most years, the average Scottish person spent less money on outdoor recreation than the UK average

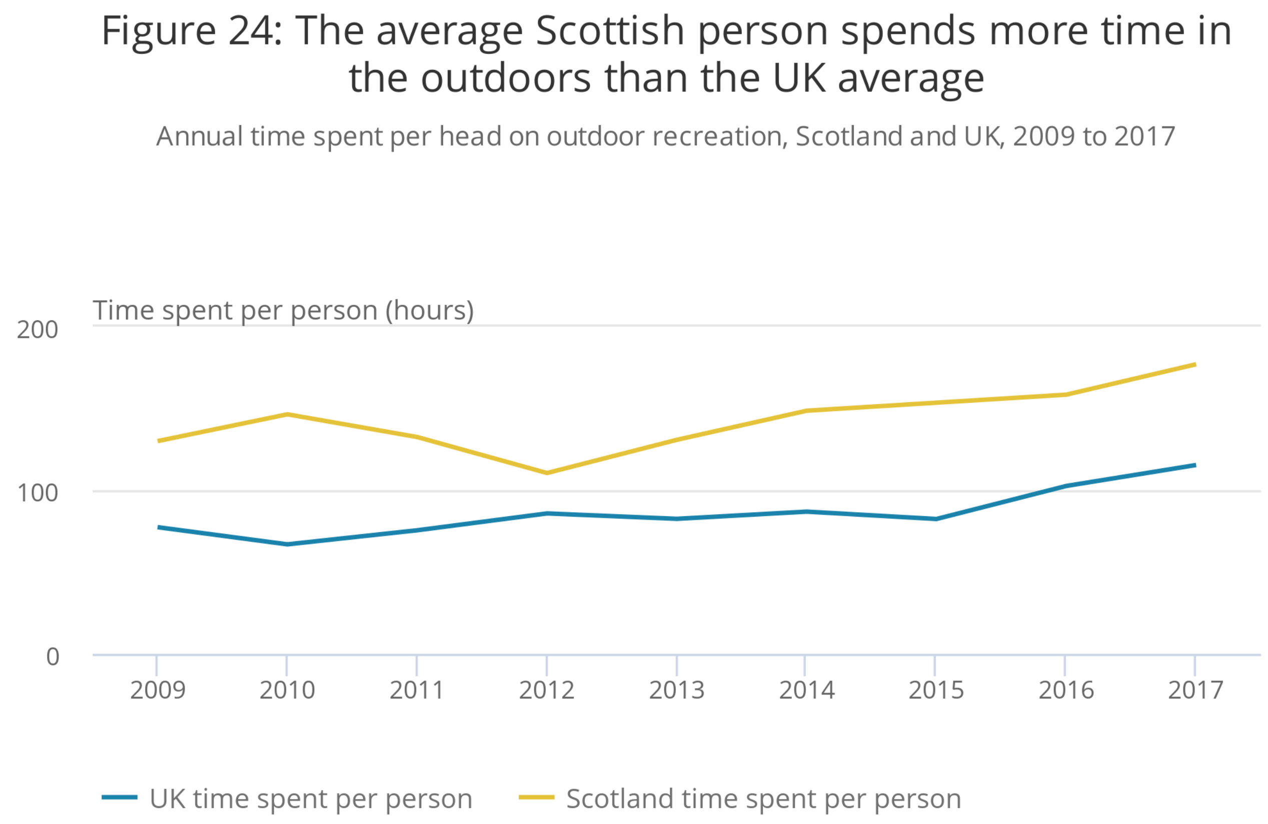
Annual expenditure per capita on outdoor recreation, Scotland and UK, 2009 to 2017



Source: Office for National Statistics and Scottish Natural Heritage

Figure 24: The average Scottish person spends more time in the outdoors than the UK average

Annual time spent per head on outdoor recreation, Scotland and UK, 2009 to 2017



Source: Office for National Statistics and Scottish Natural Heritage

For the years in which we have data (2004 to 2012) the spending by habitat in Scotland was variable but individual habitat trends were relatively stable. Mirroring visitor numbers, urban and coastal margins habitats saw the largest average annual expenditure (£109 million and £95 million respectively). However, while woodland was the third most-visited habitat, on average more money was spent on visits to mountain and moorland annually, at £57 million compared with £50 million for woodland. On average, between 2004 and 2012, expenditure per visit was greatest for visits to lochs (and reservoirs) (£3.07) followed by visits to mountain and moorland (£2.88) and coastal margin (£2.14). Despite having the largest overall expenditure, visits to urban had the lowest expenditure per visit (£0.67).

As with Scotland, between 2009 and 2012, the UK average expenditure was greatest in urban (£2,300 million), followed by coastal margins (£1,600 million). In contrast to Scotland, UK outdoor recreation expenditure in mountain and moorland was the smallest of the broad habitats (£230 million). UK annual expenditure per head in mountain and moorland was £4.50 between 2009 and 2012, as opposed to £14.27 in Scotland.

8 . Asset valuation

Natural capital asset values

The production of oil and gas makes up the majority of total asset valuation in Scotland

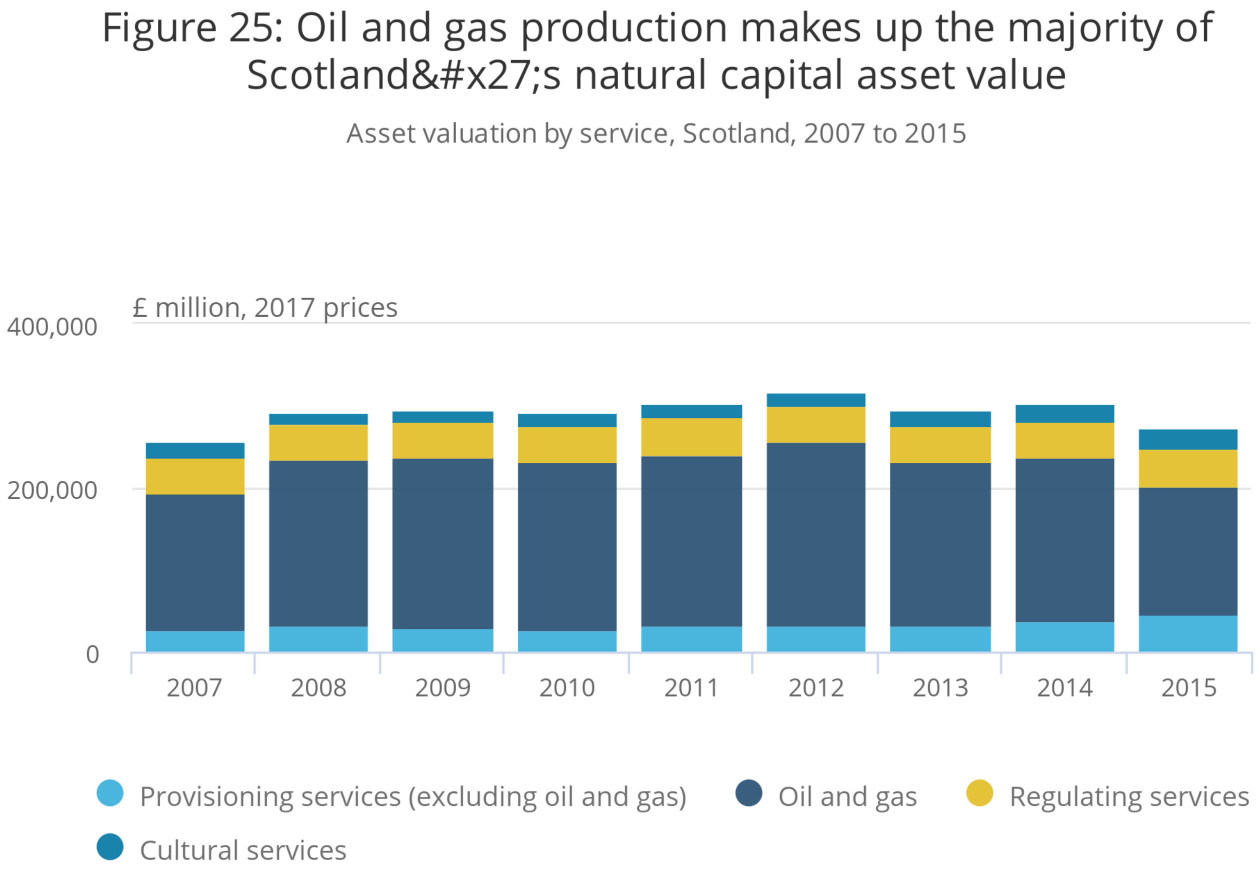
Figure 25 presents the Scottish natural capital asset values between 2007 and 2015 by service. The asset values are estimated by capitalising the annual flow of services from the natural resource that are expected to take place over a projected period. This period is known as the asset life. The annual environmental service flows provide the basis for the projected flows. This method, known as net present valuation (NPV), is explained in more detail in the methodology Section 9 of this article.

The majority of the environmental services presented in this article are produced from renewable resources whose stock is not exhausted over time, for example, Scottish woodland delivering carbon sequestration. For renewable resources, a 100-year asset life has been assumed. The non-renewable abiotic resources presented in this article are minerals, and oil and gas, where an asset life of 25 years has been assumed.

The overall natural capital asset value in Scotland fluctuated between the years 2007 to 2015 (see Figure 25), with asset values reaching a low of £257,937 million in 2007 and a peak of £318,127 million in 2012. In 2015, assets in Scotland were valued at £273,363 million. In 2016 and 2017, it is projected that the overall natural capital asset value will fall due to further decline in the oil and gas asset valuation.

Figure 25: Oil and gas production makes up the majority of Scotland's natural capital asset value

Asset valuation by service, Scotland, 2007 to 2015

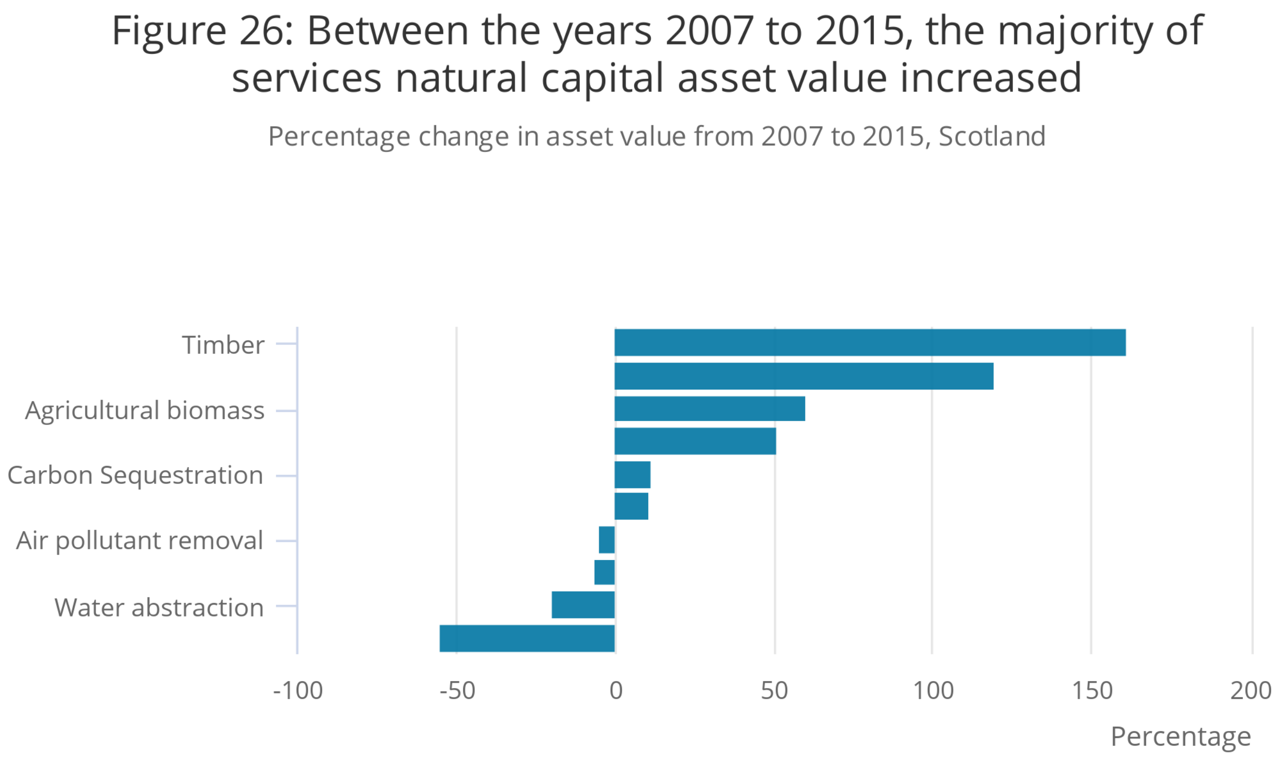


Source: Office for National Statistics

Between the years 2007 and 2015, asset values for the majority of Scottish services increased (see Figure 26). In fact, asset values for both timber and renewable energy more than doubled in this time frame. In contrast, the asset value of minerals has more than halved in this time period.

Figure 26: Between the years 2007 to 2015, the majority of services natural capital asset value increased

Percentage change in asset value from 2007 to 2015, Scotland



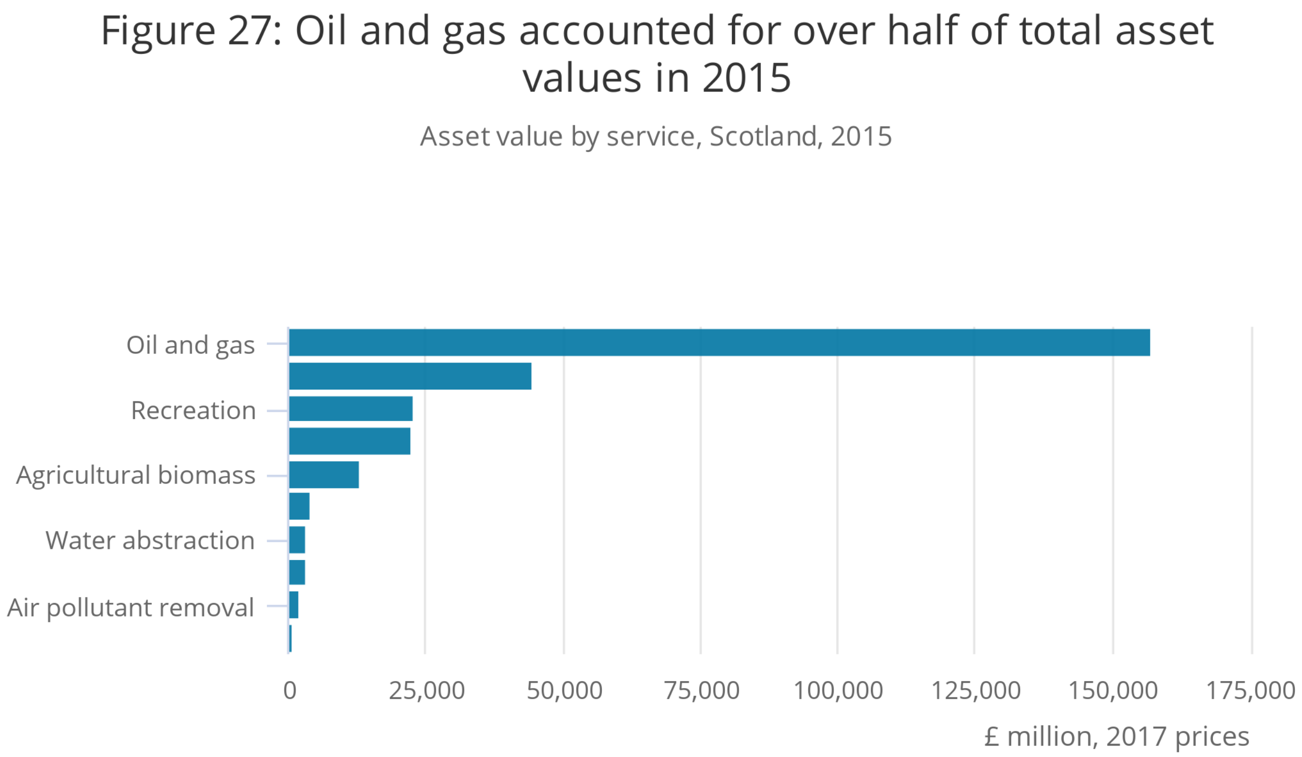
Source: Office for National Statistics

Despite the asset value of oil and gas falling by 6% between the years 2007 and 2015, this sector still made up a large proportion of the asset value of natural capital in Scotland, making up 57% of the total Scottish asset value in 2015 (see Figure 27).

In recent years, the asset value of oil and gas has decreased whilst the asset value of renewable energy has increased. Carbon sequestration was the second-largest contributor towards total asset valuation, making up 16% of the asset value in 2015. The overall asset value of non-material services not directly captured in gross domestic product (GDP) (that is, regulating services and cultural services) represented a quarter of Scotland’s asset value in 2015.

Figure 27: Oil and gas accounted for over half of total asset values in 2015

Asset value by service, Scotland, 2015



Source: Office for National Statistics

With fluctuations, neither the Scottish nor UK overall natural capital asset valuations have clear positive or negative trends. While the natural capital asset valuation in the UK has generally shown slight annual increases, like Scotland, forthcoming overall asset valuations will be increasingly impacted by the fall in the production of oil and gas in Scotland.

Between the years 2009 and 2015, the value of Scotland's natural capital assets made up on average 37% of total UK natural capital assets, largely due to the significant contribution of Scottish oil and gas. Alongside the reduction in oil and gas asset valuation, the contribution of Scotland's natural capital decreased to 34% of UK valuation in 2015.

9 . Quality and methodology

The methodology used to develop these estimates remains under development; the estimates reported in this article are experimental and should be interpreted in this context. Experimental Statistics are those that are in the testing phase, are not yet fully developed and have not been submitted for assessment to the UK Statistics Authority. Experimental Statistics are published to involve customers and stakeholders in their development and as a means of building in quality at an early stage.

This section describes the methodology used to develop Scottish Natural Capital Accounts. The broad approach to valuation and the overarching assumptions made are explained in this section, followed by a more detailed description of the specific methodologies used to value the individual components of natural capital and physical and monetary data sources.

We have used a wide variety of sources for estimates of Scottish natural capital, which have been compiled in line with the guidelines recommended by the United Nations (UN) System of Environmental-Economic Accounting Central Framework and System of Environmental-Economic Accounting Experimental Ecosystem Accounting principles, which are in turn part of the wider framework of the system of national accounts. As the UN guidance is still under development, the Office for National Statistics (ONS) and the Department for Environment, Food and Rural Affairs (Defra) published a summary of the principles underlying the accounts.

An alternative appraisal of Scottish natural capital is available through Scottish Natural Heritage's Natural Capital Asset Index (NCAI). The NCAI is a composite index which analyses nature's potential contribution to the wellbeing of Scotland's citizens.

We welcome discussion regarding any of the approaches presented.

Annual ecosystem service flow valuation

Two approaches are used to value the annual service flows. For carbon sequestration, pollution removal, recreation and timber, an estimate of physical quantity is multiplied by a price. This price is not a market price but satisfies two accounting conditions:

- firstly, identifying a price that relates, as closely as possible, to contributions provided by the ecosystem to the economy
- secondly, where no market exists, imputing a price that an ecosystem could charge for its services in a theoretical market

These conditions are necessary to integrate and align ecosystem services to services elsewhere in the national accounts, for example, in the accounts woodland timber is an input to the timber sector.

For agricultural biomass, fish capture, water abstraction, minerals, and oil and gas, a "residual value" resource rent approach is used. Before detailed data source and methodology is described, the resource rent approach is defined.

Resource rent definition and assumptions

The resource rent can be interpreted as the annual return stemming directly from the natural capital asset itself, that is, the surplus value accruing to the extractor or user of a natural capital asset calculated after all costs and normal returns have been considered.

The steps involved in calculating the resource rent are given in Table 1. Variations of this approach are applied depending on the category of natural capital under assessment; the variations are explained in the individual ecosystem service methodology.

Table 1: Derivation of resource rent

	Output
Less	Operating costs
	Intermediate consumption
	Compensation of employees
	Other taxes on production PLUS other subsidies on production
Equals	Gross operating surplus – SNA basis
Less	Specific subsidies on extraction
Plus	Specific taxes on extraction
Equals	Gross operating surplus – resource rent derivation
Less	User costs of produced assets (consumption of fixed capital and return to produced assets)
Equals	Resource rent

Source: Office for National Statistics

Most of the data used in Scottish resource rent calculations are available from the Scottish Government input-output tables (1998 to 2015). Return to produced asset estimates are calculated using apportioned industry-based net capital stocks and the nominal 10-year government bond yield published by the Bank of England, then deflated using the gross domestic product (GDP) deflator to produce the real yield. This rate is relatively conservative compared with those expected in certain markets and could overstate the resulting resource rent estimates.

Technical guidance on SEEA Experimental Ecosystems Accounting (page 107) (PDF, 2.9MB) acknowledges that the use of the method may result in very small or even negative resource rents. Obst, Hein and Edens (2015) conclude that:

“resource rent type approaches are inappropriate in cases where market structures do not permit the observed market price to incorporate a reasonable exchange value for the relevant ecosystem service. Under these circumstances, alternative approaches, for example, replacement cost approaches, may need to be considered”

If the residual value approach does not produce plausible estimates for subsoil assets and provisioning services, alternative methods should be explored (Principle 7.7). Finally, where unit resource rents can be satisfactorily derived, care still needs to be taken in applying these at a disaggregated level. Even for abiotic flows, the extraction or economic costs could vary spatially and hence national unit resource rents could be misleading for specific regions.

Asset valuation

The net present value (NPV) approach is recommended by the System of Environmental-Economic Accounts (SEEA) and it is applied for all ecosystem services to estimate the asset value. The NPV approach estimates the stream of services that are expected to be generated over the life of the asset. These values are then discounted back to the present accounting period. This provides an estimate of the capital value of the asset relating to that service at a given point in time. There are three main aspects of the NPV method:

- pattern of expected future flows of values
- asset life – time period over which the flows of values are expected to be generated
- choice of discount rate

Pattern of expected future flows of services

An important factor in the valuation of natural capital is determining the expected pattern of future flows of services. These paths are not observed and hence assumptions concerning the flows must be made, generally as a projection of the latest trends. A more basic way to estimate the expected flows is to assume that the current flow (averaged over recent years) is constant over the asset life, but this might not be the case. In some cases, more information is available on future expected levels of services in non-monetary terms or future unit prices. Where there are readily available official projections these have been considered but otherwise the default assumption in these estimates is that the value of the services is constant over time.

This article assumes constant service values throughout the asset life, except for the estimates for carbon sequestration and air pollutant removal by vegetation, where further projections are used.

Where the pattern of expected service values is assumed to be constant, it is based on averages over the latest five years, up to and including the reference year in question. This is set out in Figure 28.

Figure 28: Equation to calculate future service values

$$SV_t = \frac{SV_{t-4} + SV_{t-3} + SV_{t-2} + SV_{t-1} + SV_t}{5}$$

Where SV equals service value and t equals reference year.

Asset life

The asset life is the expected time over which the services from a natural resource are expected to be provided. An estimate of the asset life is an important component in the NPV model because it determines the expected term over which the service flows from an asset should be discounted.

Following the ONS and Defra principles paper, this article takes one of three approaches when determining the life of a natural capital asset.

Non-renewable natural capital assets: Where a sufficient level of information on the expected asset lives is available this asset life is applied in the calculations. Where a sufficient level of information on their respective asset lives is not available a 25-year asset life is assumed.

Renewable natural capital assets: A 100-year asset life is applied to all assets that fall within this category of natural capital.

Choice of discount rate

A discount rate is required to convert the expected stream of service flows into a current period estimate of the overall value. A discount rate expresses a time preference – the preference for the owner of an asset to receive income now rather than in the future. It also reflects the owner's attitude to risk. The use of discount rates in NPV calculations can be interpreted as an expected rate of return on the environmental assets.

Based on an extensive review (PDF, 453KB) by external consultants, the ONS and Defra use the social discount rate set out in the HM Treasury Green Book (2003, page 100). In line with guidance set out in the document, estimates presented in this article assume a 3.5% discount rate for flows projected out to 30 years, declining to 3.0% thereafter and 2.5% after 75 years. The rationale for this approach is discussed further in the ONS and Defra principles paper.

Methodology by service

Table 1 provides a broad overview of the steps involved in calculating a resource rent using a residual value approach. While this method forms the overarching basis to producing many of the estimates presented in this article, slight adjustments to the method are required for individual service flows. The following section provides an in-depth explanation of the adjustments made for each service, together with more detail where the resource rent approach has not been used.

Agricultural biomass

Agricultural biomass relates to the value of crops, fodder and grazed biomass provided to support agricultural production in Scotland. Physical production of cereals, fruit, and vegetables is published by the Scottish Government. Grazed biomass calculations are based upon Scottish livestock numbers, from the Scottish Agriculture Census and livestock annual roughage requirements provided in the Eurostat Economy-wide Material Flow Accounts (EW-MFA) questionnaire. This approach is used in the UK Ecosystem Service Accounts (PDF, 3.0 MB) and UK Material Flows Accounts.

For the valuation of agricultural biomass a "residual value" resource rent approach is used. This is based upon data for the Standard Industrial Classification (SIC) subdivision class: crop and animal production, hunting and related service activities (SIC 01). The approach can produce quite low values for the ecosystem service, but this is not wholly unexpected as anthropogenic inputs into the production are so significant.

In estimating the resource rent for the Scottish agricultural biomass provisioning service Scottish input-output tables and source-level apportioning of ONS UK capital stocks is used. The factor used for apportioning net capital stocks and consumption of fixed capital is the proportional relationship between Scotland and UK aggregate agriculture accounts consumption of fixed capital.

Estimating the proportion of agricultural production, which can be attributed to nature rather than modern intensive farming practices, is challenging. Modern farmers heavily manage and interact with the natural services supplied on their land. For example, sowing, irrigation, fertiliser spreading, pesticide use and livestock management are all industrial practices applied to the land. Very intensive farming may even take place entirely indoors without soil or natural light. At the other extreme, livestock may be allowed to roam freely over semi-natural grassland with very limited human intervention.

As with the principles applied to the UK Natural Capital Accounts, we draw the line between the farmland ecosystem and the economy at the point at which vegetable biomass is extracted (Principle 5.3). This means farmed animals are not included in these estimates as they are considered as produced rather than natural assets, instead the grass and feed that livestock eat are regarded as ecosystem services and so are included. This is also consistent with the boundary between the environment and the economy used in the material flows accounts.

Fish capture

Physical data on marine fish capture (live weight) is sourced from the rectangle-level landings data published annually by the EU Commission's Joint Research Centre (JRC) Scientific, Technical and Economic Committee for Fisheries (STECF) as part of the Fisheries Dependent Information (FDI) data call (deep sea).

Both the Scottish Government and the Marine Management Organisation (MMO) publish similar landings data by ICES (The International Council for the Exploration of the Sea) rectangle but the data coverage is not as comprehensive.

To calculate marine fish capture in the Scottish exclusive economic zone (EEZ) MMO ICES statistical rectangle factors were used. The overall fish capture provisioning service physical flow presented in this article represents landings (tonnage) from Scottish waters. Physical flow presented in the 1997 to 2015 UK Ecosystem Service Accounts was sourced from the Food and Agriculture Organisation (FAO) and represented the fish capture of the UK, not fish capture from UK waters. For comparable data, which are used in analysis, on landings by Scottish vessels and landings into Scottish ports see Scottish Sea Fisheries Statistics 2017. Freshwater fish capture data are available from Marine Scotland.

Valuations are calculated using a resource rent-based approach on the industry subdivision: fishing (SIC 03.1). In estimating the resource rent for the Scottish fish capture provisioning service Scottish input-output tables and source-level apportioning of ONS UK capital stocks is used. The factor used for apportioning net capital stocks and consumption of fixed capital was the proportional annual relationship between Scotland fishing (SIC 03.1) and UK fishing and aquaculture (SIC 03) intermediate consumption at purchasers' prices. The Scottish fish capture provisioning service valuation should be interpreted as a minimum valuation as it excludes fish capture in Scottish waters not represented in Scottish National Accounts.

Aquaculture or farmed fish, like farmed livestock, have been removed from estimates, as farmed fish are viewed as a produced asset and not a natural asset. This method does not recognise that farmed fishing may have different productivity and resource intensity than catching fish at sea or in inland waters. Further work is needed to assess if other data sources could be used to estimate the value of caught fish only.

Timber

The method used to value the provisioning services related to timber supply requires two inputs: the stumpage price and the physical amount of timber removed. Annual flow values are then generated by multiplying the two factors together.

Removals estimates are taken from Forestry Commission Timber Statistics and converted from green tonnes to metres cubed (m3) overbark standing, using a conversion factor of 1.222 for softwood and 1.111 for hardwood.

The stumpage price is the price paid per standing tree, including the bark and before felling, from a given land area. Stumpage prices may include some management overheads and return to capital but these amounts are not expected to be significant. Stumpage prices are sourced from the Forestry Commission Coniferous Standing Sales Price Index in the Timber Price Indices publication (2018). The Coniferous Standing Sales Price Index monitors changes in the average price received per cubic metre (overbark) for timber that the Forestry Commission or Natural Resources Wales sold standing, where the purchaser is responsible for harvesting.

Water abstraction

Physical estimates of water abstraction for public water supply are available from Scottish water.

Monetary estimates are based on the "residual value" resource rent approach calculated for the SIC subdivision class: water collection, treatment and supply (SIC 36). The definition of this industry subdivision states:

“the collection, treatment and distribution of water for domestic and industrial needs. Collection of water from various sources, as well as distribution by various means is included”

A limitation of this approach, therefore, is that the calculated resource rent is not purely related to water supply, but also includes the process of treating the water.

As with the UK Ecosystem Service Accounts, the valuation of water abstraction does not include significant uses, particularly in Scotland, such as drinks manufacturing and hydroelectric power.

In estimating the resource rent for the Scottish water abstraction provisioning service Scottish input-output tables and source-level apportioning of ONS UK capital stocks is used. The factor used for apportioning net capital stocks and consumption of fixed capital was the proportional annual relationship between Scotland and UK water collection, treatment and supply (SIC 36) intermediate consumption at purchasers' prices.

Future work is required to better value the range of services relating to water provided by the natural environment. The residual value method has in our experience to date generated a relatively high resource rent for public water supply, which could be considered inconsistent with the concept of a price regulator and normal returns.

In future, water may be traded between water companies although the prices charged may depend more upon covering the overheads of delivery than on the value of the resource on its own. It is also possible that abstraction licence charges may provide an estimate of the amount of resource rent captured by the government. This requires further research.

Minerals

Physical estimates of mineral extraction in Scotland have been provided by the British Geological Survey (BGS) as a country-level breakdown of the United Kingdom Minerals Yearbook.

Monetary estimates are based on the “residual value” resource rent approach calculated from the SIC subdivision class: other mining and quarrying (SIC 08). In estimating the resource rent for the Scottish minerals abiotic provisioning service Scottish input-output tables and source-level apportioning of ONS UK capital stocks is used. The factor used for apportioning net capital stocks and consumption of fixed capital was the proportional annual relationship between Scotland and UK other mining and quarrying (SIC 08) intermediate consumption at purchasers' prices.

Oil and gas

Physical estimates of oil and gas production in Scotland are available from the Scottish Government Oil and Gas production statistics 2017 to 2018.

Monetary estimates are based on the methodology published by the ONS in June 2013, following a “residual value” resource rent approach calculated from the SIC subdivision class: extraction of crude petroleum and natural gas (SIC 06). Production statistics are combined with oil and gas price data supplied by the Oil and Gas Authority (OGA) to calculate income. Deductions are then made for operating expenditure, sourced from Scottish Government and user costs of produced assets, apportioned from ONS UK capital stocks data. The factor used for apportioning net capital stocks and consumption of fixed capital was the proportional annual relationship between Scotland and UK oil and gas production.

As with the 1999 to 2015 UK Ecosystem Service Accounts, for asset valuation of oil and gas an asset life of 25 years has been assumed. Asset valuation utilises annual projected UK oil and gas production from the OGA until 2035. Then, following OGA methodology, assumes a further 5% production decline per year (for all years following 2035) to be able to project over the full 25-year asset lifetime. UK production projections are apportioned for Scotland based upon current Scottish contribution to UK production. To estimate valuations in future years annual five-year averages of "unit resource rent" (average resource rent divided by average production) are applied to production projections.

As with all services, the methods used will be reviewed for future updates.

Renewables

Energy generated by renewable sources is published in the Scottish Government Energy Statistics Database. Other biofuels renewable sources published in the reference tables include energy from waste combustion, co-firing with fossil fuels, animal biomass and anaerobic digestion.

The monetary estimates are gross value added (GVA) only and not resource rent calculations, therefore are over-estimates. GVA estimates were calculated on the same basis as the UK environmental goods and services sector (EGSS) estimates. A detailed publication on EGSS estimates was published in May 2018.

GVA attributed to electric power generation, transmission and distribution is derived from the Scottish input-output tables using classification of product by activity (CPA) 35.1. These data are then apportioned using detailed information from the ONS regional Annual Business Survey (ABS) to derive the GVA of 35.11: production of electricity. Then differential levelised costs of production (Department for Business, Energy and Industrial Strategy) between conventional and renewable electricity generation, weighted by the physical amount of electricity generated by the different sources, were applied to the GVA of electric power generation to estimate the GVA of electricity from renewable sources.

A "levelised cost" is the average cost of the lifetime of the plant per megawatt-hour of electricity generated. They reflect the cost of building, operating and decommissioning a generic plant for each technology.

Using current methods for renewable electricity generation valuation, decreasing levelised costs of renewable generation acts as a counterweight to increasing generation.

Carbon sequestration

Estimates relate to the removal of carbon gas from the atmosphere by Scottish terrestrial ecosystems. The approach used combines data on the physical changes in subdivisions of the land use, land-use change, and forestry (LULUCF) sector (published in the Greenhouse gas inventory and LULUCF emission projections, with information on the central non-traded price of carbon.

Due to data constraints, values related to carbon sequestration by marine ecosystems, including those intertidal areas such as coastal margins, are not included in current estimates. As a result, annual flow values related to carbon sequestration services are likely to be an underestimate.

The LULUCF sector breakdown identifies carbon sequestration activities in the following subcategories:

- forest land remaining forest land
- land converted to forest land
- grassland remaining grassland
- land converted to grassland

For the years 1990 to 2016, actual physical estimates of carbon sequestration by land use class are sourced from the greenhouse gas inventory. In the asset valuation, projections of carbon sequestration rates are provided for the years 2017 to 2050 by the National Atmospheric Emission Inventory (NAEI) in the LULUCF emission projections. Central projections are used. For years used in the projections beyond 2050, the carbon sequestration rate is assumed to be constant as at 2050 levels.

The carbon price used in calculations is based on the projected non-traded price of carbon schedule. This is contained within the data table 3 of the Green Book supplementary guidance. Carbon prices are available from 2010 to 2100. Prices prior to 2010 are backdated in line with recent trends. Prices beyond 2100 are assumed to be constant at 2100 levels.

The non-traded carbon prices are used in appraising policies influencing emissions in sectors not covered by the EU-ETS (the non-traded sector). This is based on estimates of the marginal abatement cost (MAC) required to meet a specific emission reduction target. Beyond 2030, with the development of a more comprehensive global carbon market, the traded and non-traded prices of carbon converge into a single-traded price of carbon.

Air pollutant removal by vegetation

Air quality regulation estimates have been supplied in consultation with the Centre for Ecology and Hydrology (CEH). A full methodology report published in July 2017 is available.

Calculation of the physical flow account uses the European Monitoring and Evaluation Program Unified Model for the UK (EMEP4UK) atmospheric chemistry and transport model, which generates pollutant concentrations directly from emissions and dynamically calculates pollutant transport and deposition, considering meteorology and pollutant interactions.

The health benefits were calculated from the change in pollutant exposure from the EMEP4UK scenario comparisons, that is, the change in pollutant concentration to which people are exposed. Damage costs per unit exposure were then applied to the benefitting population at the local authority level for a range of avoided health outcomes:

- respiratory hospital admissions
- cardiovascular hospital admissions
- loss of life years (long-term exposure effects from PM2.5 and nitrogen dioxide (NO2))
- deaths (short-term exposure effects from ozone (O3))

Some years generated negative values for the economic value of NO2 removal. In cases where a net disservice is presented the economic value is adjusted to zero.

Future flow projections used for asset valuation incorporate population projections and an assumed 2% increase in income per year (declining to 1.5% after 30 years and 1% after 75 years). Income elasticity is assumed to be 1. More work is being conducted in this area.

Recreation

The recreation estimates are adapted from the “simple travel cost” method developed by Ricardo-AEA. The methodological report [Reviewing cultural services valuation methodology for inclusion in aggregate UK natural capital estimate is available]. This method was originally created for use on the Monitor of Engagement with the Natural Environment (MENE) Survey, which covers recreational visits by respondents in England.

The method looks at the expenditure incurred to travel to the natural environment and expenditure incurred during the visit. This expenditure method considers the market goods consumed as part of making the recreational visit (that is, fuel, public transport costs, admission charges and parking fees). This expenditure is currently assumed as a proxy for a marginal price for accessing the site.

The 2003 to 2012 Scottish Recreation Survey (ScRS) was the primary data source used in producing the recreation estimates in this article. The ScRS questions used in the method largely mirrored those in the MENE survey. The ScRS ran between 2003 and 2012 and was undertaken through the inclusion of a series of questions in every monthly wave of the TNS consumer omnibus survey, the Scottish Opinion Survey (SOS).

In every month of the Scottish Opinion Survey around 1,000 face-to-face interviews are undertaken with adults in Scotland aged 16 years and over. The survey approach followed ensures that the resultant sample is consistently representative of the Scottish adult population in terms of sex, age group, working status and socioeconomic status. Replacing the ScRS, Scottish Natural Heritage commissioned the Scotland’s People and Nature Survey (SPANS) for the first time in 2013 to 2014, then again in 2017 to 2018.

These surveys focus on short day-trips from home and miss out potentially large amounts of spending on outdoor activity from domestic tourism, which future reports will include.

Unlike ScRS, the SPANS does not include questions on respondent expenditure during their last outdoor recreation visit. To produce estimates beyond 2012, expenditure and time spent in 2012, from the ScRS, have been scaled in accordance with SPANS visit numbers. This method has been taken to produce timely estimations of overall Scottish natural capital asset value, which are comparable with the [1997 to 2015 UK Ecosystem Service Accounts]. In future releases, we will seek to fully incorporate SPANS data on time spent, and calculated fuel costs to increase the accuracy of estimates. Beyond 2012, habitat disaggregation of Scottish outdoor recreation is not currently available.

Habitat disaggregated estimations of expenditure and time spent may not sum to overall time spent. This is because habitat estimates were based upon a portion of the sample, which answered a question on habitats visited.

The visits numbers are taken directly from the habitats that each respondent reported. The visit weighting is split equally across all habitats reported by each participant. The time spent in the habitat is calculated by taking the total time (including travel time), which is asked in the survey and subtracting an estimated travel time. Travel time is calculated using the reported distance travelled to get to the visit, which is multiplied by the average speed relating to the form of transport used, taken from the Ricardo report.

The “simple travel-cost” method used on the ScRS data forms a monetary estimate for the amount a person is willing to spend visiting the natural environment. This is done by adding the reported costs on admissions, car parking and bus, train or ferry fares; for participants who travelled by car, motorcycle or taxi then the cost was calculated and added. The reported fuel costs were deemed to be unreliable for the purposes of this estimation. The fuel costs for these vehicles are estimated using the mileage and multiplied by a cost per mile value, which is taken from the Ricardo report.

The UK estimates are scaled from the MENE survey to represent the UK population. Therefore, since UK estimates did not include Scottish, Welsh, or Northern Ireland surveys, comparisons between Scottish and UK values are, in effect, comparisons with inflated English trends. We will seek to fully incorporate additional surveys, such as ScRS and SPANS, in future UK estimations of outdoor recreation.

Question 7 in the Scottish Recreation Survey asks respondents about what types of location they visited on their last outdoor recreation visit. These locations form the basis of broad habitat disaggregation of outdoor recreation estimates in this article.

Table 2: Broad habitat classifications derived from Scottish Recreation Survey destinations (Question 7)

Broad habitat	Scottish Recreation Survey habitats
Woodland	Woodland\forest – managed by Forestry Commission\Forest Enterprise
	Woodland\forest – other type of owner
	Woodland\forest – don't know owner
Mountain and moorland	Mountain\moorland
	Moorland
	Mountain\hill
Rivers and canals	River\canal
	River
	Canal
Farmland	Farmland – fields of crop
	Farmland – fields with livestock
	Farmland – mixed crop and livestock
	Farmland unspecified
	Country\countryside
Coastal margin	Beach
	Cliff
	Beach\cliff
	Sea\sea-loch
Wildlife area	Wildlife areas
Lochs and reservoirs	Lochs
	Reservoirs
Urban	Village
	Local park or open space
	Towns
	Golf course\football stadium
	Local urban
	Local area
	City
	Country lanes
	Castle\historical building
	Local show\festival
	Leisure\sports centre
	Streets\roads
	Garden
Other	Other
	None of these

Source: Office for National Statistics

In the ScRS there is a question for the main habitat that was visited; it was considered that this could be used as opposed to splitting the respondent data across the habitats they reported visiting, however, it was decided that the same method should be used to ensure the Scottish estimates would be as comparable as possible with the UK estimates.

For the asset valuation of outdoor recreation in Scotland, projected population growth calculated from ONS population statistics and income uplift assumption, matching the method used in the most recent UK ecosystem services accounts, were implemented into the estimation. The income uplift assumptions are 1%, declining to 0.75% after 30 years and 0.5% after a further 45 years.

It is acknowledged that the “simple travel-cost method” provides an underestimation of the monetary worth of the natural environment. Primarily, this is because there are several benefits that are not accounted for including scientific and educational interactions, health benefits and aesthetic interactions. Currently, there is no method in use that incorporates these considerations. Additionally, the value of the time spent by people in the natural environment is not incorporated because no method is thought to be reliable enough to accurately capture this.