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AGRICULTURE, ENVIRONMENT, MARINE AND ECONOMY

Scottish natural capital accounts: 2021

1. Main points

Overview

Natural capital is the world's stock of natural resources. This includes air, water, minerals and all living things. These natural resources underpin our society and economy because they provide a wide range of benefits (e.g. pollution removal, carbon sequestration, flood management etc.). These benefits are often known as 'eco-system services'.

The benefits derived from our natural assets can be divided into three categories:

- **provisioning services** that create products such as food, water, and minerals.
- **regulating services** such as air pollution removal and carbon sequestration; and
- **cultural services** such as recreational use of nature.

This publication looks at natural capital assets, including the physical and monetary flows of assets and the values of services that they provide. These terms help us think logically about how to measure aspects of the natural world and their impact upon people. Throughout, the benefits resulting from our natural assets are grouped by the types of services that they provide (i.e. provisioning, regulating or cultural).

Scotland's natural capital accounts have been produced by the Office for National Statistics who also produce UK natural capital accounts. Several ecosystem services are not being measured in this article, such as flood mitigation and wider recreation values found in tourism as opposed to the day visits we do capture, so the monetary accounts should be interpreted as a partial or minimum value of Scottish natural capital.

Asset valuation

- Scottish natural capital assets that we can currently value were estimated to be £156 billion in 2017, 17% of the UK asset value.
- The total asset value has fallen from £191 billion in 2016. This decrease is due to a fall in the asset value of fossil fuels, driven by a fall in the global price of oil.
- 55% of the total asset value came from provisioning services. The largest element of this was fossil fuels, which accounted for 30% of the total Scottish asset value in 2017.
- The asset value of regulating and cultural services, which are not directly included in national accounts, amounted to £68 billion in 2017, or 44% of Scotland's total quantified natural asset value. The largest single service not included in national accounts was carbon sequestration (a regulating service) with an asset value of £42 billion in 2017.

Annual monetary flows

- The total value of annual monetary flows in 2017 was £7 billion. The largest monetary annual flow was from fossil fuels (£4 billion), followed by carbon sequestration (£775 million) and agricultural biomass (£562 million).
- The timber provisioning service valuation has increased by 253% over the last decade from £69 million in 2009 to £244 million in 2019. This has been driven by a 21% increase in production and a 191% increase in price over the last decade
- Living near publicly accessible green and blue spaces added on average £2,438 to property prices in Scottish urban areas during 2016.

Annual physical flows

- On average 70% of UK waters fish capture tonnage came from Scottish waters between 2015 and 2018.
- Scottish renewable energy generation reached 28,236 GWh in 2019, increasing by 743% from 2003, driven largely by growing wind energy provisioning.
- During 2018, over 1 billion hours were spent on Scottish outdoor recreation (including travel time) over an estimated 534 million visits.

2. Things you need to know about this release

This article looks at natural capital assets, including the flows and values of services. These terms help us think logically about how to measure aspects of the natural world and their impact upon people. Natural capital assets are environmental resources that persist long-term, such as mountains, woodlands, or a fish population.

From these assets, people receive a flow of services, such as mountain hikes and fish captured for consumption. 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 any profit from bringing the fish into the market. Applying this logic consistently across assets and services enables us to start building accounts of Scotland's nature.

Where available, estimates are presented between the period 1998 to 2019 and all monetary valuations are given in 2019 prices. Because of data coverage constraints, 2017 is the latest year we can estimate an overall Scottish natural capital asset value.

The Scottish and UK accounts remain experimental and future publications will be subject to methodological improvements. There have been fewer methodological improvements since the Scottish Natural Capital accounts: 2020 than between that and the Scottish natural capital accounts: 2019; however, we still caution against comparison between accounts. Please use the data available alongside this release for time series analysis.

For context, the £196 billion (in 2018 prices) asset value of natural capital for 2016 in the 2020 accounts is now 4% lower (£188 billion in 2018 prices) based upon the methodological differences in this publication. In addition to the decrease caused by the methodological improvements, there has been a further 19% real drop in asset valuation between 2016 and 2017.

Readers should also be cautious in how they interpret a fall or increase in value. An increase in asset value does not directly measure an increase in the quality or quantity of an asset. If there are crop failures in other parts of the world then farming in Scotland might be worth more with no change in yield. The change in value is still interesting but requires analysis. This is equally true of "air pollution removal" which might fall in value when the total air pollution requiring removal falls. This would actually be a good outcome with no signal that Scottish vegetation's capacity to remove air pollution is degraded.

Several ecosystem services are not being measured in this article, such as flood mitigation, water quality regulation and tourism, so the monetary accounts should be interpreted as a partial or minimum value of Scottish natural capital.

3. Provisioning services

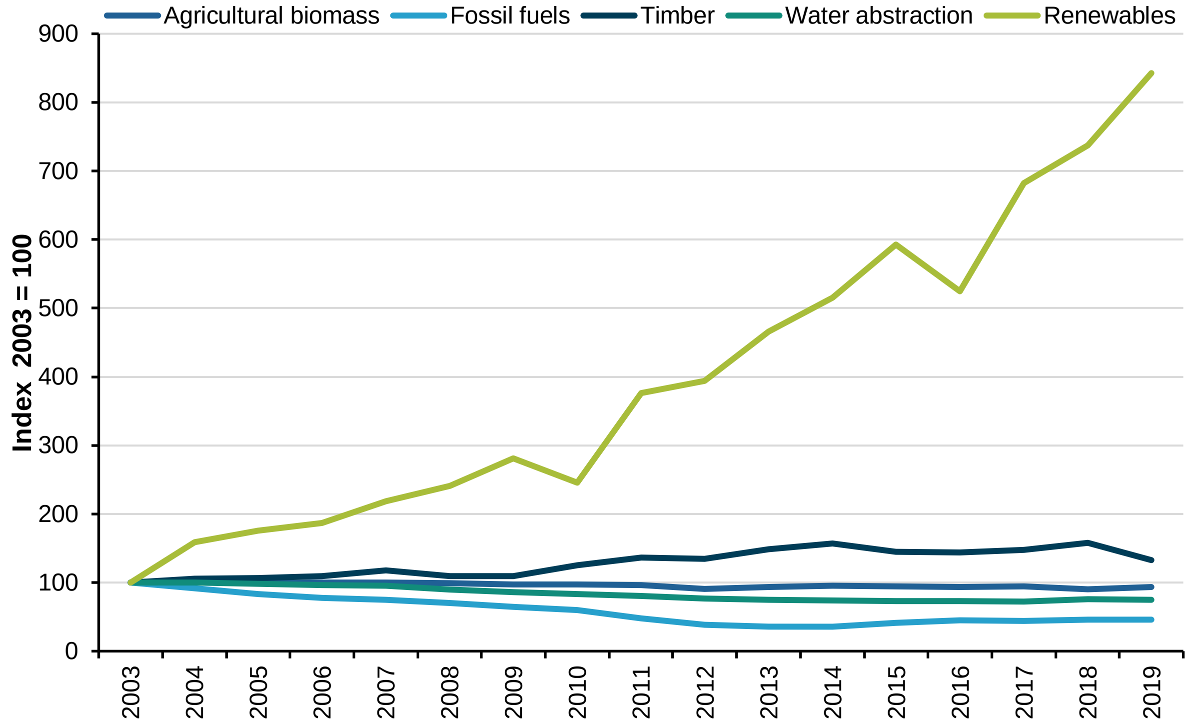
Provisioning ecosystem services create products that include food, water, and materials. These are produced by nature, extracted, and then consumed by society. Provisioning services are largely based on existing market prices. This means that the asset values of these services are subject to changes in market conditions, such as price changes. These price changes can often distort how natural assets are valued, and therefore a wider view of our interrelated economy must be taken to understand asset value behaviour. Utilising the provisioning services of a natural asset may impact its ability to provide regulating or cultural ecosystem services.

Provisioning services currently included in the Scottish ecosystem accounts are:

- Agricultural biomass
- Fish capture
- Timber
- Water abstraction
- Minerals
- Fossil fuels
- Renewable energy

Figure 1: Renewable energy provisioning was eight times larger in 2019 than in 2003

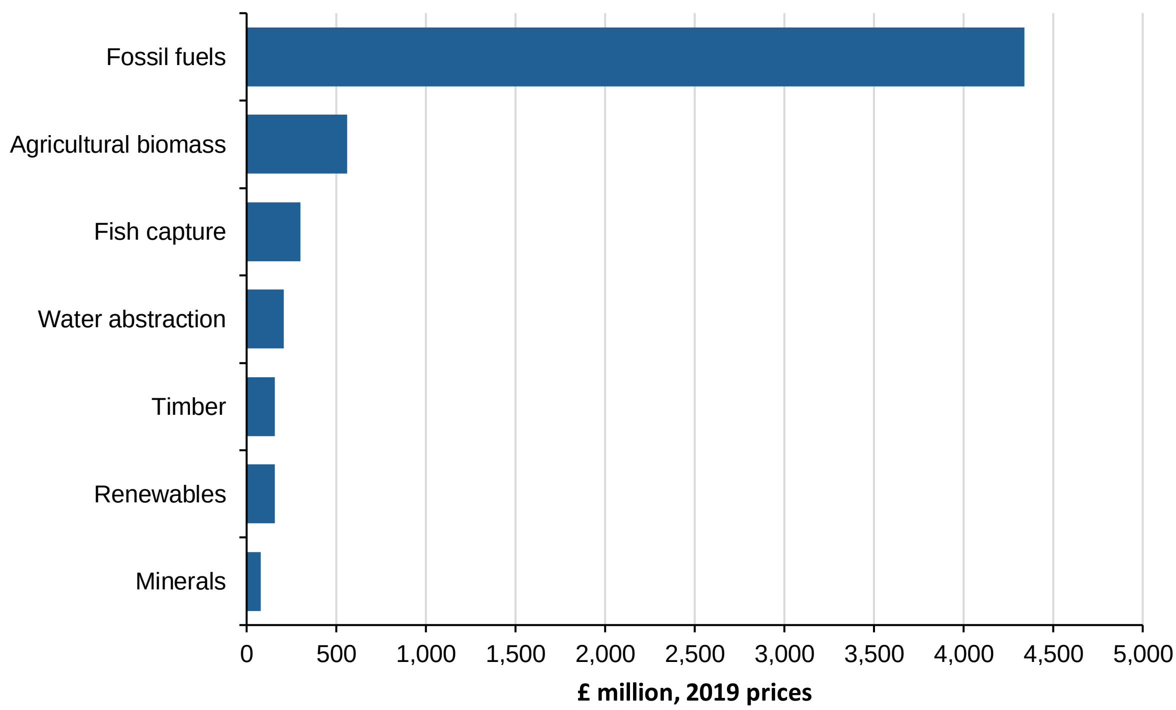
Index of provisioning services physical flow (index 2003=100), Scotland, 2003 to 2019



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

Figure 2: Fossil fuels continue to dominate the annual value of the provisioning services, representing 79% of the total value in 2017

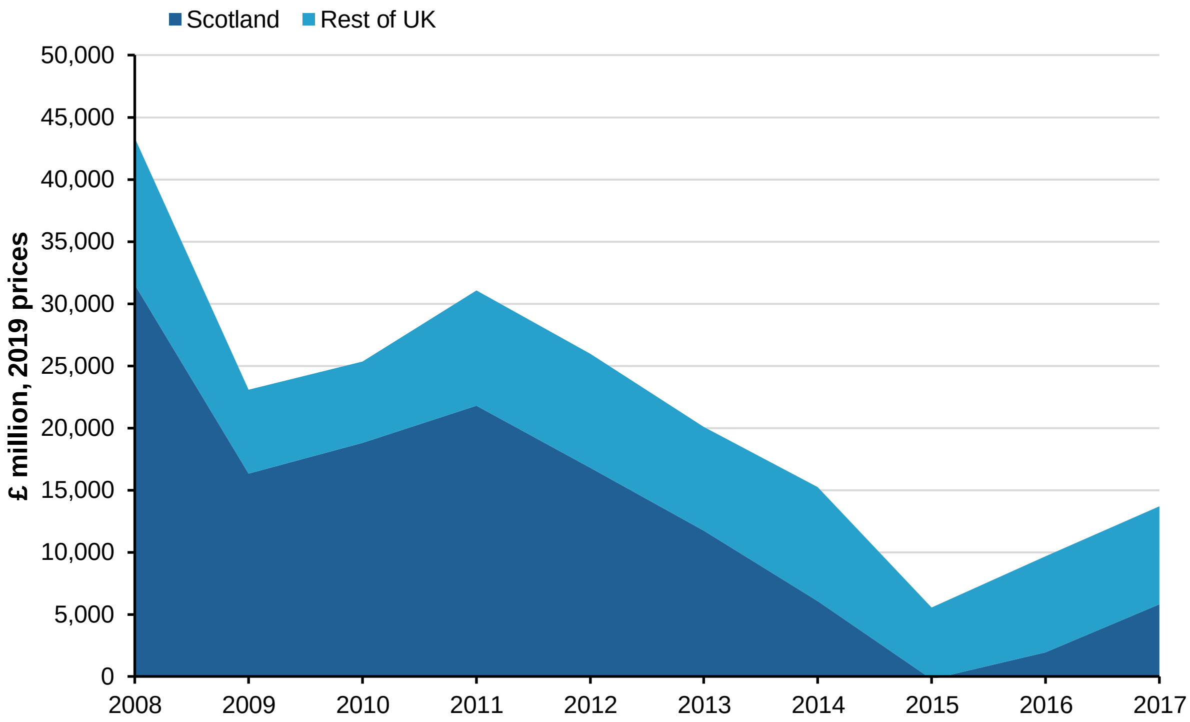
Annual value of provisioning services (£ million, 2019 prices), Scotland, 2017



Source: Office for National Statistics

Figure 3: Scotland represented 42% of the UK's provisioning service value in 2017

Aggregate annual value of provisioning services (£ million, 2019 prices), UK, 2008 to 2017



Source: Office for National Statistics and Scottish Government

Agricultural biomass

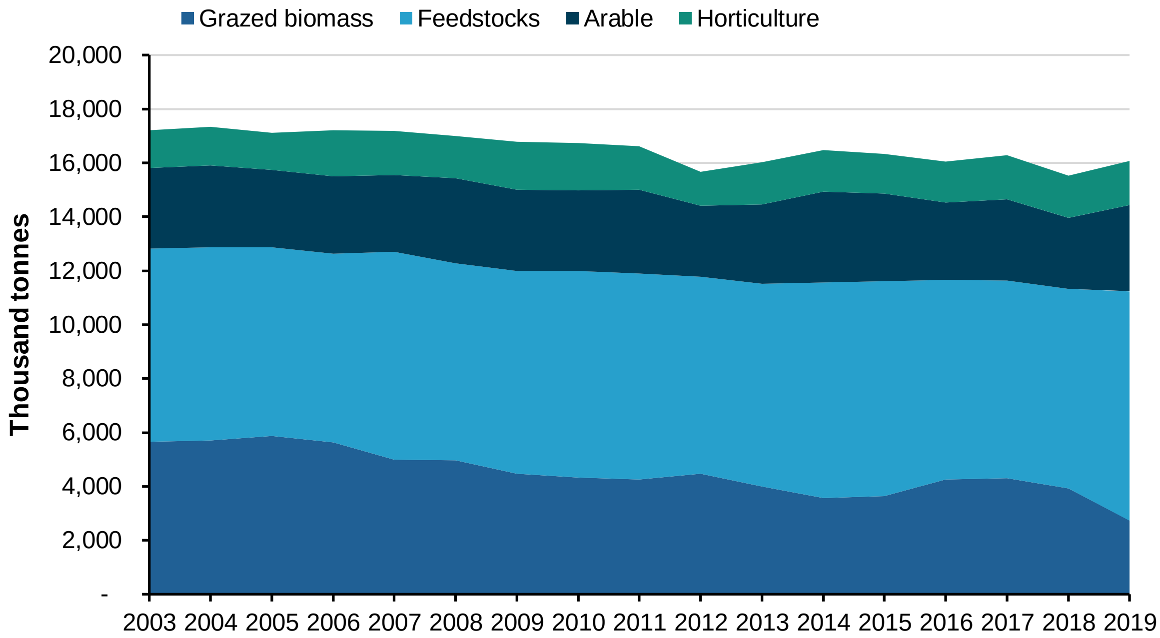
Agricultural biomass refers to the value of crops, fodder and grazing which support Scottish agricultural production. The food eaten by farmed animals is included in this analysis, however the farmed animals themselves are not. It is assumed that farmed animals are produced assets, rather than natural assets.

As illustrated in Figure 4, the volume of agricultural biomass in Scotland in 2019 is 16 million tonnes, decreasing by 7% from 17.2 million tonnes in 2003. Scottish agricultural biomass peaked in 2004 at 17.3 million tonnes. However, total Scottish agricultural biomass increased by 4% from 2018 to 2019.

Arable biomass, which includes the production of wheat and barley, has increased by 21% from 2018 to equal 3.2 million tonnes in 2019. Production of spring and winter barley, wheat and oats have all increased from 2018 to 2019, by 11%, 49%, 38% and 8%, respectively. Oilseed rape production has decreased by 2% in the same time period. Horticulture, which includes vegetables, fruits, and potatoes, has grown by 5% to equal 1.6 million tonnes in 2019.

Figure 4: Scottish agricultural biomass declined by 7% from 2003 to 2019

Agricultural biomass production, Scotland, 2003 to 2019



Source: Office for National Statistics and Scottish Government

Grazed biomass and feedstocks continue to account for most of the Scottish agricultural biomass production. As reported in the provisional results of the Agricultural Census 2020 (Scotland), the number of cattle in Scotland continues to fall, dropping by 1% to 1.71 million from 2019 to 2020. This explains the fall in grazed biomass. In 2019, feedstocks make up 53% of total tonnage, grazed biomass is equal to 17%, arable production is equal 20% and horticulture is equal to 10%. For comparison, in 2018, feedstocks, grazed biomass, arable production, and horticulture equalled 48%, 25%, 17%, 10%, respectively.

Previous Scottish natural capital accounts have provided resource rent annual valuations using the residual value approach. This is the surplus value to the agricultural industry after all costs have been considered. Estimated at an aggregate scale, it may include non-agricultural aspects of farm businesses. As part of our development, we will look at alternative measures of capturing food production value. Using the industry residual value, the annual value equalled £562 million in 2019. The highest industry residual value occurred in 2004 at £626 million and the lowest residual value occurred in 2009 at £66 million. Farm rent remains consistent across the time series, with its 2019 value at £222 million.

Fish capture

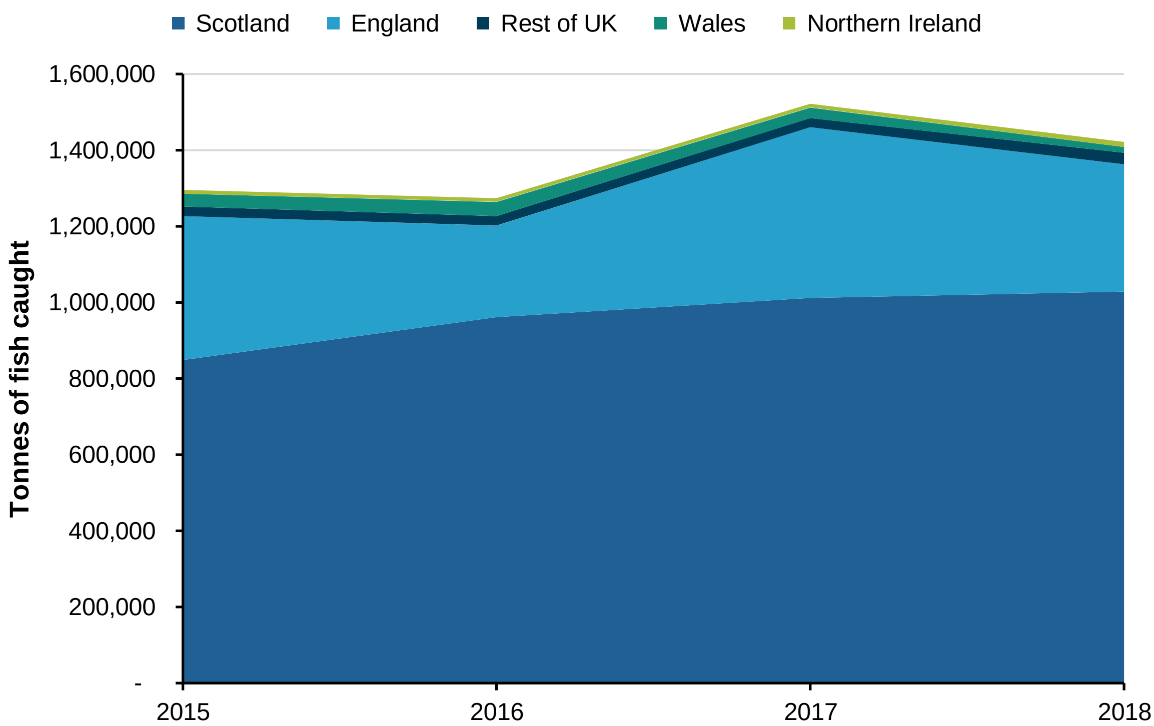
We have been working to improve our fisheries statistics and more work is needed. We rely on a range of external sources, which all involve known uncertainties.

For instance, Norway and Faroese landings are excluded from this analysis. The economic data are based on UK fleet data, which we also apply to foreign vessels that may face different costs and prices. In addition, UK boundaries do not perfectly align with the geographical areas of fish capture statistics. For more detail on how fish capture in UK waters is estimated, see the [Marine Management Organisation Exclusive Economic Zone Analysis]() and associated publications.

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. For more information on the method please see the methodology section.

Figure 5: On average 70% of fish capture tonnage came from Scottish waters between 2015 and 2018

Tonnes of fish capture, UK waters, 2015 to 2018



Source: Office for National Statistics, Scientific, Technical and Economic Committee for Fisheries, Seafish, Marine and Management Organisation

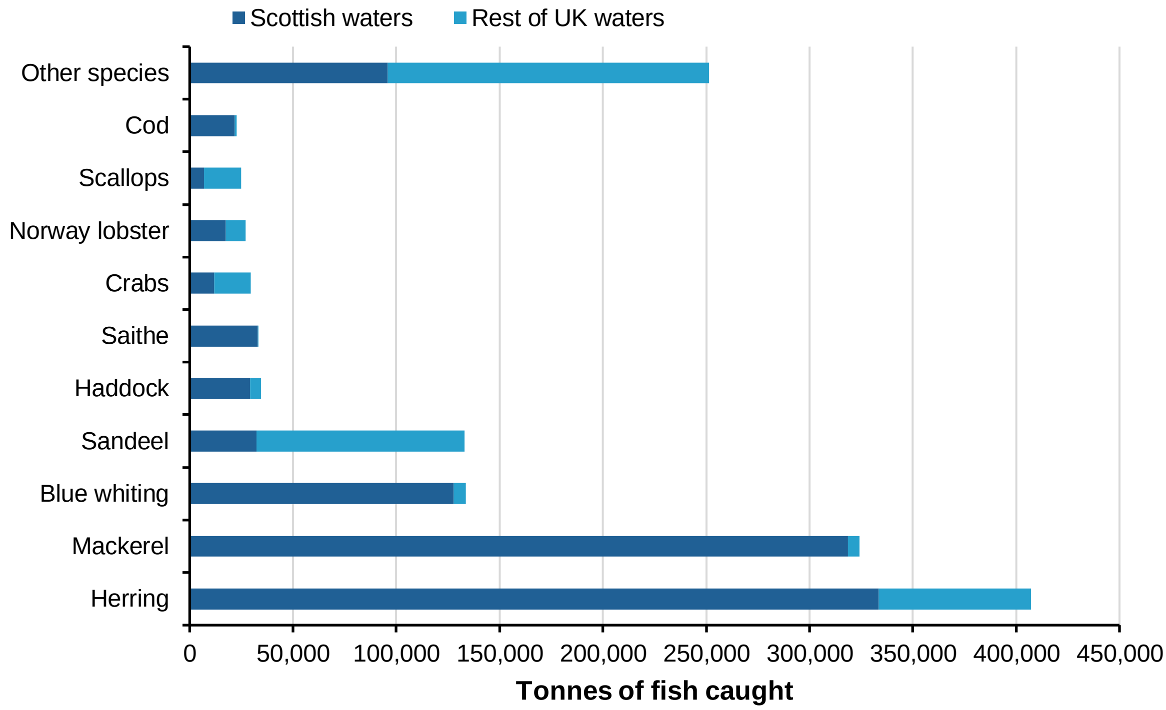
Notes:

1. Rest of UK includes UK crown dependencies

Scottish waters have represented most of the fish capture from UK waters since 2015. Fish capture from Scottish waters has risen by 21% from 2015 to 2018, driving much of the 10% increase in overall fish capture from UK waters.

Figure 6: By tonnage open sea species are largely caught in Scottish waters

Top fish capture species by tonnage, UK waters, 2018



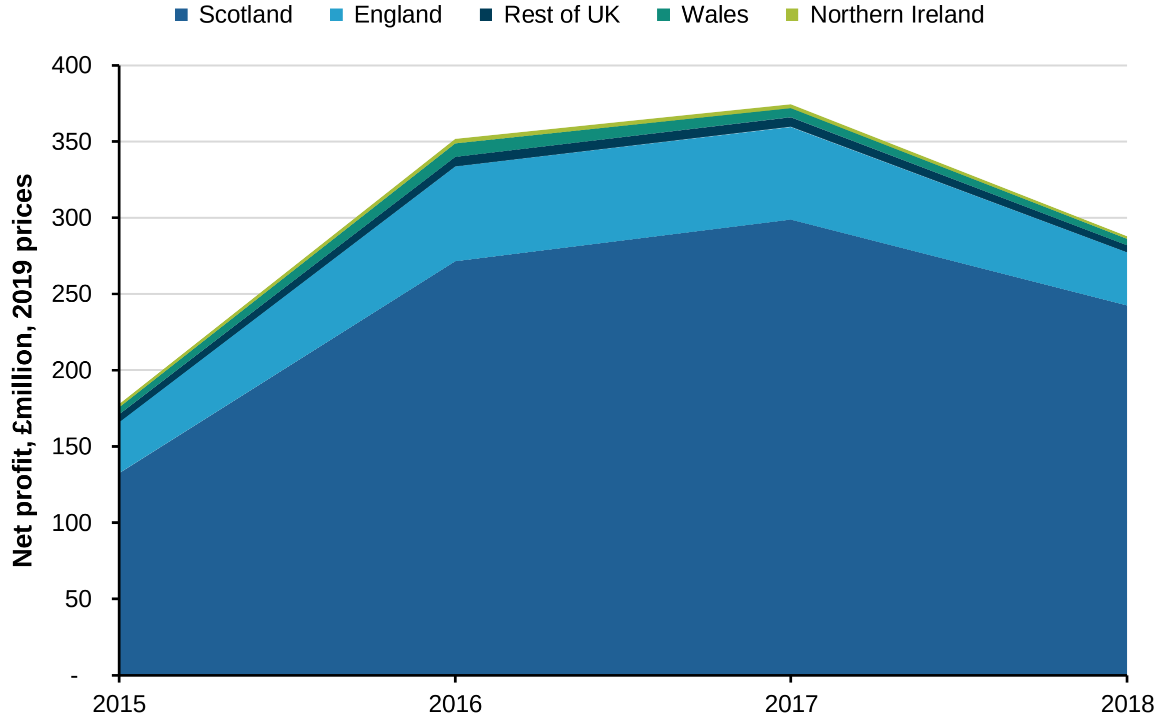
Source: Office for National Statistics, Scientific, Technical and Economic Committee for Fisheries, Seafish, Marine and Management Organisation

Of the 328 different fish species caught in UK waters in 2018, 157 (48%) were found in Scottish waters. Making up 51% of overall catch tonnage in 2018, the two most caught species in UK waters (by tonnage) were herring (82%) and mackerel (98%), which were largely caught in Scottish waters.

The value of fish capture is calculated using net profit per tonne (landed) estimates, provided by Seafish, for different marine species. Across the period 2015 to 2018 an average of 94% of the fish capture by tonnage had profit data.

Figure 7: Scottish fish capture provisioning value dropped 19% from 2017 to 2018 mainly due to a drop in the net profit of Herring and Mackerel

Net profit from fish capture £ millions (2019 prices), UK waters, 2015 to 2018



Source: Office for National Statistics, Scientific, Technical and Economic Committee for Fisheries, Seafish, Marine and Management Organisation

Notes:

1. Rest of UK includes UK crown dependencies.

The net profit of mackerel fell 3% between 2017 and 2018 and herring fell by 19%. Other predominantly Scottish stocks fell over this period, such as fish and chip shop classics: cod and haddock fell by 27% and 25%, respectively.

Scottish waters represent even more of the UK by net profit than by tonnage as fish stocks are on average more profitable per tonne in Scotland. Mackerel, which is by far the UK's most profitable fish stock, almost entirely comes from Scottish waters. The contribution of Scottish waters toward overall net profit has grown year on year from 75% in 2015 to 84% in 2018. The value of Scottish fish capture provisioning services was £243 million in 2018, with an asset value of £7.2 billion.

Timber

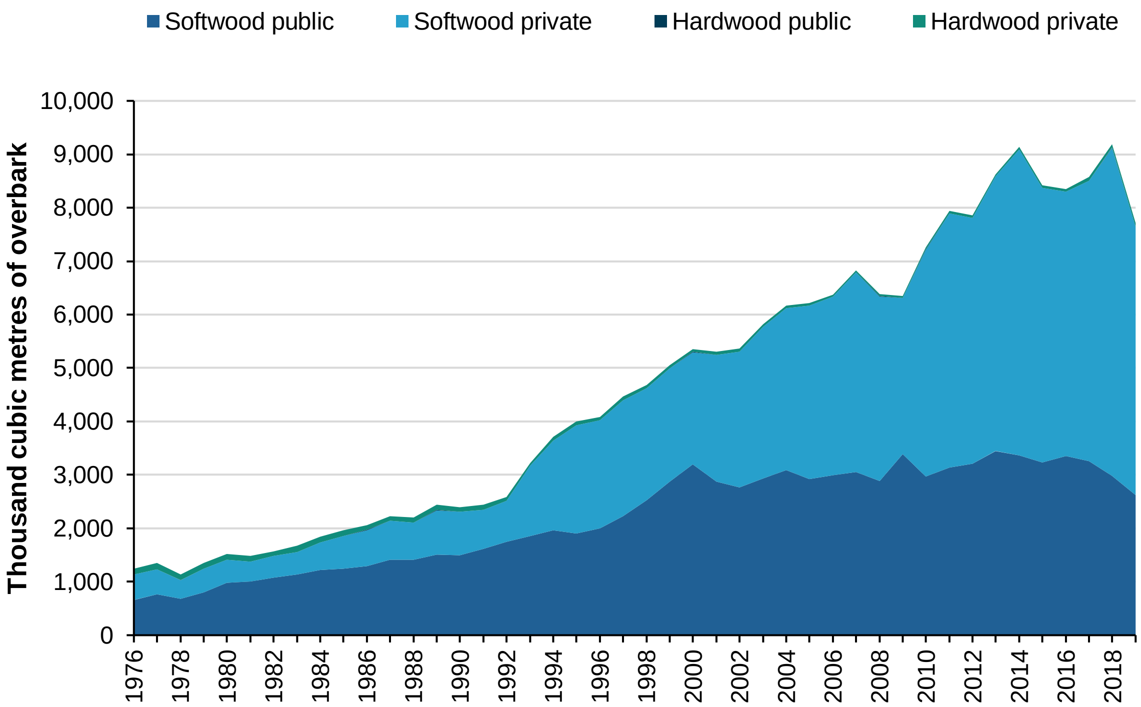
The total volume of timber production in Scotland has increased by 53% from 1999 to 2019. In 2019, around two thirds of Scottish timber were produced by the private sector, increasing from around half of timber production 20 years before. Across the time series, most of the timber production is softwood from coniferous trees, which generally grow faster than hardwood species.

An individual hectare of forest plantation that exclusively produce timber may not provide continuously provide a full range of additional ecosystem services.

Once trees are felled, they cease to, for example, capture pollutants from the air. Following replanting the provision of carbon sequestration will be lower than for older growth as it recovers. Some of the fellings will store carbon longer term in, for instance, building materials; while other carbon may be released into the atmosphere when wood is burned for heat or energy generation. This leads to some spatial complexity at a granular level in the measurement of ecosystem services from plantation woodland. However on a national scale – as the age structure of the overall forest moves on – we assume these issues are rebalanced.

Figure 8: Scottish timber production has increased by 53% from 1999 to 2019

Timber production in Scotland, thousand cubic metres of overbark, 1976 to 2019



Source: Forest Research

Notes:

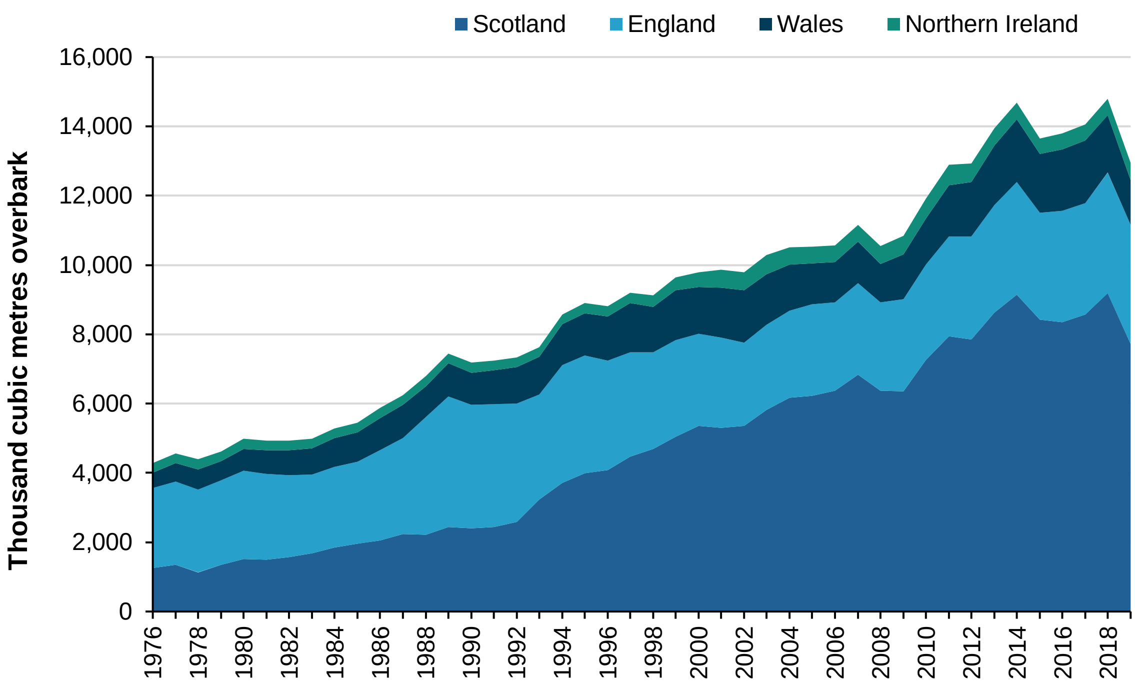
1. Public refers to Forestry and Land Scotland.

Softwood production peaked in 2018 at 9,188 metres of overbark (m^3) but has since dropped by 16% to 7,719m^3 in 2019. Hardwood production has increased in recent years. In 2019, hardwood production was at its highest level since 1991.

Relative to the rest of the UK, Scotland's timber production has increased significantly in recent decades. Scotland represented 60% of UK timber production in 2019, from 52% in 1999 and 33% in 1989. Scottish forests make up 46% of the woodland area in the UK.

Figure 9: Scottish timber production has increased significantly over the last two decades to equal 60% of UK timber production in 2019

Timber production (thousand cubic metres overbark), UK, 1976 to 2019

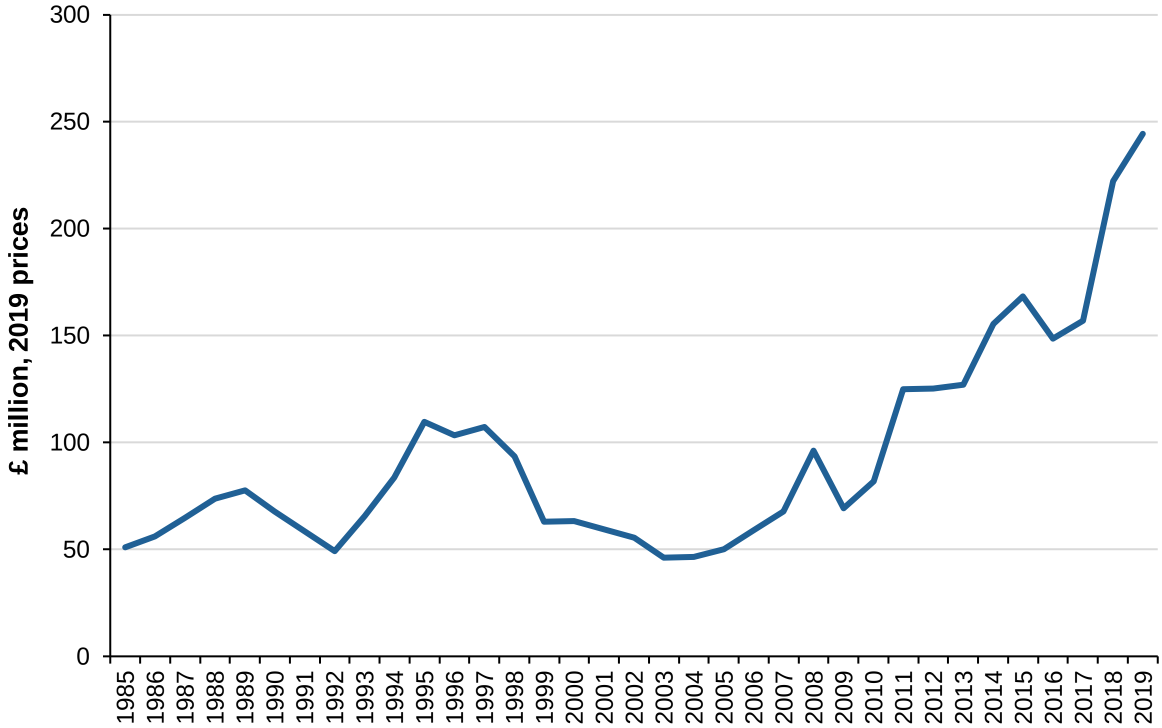


Source: Forest Research

The timber provisioning service valuation has increased by 253% over the last decade, from £69 million in 2009 to £244 million in 2019. The increase in the annual valuation has been driven by a 21% increase in production and a 191% increase in stumpage price for the same period. The stumpage price is the price paid per standing tree for the right to harvest timber from a given area.

Figure 10: The timber provisioning service valuation has increased by 253% over the last decade

Timber provisioning annual value, £ million 2019 prices, Scotland, 1985 to 2019



Source: Office for National Statistics and Forest Research

Scotland's forestry strategy states that between 2030 and 2050 there will be a decline in softwood availability, mainly due to the uneven age structure of the forest estate following high levels of planting prior to the 1990s. Scotland contributed 81% of the UK's new planting in 2019. Of the 68,000 hectares of new planting in Scotland between 2010 and 2019, 42% of this new planting were softwood (conifers) and 58% was hardwood (broadleaved).

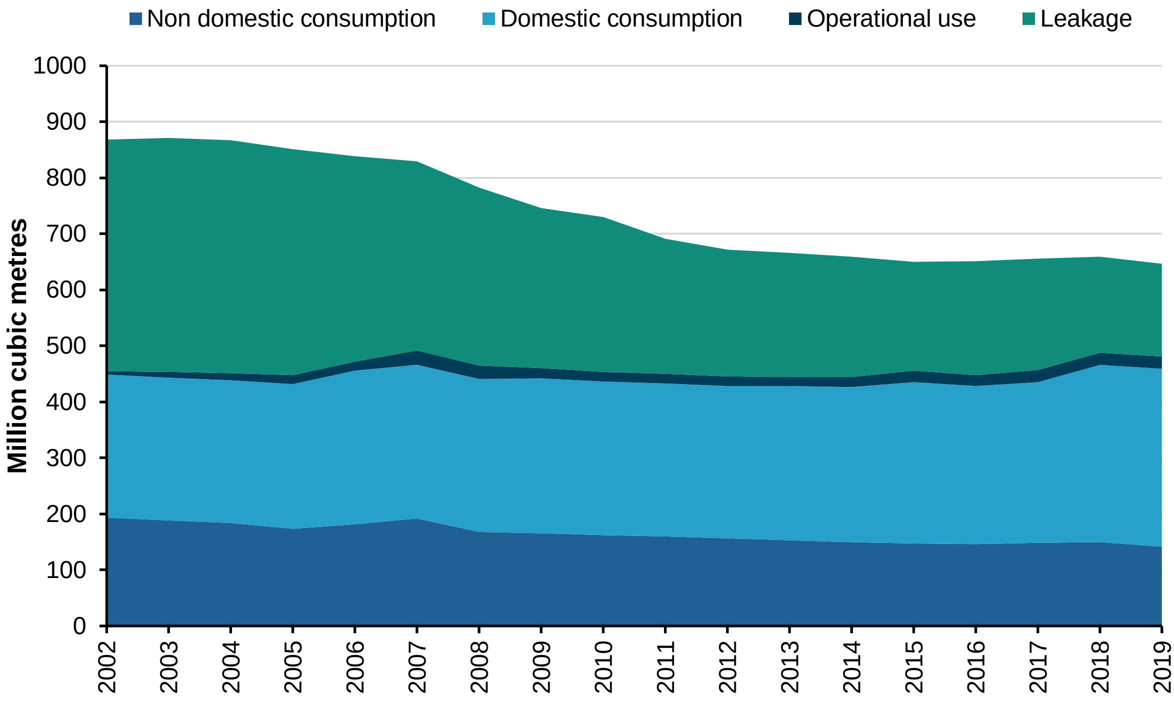
Current and historic planting data informs forecasts of timber production, which we use to estimate the value of the timber provisioning service in the future. In 2019 the asset value of Scottish timber was £7 billion, contributing 60% towards the total UK value of £11.7 billion.

Water abstraction

Water abstraction for public water supply between 2002 and 2019 has decreased by 25%, from 912 million to 683 million cubic metres, primarily due to a reduction in demand caused by less leakage. Of water abstracted, on average 96% became treated water.

Figure 11: Scottish water abstraction fell due to reduced demand from fewer leakages

Treated water produced million cubic metres, Scotland, 2002 to 2019



Source: Scottish Water

Over the past 18 years, Scottish water has reduced leakages by 60% from 413 million to 166 million cubic metres. In 2002, around 45% of water was lost to leakages compared to 24% in 2019.

According to a Scottish Environment Protection Agency report, climate change is likely to bring more uncertainty, with a projected decrease in summer rainfall. NatureScot research shows that the number of extreme drought events across the country could increase from an average of one every 20 years to one every 3 years. This may exert pressure in areas that have not yet experienced water scarcity.

We derive monetary estimates of the water abstraction provisioning service from industry level data on the collection, treatment, and distribution of water for domestic and industrial needs. This valuation fluctuates year on year but was estimated to be £206 million in 2017, which is 6% of the UK annual value.

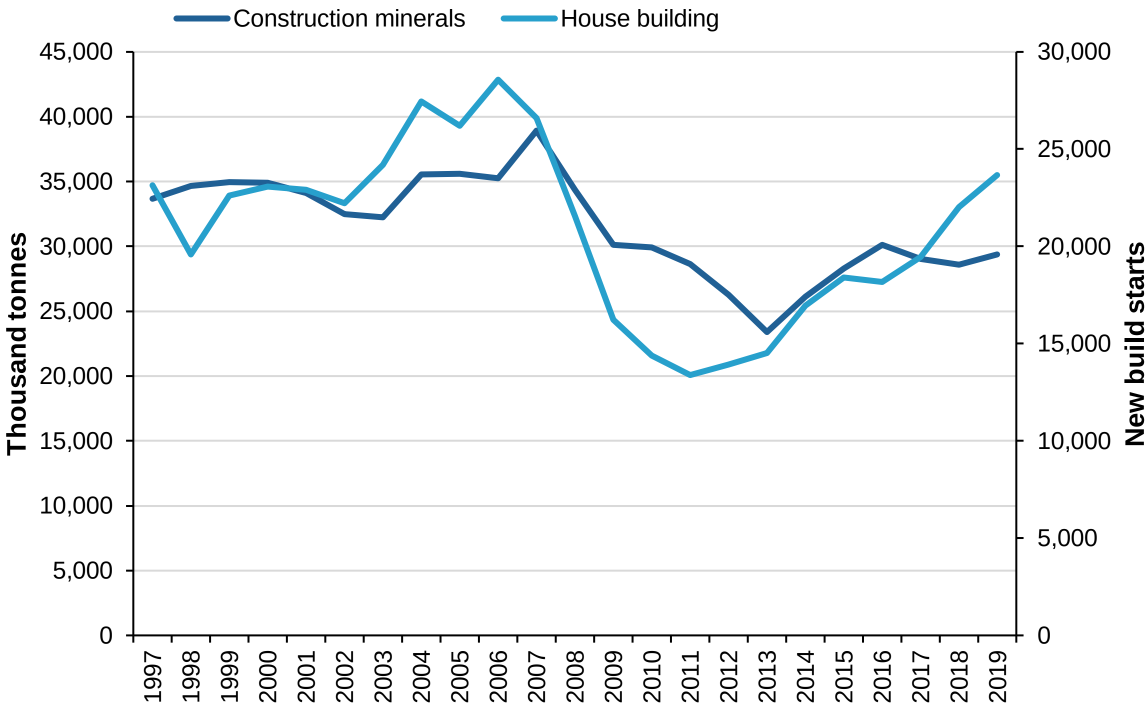
Minerals

Mineral extraction in Scotland, largely consisting of construction mineral aggregates, increased by 3% between 2018 and 2019. Mineral production peaked in 2007 with 39.4 million tonnes extracted. By 2019, this had declined by 10 million tonnes.

Construction minerals are used for housing and infrastructure. The largest extraction declines were seen in 2008 and 2009, dropping 11.7% and 12.5%, respectively. New house building in Scotland declined by 18.9% and 24.7% across the same period. Since 2013, construction mineral production and new house builds have generally increased each year. This analysis excludes imports, exports, and movement of materials from within the UK.

Figure 12: House building and construction mineral extraction declined following the economic downturn

Construction mineral extraction and new house building, Scotland, 1997 to 2019



Source: British Geological Survey and Scottish Government

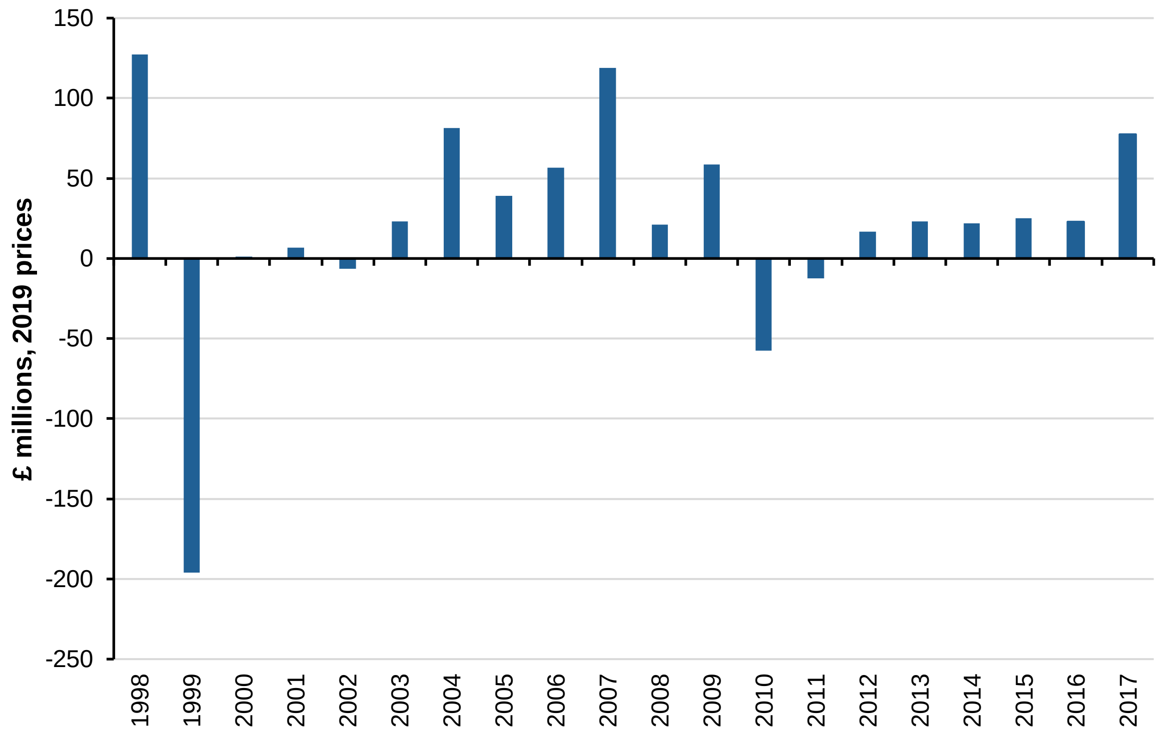
Notes:

1. Construction minerals include sand and gravel, slate, igneous rock, limestone and dolomite, and sandstone.
2. A dwelling is regarded as ‘started’ on the date that work begins on its foundations, not on the date when site preparations begin.

Using the resource rent approach (see Methodology guide), the annual value of mineral provisioning fluctuated between 1998 and 2017. There are costs incurred for making use of natural resources, and in 1999 and 2010 these estimated costs outweighed income from the extraction of minerals. In 2017, the annual value increased to £77 million.

Figure 13: Mineral provisioning value increased to £77 million in 2017

Annual value of mineral extraction (£ millions, 2019 prices), Scotland, 1998 to 2017



Source: Office for National Statistics

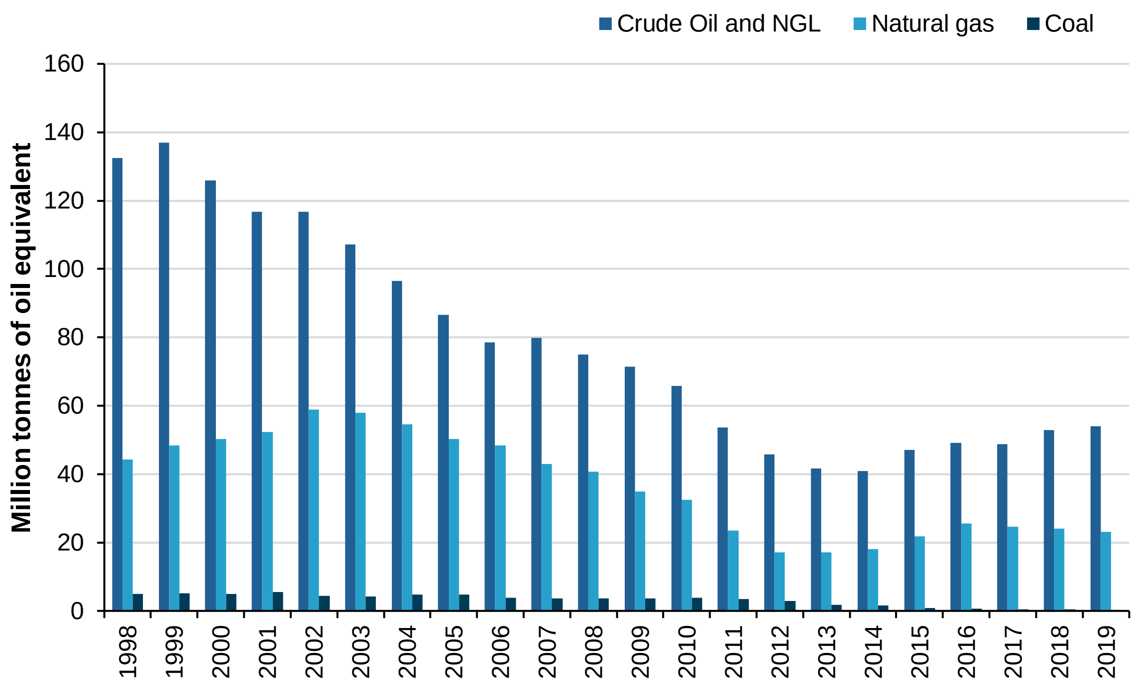
Unstable valuations of the mineral production abiotic provisioning service, along with years of negative gross operating surplus for the minerals industry in the UK National Accounts, do not lend well to valuation comparisons between the UK and Scotland. Data inputs and methods will be reviewed in future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

Fossil fuels

The production of fossil fuels between 1999 and 2019 has decreased by 59%. Coal, representing the minority of fossil fuels, has decreased by 95%. Crude oil and natural gas liquids (NGL) production has dropped by 61% and natural gas has declined by 52%. In recent years, the production of oil has been increasing. Crude oil and NGL production increased by 2% from 2018 to 2019, putting it at its highest level since 2012.

Figure 14: Across the time series, crude oil and natural gas liquids production has fallen by 61% and 52%, respectively

Fossil fuel production, million tonnes of oil equivalent, Scotland, 1998 to 2019



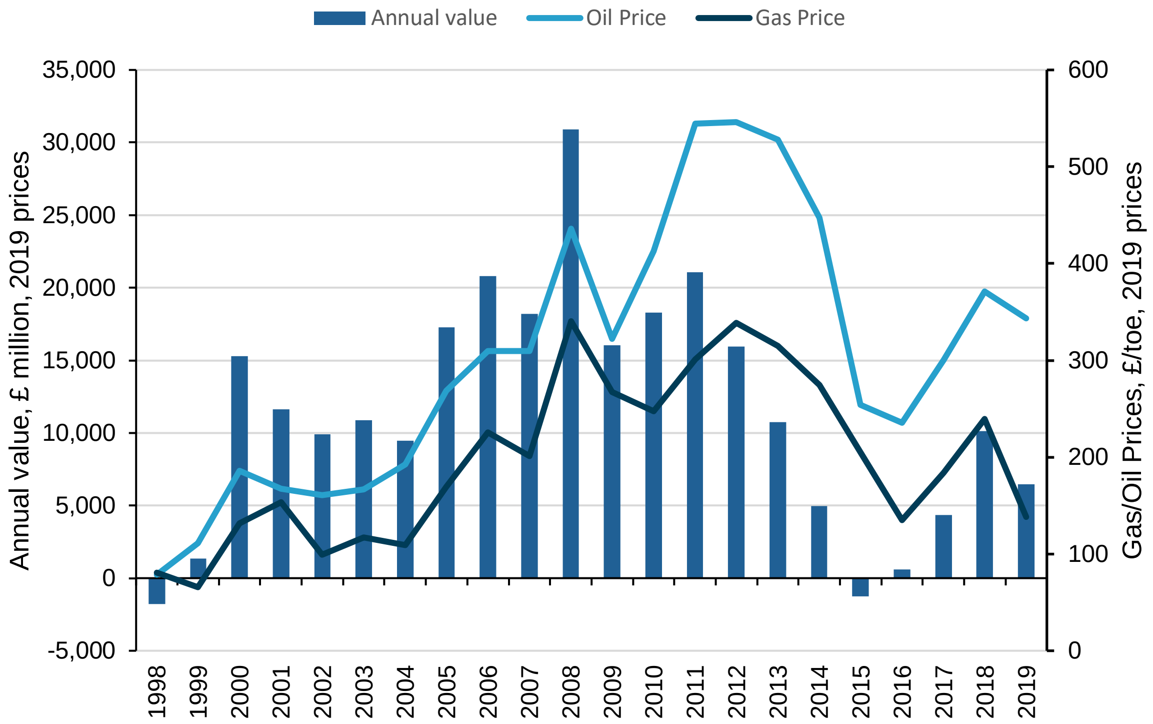
Source: Scottish Government and Department for Business, Energy, and Industrial Strategy

Scottish production of crude oil and NGL peaked in 1999 with 136.9 million tonnes of oil equivalent, before declining to its lowest level in 2014 to 41 million tonnes of oil equivalent. Scotland produced 95% of the UK's crude oil and NGL, 70% of the UK's natural gas and 18% of the UK's coal production in 2019.

Whilst the general trend shows lasting production shifts, the annual value of fossil fuel abiotic provisioning fluctuates year on year, driven largely by oil and gas price changes. The Brent crude oil price was on average 6% lower in 2019 compared to 2018.

Figure 15: Fossil fuels' annual value varies with oil and gas prices, reaching a peak in 2008 at £30,897 million

Fossil fuels' annual value, £ million 2019 prices, Scotland, 1998 to 2019 and Gas/Oil prices, £/toe, 2019 prices, 1998 to 2019



Source: Office for National Statistics

The Scottish fossil fuels provisioning service annual value was £4.4 billion in 2017, representing 94% of the UK value.

This is a resource rent approach, which estimates the surplus remaining to the extractor after all costs and normal returns are considered. This is closely related to profitability. The details of the methodology used to estimate the value of fossil fuels can be found in the methods section.

Resource rent is different from an intrinsic measure of value, such as the wholesale price determined by the market or the value it provides to the economy in terms of economic output (that is, gross value added). Resource rent does not value government receipts, employment, supply chain activity or energy security as benefits.

Renewable electricity generation

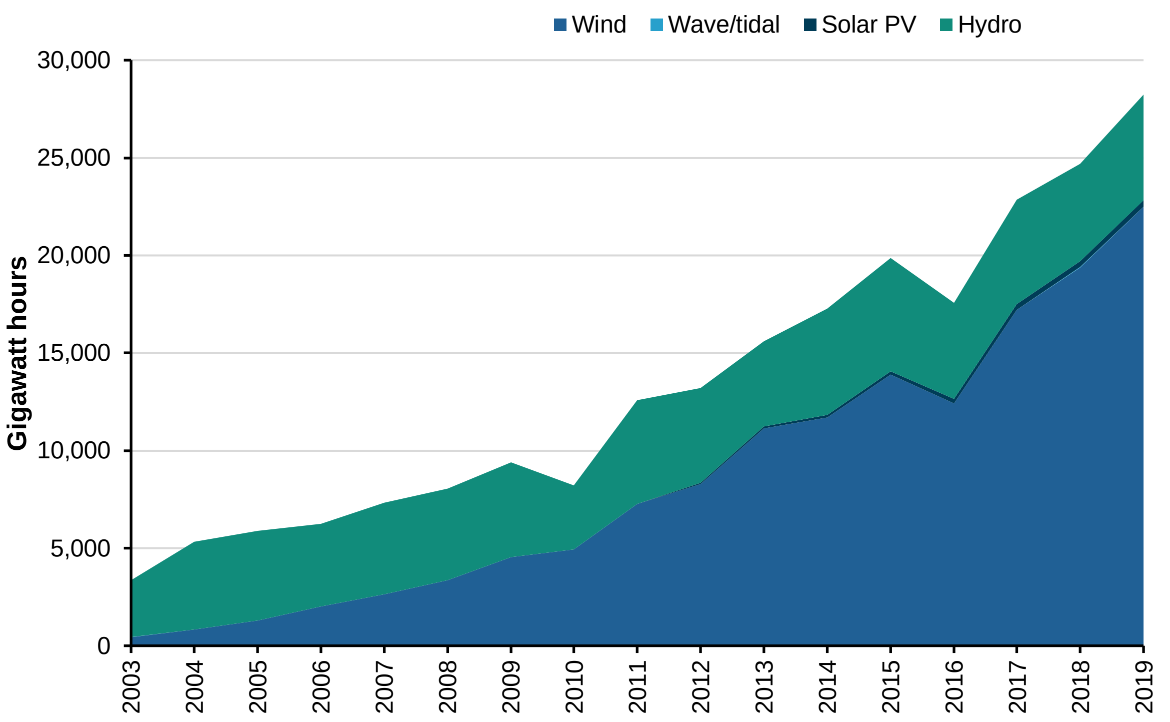
Scotland's renewable electricity generation has increased by 14% between 2018 and 2019. By the fourth quarter of 2020, Scotland produced 97.4% of its electricity demand from renewable energy sources, falling just short of the 100% by 2020 renewable electricity target.

In 2003, Scotland generated 3,351 gigawatt hours (GWh) of electricity from renewable sources. This has increased to 28,236 GWh in 2019, which is a 743% increase, or eight times larger. Scottish hydroelectricity was by far the largest producer of renewable energy in 2003, with 2,902 gigawatt hours generated. Since 2010 wind generation has become the largest source of renewable energy.

Scotland's renewable electricity generation in 2019 accounted for 34% of the UK's generation from renewables. All sources of renewable electricity generation grew from 2018 to 2019, with wind showing an increase of 16%. Although a small source of renewable generation, wave and tidal had a 50% increase over this period.

Figure 16: Scottish renewable energy production reached 28,236 GWh in 2019, increasing by 743% from 2003

Electricity generation from renewables (Gigawatt hours), Scotland, 2008 to 2019



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

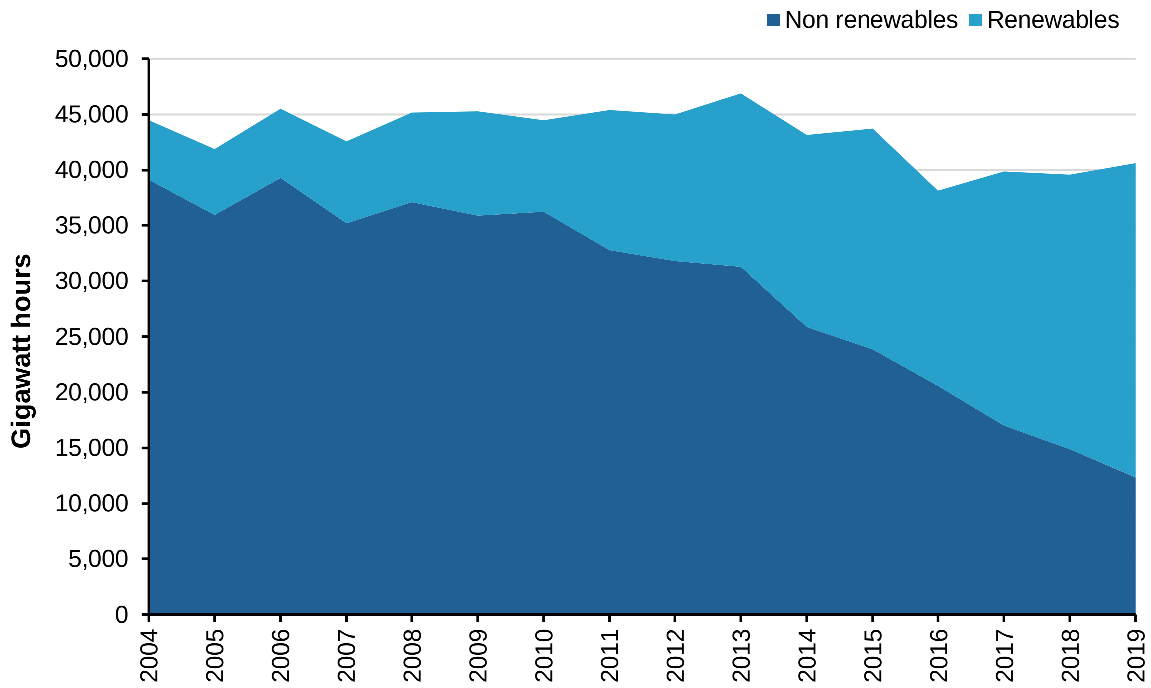
Notes:

1. Electricity generation from renewables excludes landfill and sewage gas, other bioenergy, anaerobic digestion and biomass and waste.
2. Generation from "other sites" is not included. "Other sites" are sites that have not been attributed to a region so that data related to individual companies are not disclosed.

In 2019, of all Scottish electricity generation, 70% was produced from renewables. The total electricity generation from all sources in Scotland has seen a decrease of 9% between 2003 and 2019, with generation from non-renewables decreasing by 68%. There is now no electricity generation from coal in Scotland and power generation from oil, gas, and nuclear has fallen by 17%, 51% and 32% respectively, from 2003 to 2019.

Figure 17: 70% of Scottish electricity generation was produced by renewable sources in 2019

Electricity production generation from renewable and non-renewable sources (gigawatt hours), Scotland, 2004 to 2019



Source: Department for Business, Energy, and Industrial Strategy

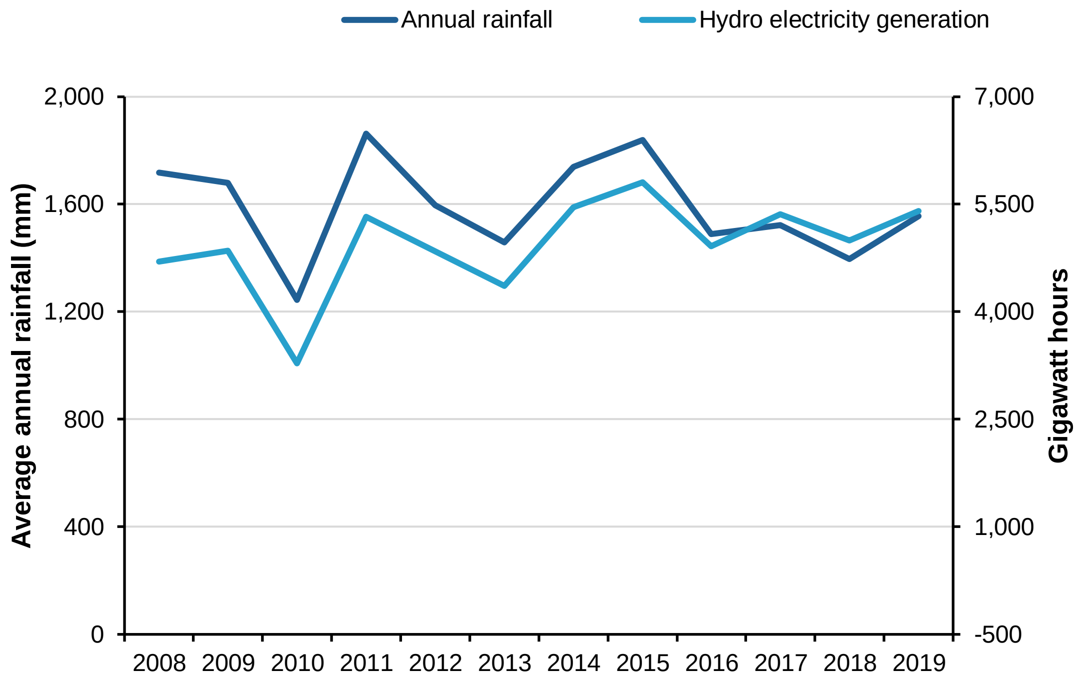
Notes:

1. Renewables include wind, hydro, solar PV, and wave and tidal.
2. Non-renewable includes coal, oil, gas, nuclear, other thermal, hydro, pumped storage, and non-biodegradable waste combustion.
3. Non-renewable generation only includes generation from Major Power Producers (MPPs).
4. Renewable generation from "other sites" is not included. “Other sites” are sites that have not been attributed to a region so that data related to individual companies are not disclosed.

Hydroelectricity generation is sensitive to changes in precipitation as flowing water is needed to spin turbines which generate electricity. In 2010 hydropower generation declined significantly due to the comparative lack of rainfall.

Figure 18: Scottish hydroelectricity generated 5,406 GWh in 2019, increasing by 15% from 2008

Average rainfall and hydroelectricity generation, Scotland, 2008 to 2019

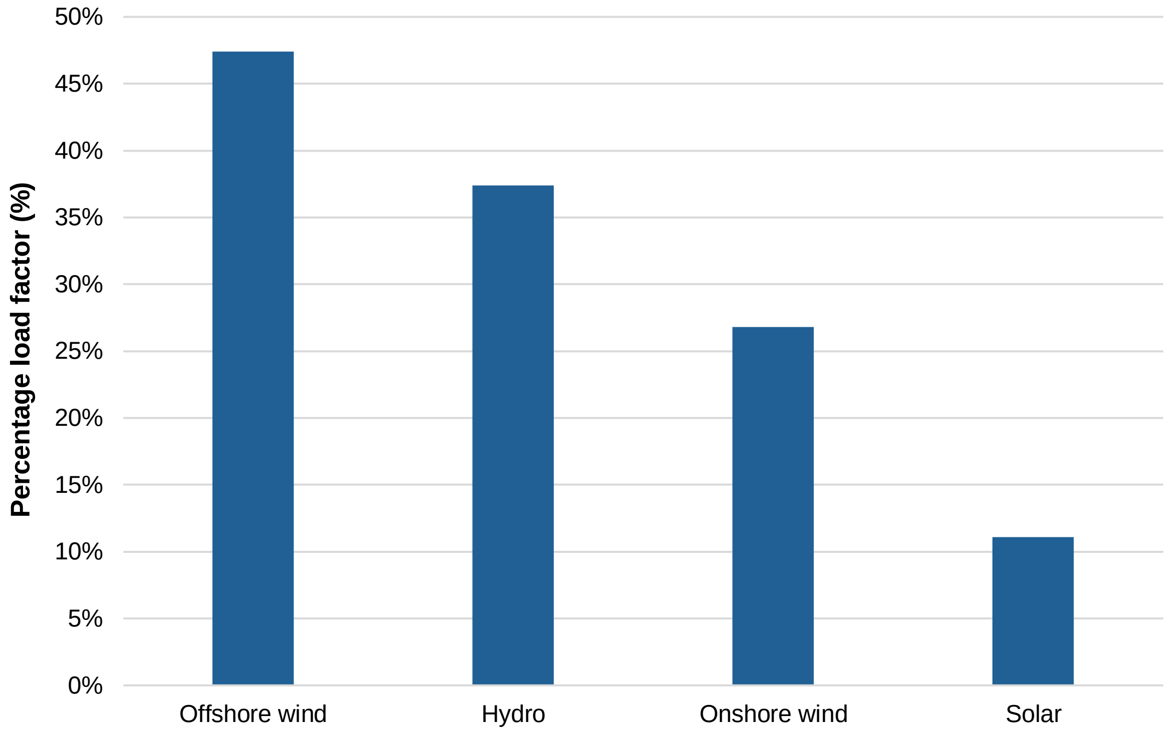


Source: Department for Business, Energy, and Industrial Strategy

Load factors are a measure of generation efficiency using a ratio of actual to potential total generation capacity. Hydropower load factors dropped from 38.4% to 25.8% between 2009 and 2010. Load factors fluctuate with the weather but can improve with developments in the efficiency of renewable technologies. In 2019 offshore wind had the highest load factor but until recently old standing hydroelectricity plants have had the highest load factor of renewables.

Figure 19: Scottish offshore wind load factor averaged 47.4% in 2019

Load factors of renewable energy technologies (percentage), Scotland, 2019

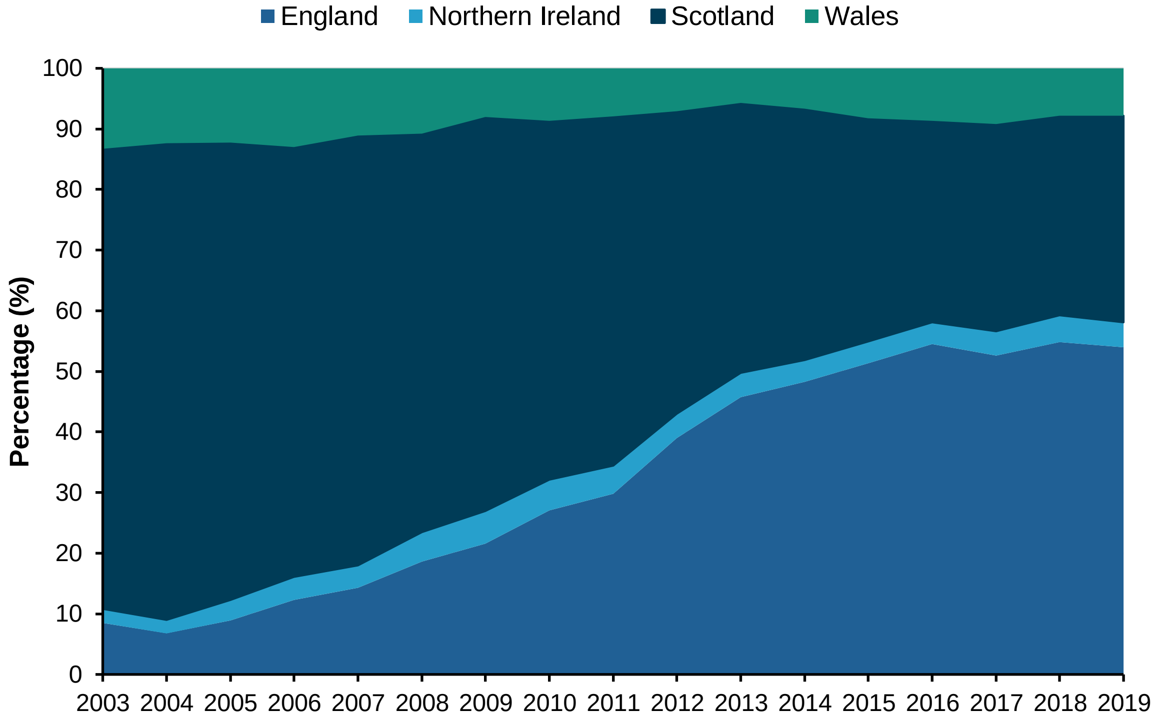


Source: Department for Business, Energy, and Industrial Strategy

Scotland’s contribution to UK renewable energy provisioning decreased from 79% in 2003 to 34% in 2019. This is because hydropower, which is largely in Scotland, was historically the largest renewable electricity generation source in the UK. Although its generation has remained stable, with other renewables growth it now represents a minority of UK renewable generation.

Figure 20: Scotland produced 34% of electricity generation in 2019, with England, Wales and Northern Ireland producing 54%, 8% and 4%, respectively

Percentage contribution of renewable energy provisioning by country, UK, 2003 to 2019



Source: Department for Business, Energy, and Industrial Strategy

4. Regulating services

As well as provisioning services, natural assets provide several less visible services known as regulating services. A regulating service is an ecosystem benefit, which moderates natural phenomena. Regulating services include cleaning the air, sequestering carbon and regulating water flows to prevent flooding.

This section presents four regulating ecosystem services:

1. Carbon sequestration
2. Air pollution removal
3. Noise mitigation
4. Urban cooling

Green and blue areas in Scotland's urban areas can help reduce the temperature on hot days, leading to savings in productivity, and can reduce noise disturbance. The annual value of Scottish urban cooling in 2018 was £3.22 million and Scottish noise mitigation equalled £0.63 million in 2018.

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

Both carbon sequestration and air pollution removal are carried out by vegetation. The capacity for vegetation to sequester carbon and remove air pollution changes with the amount of vegetation.

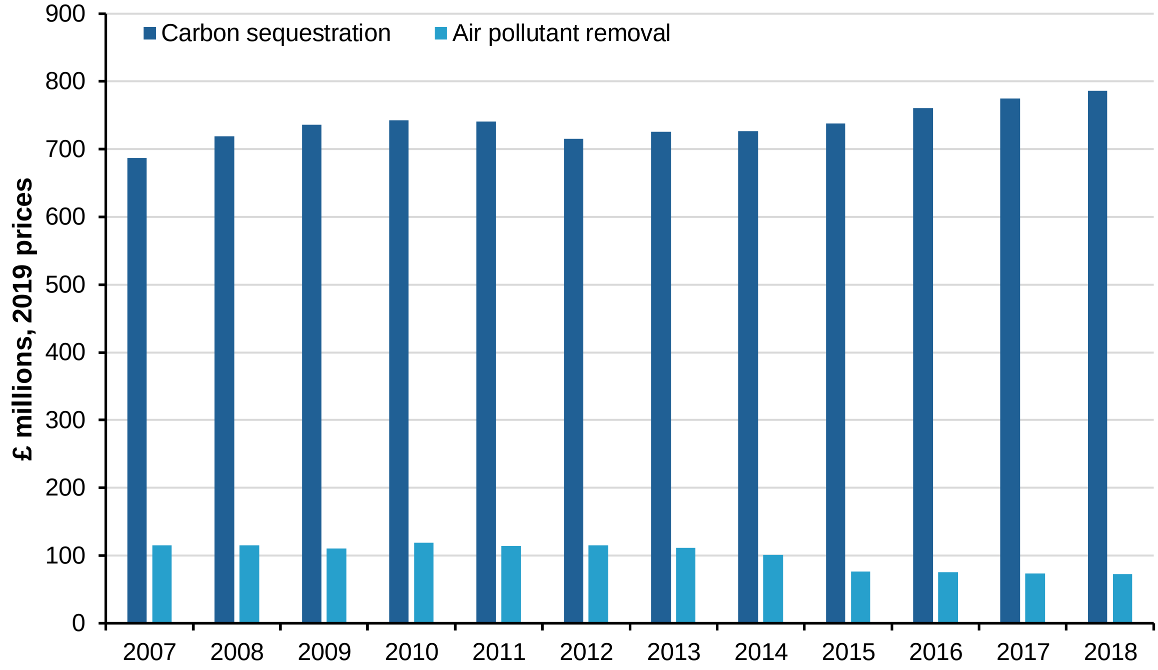
The valuation methods used differ; carbon sequestration is a removal cost, and air pollution removal is a societal cost. That is, we are measuring the value of avoiding damage (for carbon) and the value of treating existing damage (for air pollution). Air pollution removal valuation does not account for the cost of abatement, and carbon sequestration valuation does not consider the global societal impacts of carbon dioxide.

The amount of carbon sequestrated is substantially more than the amount of air pollutants removed by vegetation. However, the value per tonne of air pollutant removed is on average four times higher than a tonne of carbon removed. This is because the avoided health impacts of pollutants, mainly PM2.5, provide significant benefits to society.

In 2018, the annual values for Scottish carbon sequestration and air pollutant removal equalled £768 million and £72 million, respectively (2019 prices).

Figure 21: The annual value of carbon sequestration is consistently larger than that of air pollutant removal, reaching £786 million in 2018

Annual value of carbon sequestration and air pollutant removal, Scotland, 2007 to 2018



Source: Office for National Statistics, National Atmospheric Emissions Inventory (NAEI), and UK Centre for Ecology and Hydrology

Carbon sequestration

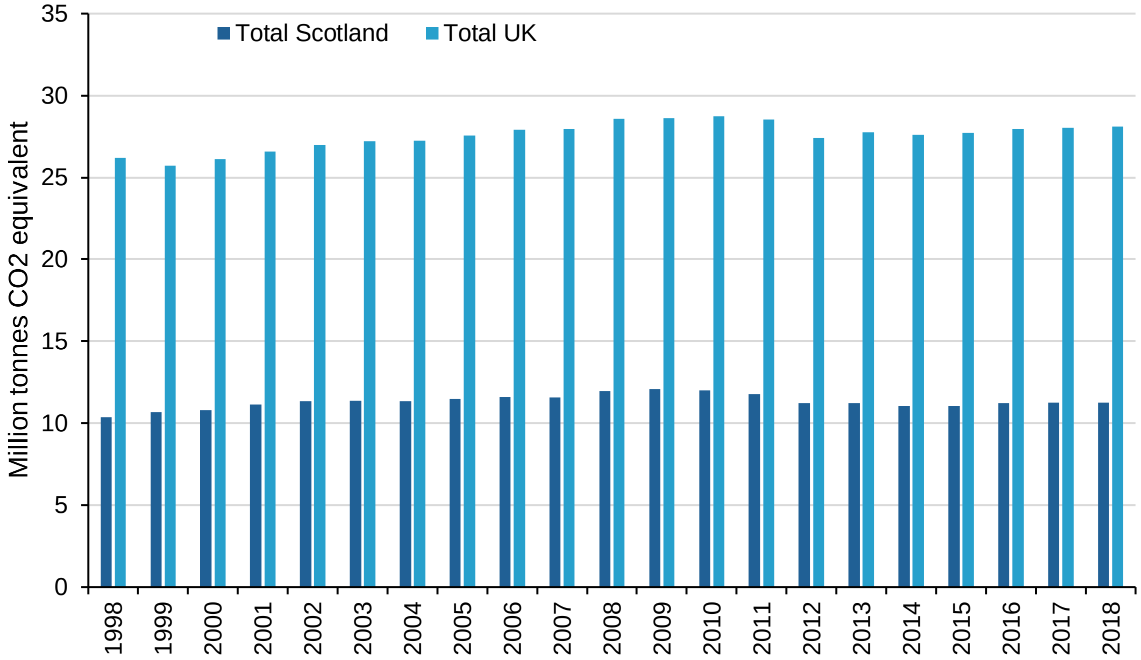
When using this analysis, it is important to note that we do not capture all carbon sequestration. Because of a lack of data, values related to carbon sequestration by marine ecosystems are not included in the current estimates. Peatlands, which are a significant source of emissions, are only partially seen in the data.

A 2017 report by the UK Centre for Ecology and Hydrology (UKCEH) for the Department for Business, Energy, and Industrial Strategy (BEIS), estimates that Scotland has only 25% (or 490,497 hectares) of its total peatlands (1,947,750 hectares) in a near natural condition, which have a net cooling effect on the climate. Scottish peatlands, which make up 67% of the UK's total peatland area, generated an estimated 41% (9,706 ktCO2 equivalent) of 1990 UK emissions (23,664 ktCO2 equivalent). This almost completely negates the gross terrestrial sequestration of Scotland reported in the Greenhouse Gas Inventory (GGI).

Over the time series, the amount of carbon sequestered has been fairly consistent, with 11.27 million tonnes of CO2 equivalent being sequestered in Scotland in 2018 (Figure 22). This represents 40% of the UK total amount sequestered (28.09 million tonnes). The annual value of this ecosystem service for Scotland was valued at £786 million in 2018 (Figure 21). The asset value was £44 billion in 2018, which reflects the value of carbon sequestration by nature into the future. However, this excludes the emission costs related to the management of natural habitats.

Figure 22: Scottish carbon sequestration is valued at £768 million in 2018, representing 40% of CO2 equivalent sequestered in the UK

Million tonnes of CO2 equivalent of carbon sequestered for Scotland and UK, 1998 to 2018



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

An assessment of Scotland's blue carbon resources (2017) estimates the scale of carbon production and storage in Scottish inshore Marine Protected Areas (MPA) and Special Areas of Conservation (equal to around 11,350 km2). Estimates show that stocks of carbon, in inshore MPAs in both living materials and sediment, are estimated to be 9.4 megatons of organic carbon and 47.8 megatons of inorganic carbon.

Annually, the living components of inshore MPA habitats are estimated to emit 248,000 tonnes of organic carbon. MPA sediments sequester 126,000 tonnes of organic carbon. This means that Scotland's MPAs stores around half of the organic carbon it produces. However, most of the sequestered organic carbon is likely to originate from land rather than the marine environment.

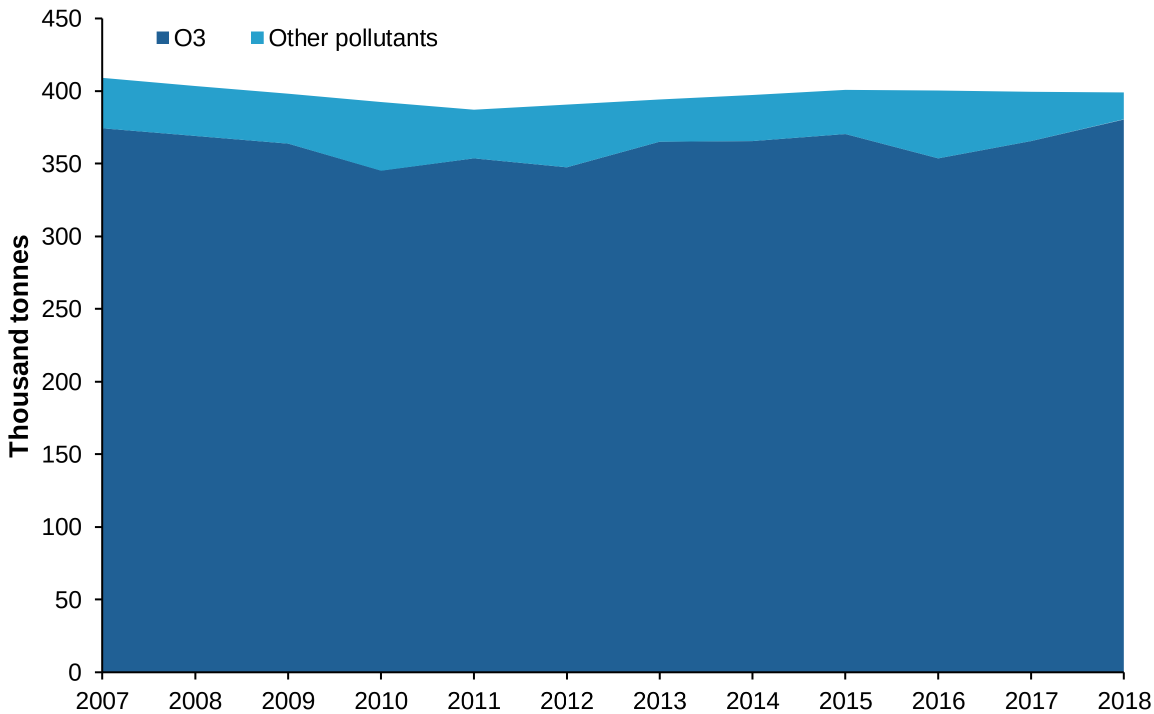
Scottish MPAs production of inorganic carbon is vastly outweighed by the quantity of inorganic carbon it sequesters, by around 950% – while 36,000 tonnes of inorganic carbon are produced, 348,000 tonnes of carbon are stored each year. The major difference between inorganic carbon production and sequestration has several possible explanations. Inorganic carbon production may be underestimated, and inorganic carbon sequestration may be overestimated. Furthermore, Scottish inshore MPAs may sequester inorganic carbon that originates from outside the MPA zone.

Air pollution removal

Vegetation removes airborne pollution from the atmosphere. We can measure the benefits of this to humanity by looking at the savings to health costs associated with breathing in air pollutants. The air pollutants we measure are PM10, PM2.5, SO2, NH3, NO2 and O3. More information on the type of health costs saved and the method of measuring this benefit can be found in the methodology section. In 2018, it is estimated that vegetation in Scotland removed 399 thousand tonnes of pollutants, representing 30% of the total air pollution removed in the UK during 2018. Ground level ozone (O3) represented 95% of all pollutants removed in 2018 (Figure 23). Woodland habitats in Scotland removed the most pollution at 111,000 tonnes (Figure 24).

Figure 23: Ground-level ozone represents most pollutants removed by vegetation

Air pollution removal, thousand tonnes, Scotland, 2007 to 2018



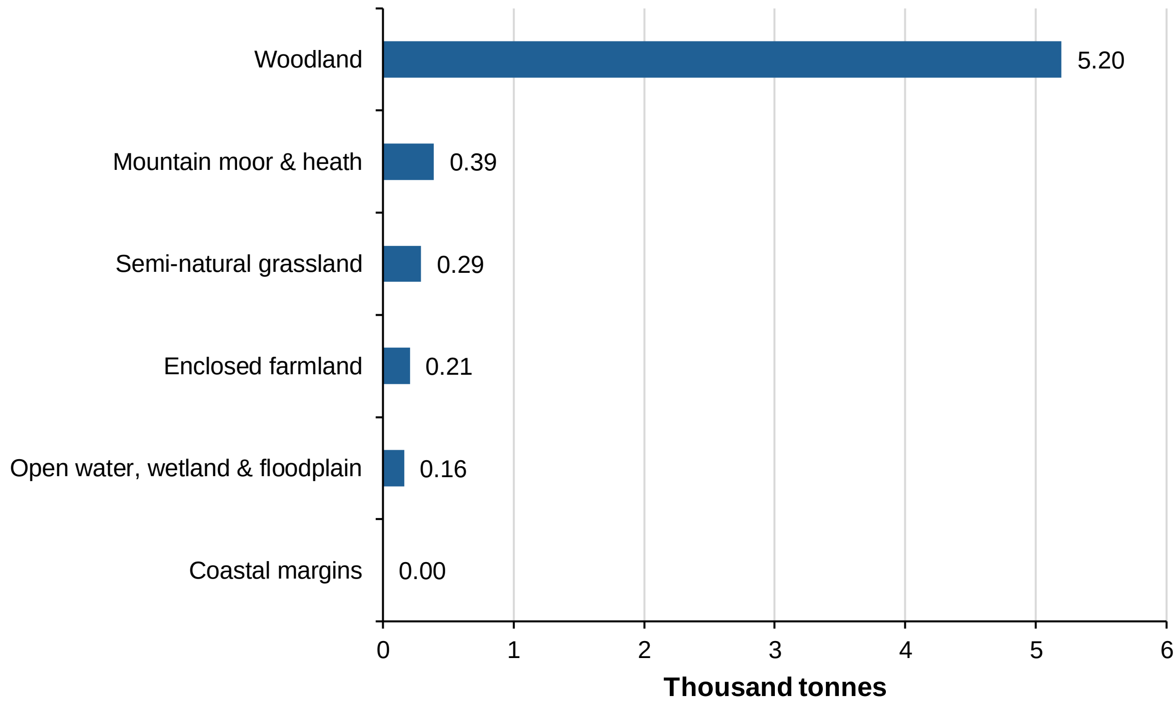
Source: Office for National Statistics and UK Centre for Ecology and Hydrology

Out of the pollutants, PM2.5 (fine particulate matter with a diameter of less than 2.5 micrometres, or 3% of the diameter of a human hair), is the most harmful. PM2.5 can bypass the nose and throat to penetrate deep into the lungs, leading to potentially serious health effects and healthcare costs. In Scotland 83% of PM2.5 is removed by woodlands.

In Scotland, the local authority level that removed the most PM2.5 per hectare was South Ayrshire (1.59 kilograms per hectare), closely followed by Dumfries and Galloway (1.56 kilograms per hectare). Despite this, these areas do not feature in the top areas that benefit from the removal of air pollution because they have low population densities compared with the city regions.

Figure 24: Woodland removed the greatest amount of PM2.5, the most harmful pollutant

Air pollutant removal by habitat, thousand tonnes, Scotland, 2018

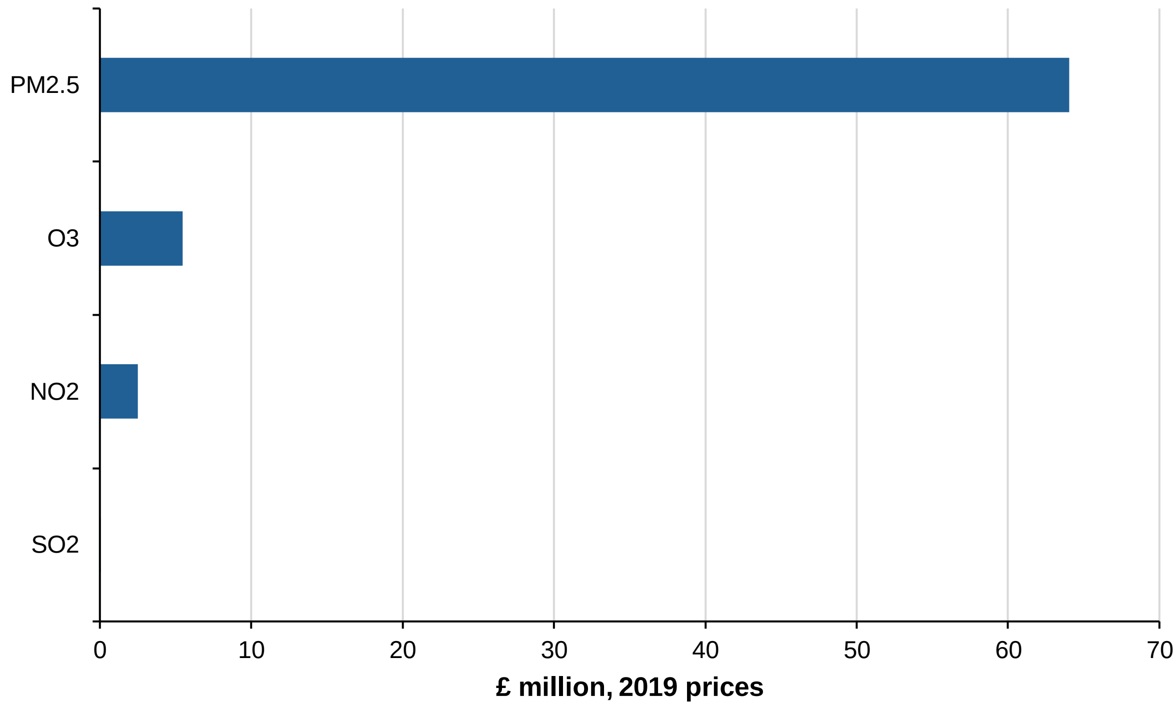


Source: Office for National Statistics and UK Centre for Ecology and Hydrology

It is estimated that in 2018, the avoided health costs in the form of avoided deaths, avoided life years lost, fewer respiratory hospital admissions, and fewer cardiovascular hospital admissions, amounted to a substantial £72.1 million. Although the removal of PM2.5 represents only 1.6% of total pollution removed, 89% of the avoided health impacts are a result of reductions in PM2.5 concentrations.

Figure 25: The removal of PM2.5 resulted in nearly 90% of total avoided health costs in 2018

Avoided health costs from the removal of pollutants, Scotland, 2018

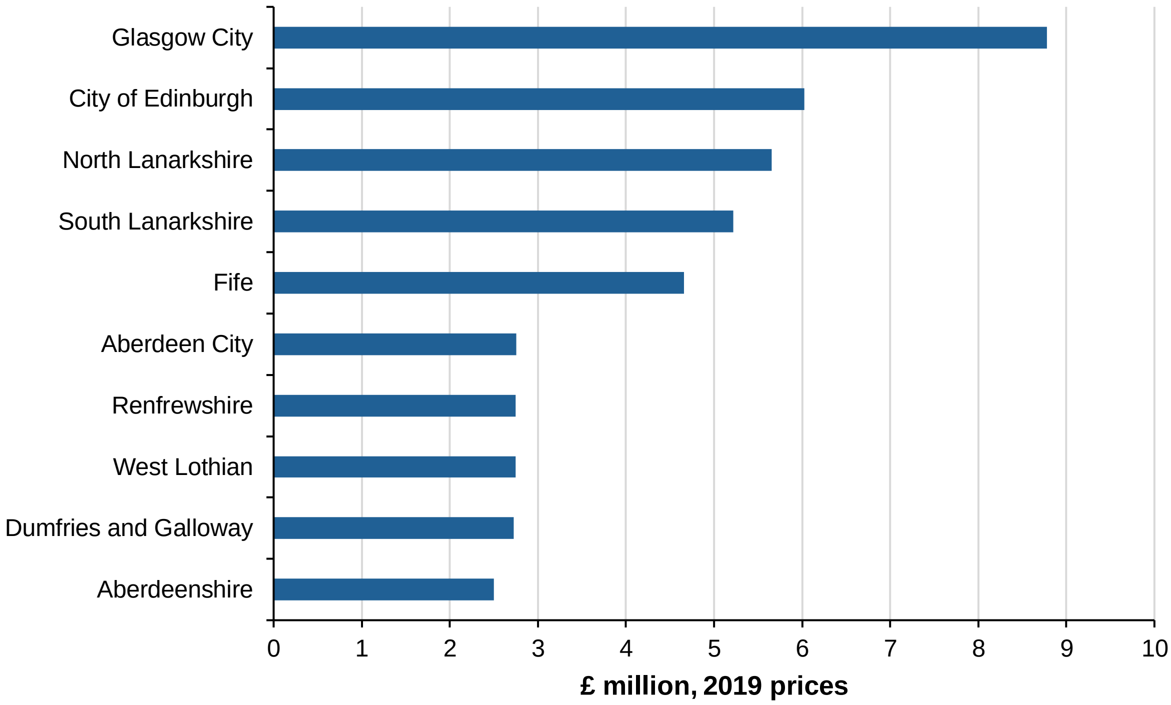


Source: Office for National Statistics and UK Centre for Ecology and Hydrology

The two most populated areas in Scotland (Glasgow and City of Edinburgh) reported the most savings in associated health costs during 2018. This is because annual value estimates look at the total impact on health, which relates to the size of the population.

Figure 26: Glasgow City benefitted the most from air pollution removal in 2018

Avoided health costs from the removal of pollutants, Scottish local government councils, £ million, 2019 prices, 2018



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

The present long-term asset value over a 100-year period, with income uplift and population growth, was £2.3 billion in 2018 (2019 prices).

Noise mitigation by vegetation

The Scottish Government estimated over one million people in Scotland are exposed to regular noise of 55 decibels or greater, around the volume of normal speech. Vegetation acts as a buffer against noise pollution in, for example, urban areas with road traffic noise. Forest Research identified planting buffers of trees and shrubs can reduce noise by five to ten decibels for every 30 metres width of woodland. Noise pollution causes adverse health outcomes through lack of sleep and annoyance, even hearing loss from prolonged exposure. Eftec and others (2018) have developed initial estimates of the benefits vegetation has in reducing noise.

These estimates are considered minimum values, but further work is needed to develop more refined and robust estimates. The number of buildings receiving mitigation in Scotland is estimated to be 7,000 (Table 1). This is lower than estimates for other countries but could be largely influenced by the different noise metric used. Where these metrics were compared, the metrics used in Scotland covered a smaller area than the metric used elsewhere. For further methodological information please see the scoping study produced by Eftec and others (2018).

Table 1: 7,000 buildings benefitted from noise reduction resulting from urban vegetation in Scotland

Number of buildings where road noise levels are mitigated by vegetation in Scotland (rounded to the nearest thousand)

Noise band in noise metric by decibel[1]	England	Scotland	Wales	Northern Ireland	UK
More than 80	-	-	-	-	-
75.0-79.9	1,000	-	-	-	-
70.0-74.9	8,000	-	1,000	-	-
65.0-69.9	36,000	1,000	3,000	1,000	-
60.0-64.9	98,000	6,000	8,000	4,000	-
Total	143,000	7,000	12,000	5,000	167,000

Source: Eftec and others

Notes:

1. 5 dBA bands applied along with guidance in Defra's noise pollution: economic analysis published in 2014.
2. Number of dwellings receiving mitigation in Scotland is likely to be lower than the estimates for the other countries because Eftec and others 2018 used the Lden noise metric rather than the LA1018 metric which was not available for Scotland.
3. Urban vegetation includes large woodlands (>3,000m^2) and smaller woodlands (<3,000m^2), but not very small woodlands (<=200m^2).

In 2019, the value of noise reduction in Scotland was £625,000 in avoided loss of quality adjusted life years (QALY) from sleep disturbance and annoyance. Valuations based on QALY are economic welfare values, which investigate how noise reduction affects people's social welfare. The annual avoided loss of quality adjusted life for the UK was worth £15.6 million in 2019.

Table 2: Noise mitigation from natural capital led to a saving of £625,000 in avoided loss of quality adjusted years associated with a loss of amenity and adverse health outcomes in Scotland

Annual value of noise mitigation (£ thousand, 2019 prices), UK, 2019

Noise band in noise metric by decibel[1]	England	Scotland	Wales	Northern Ireland	UK
More than 80	1	-	-	-	1
75.0-79.9	151	-	11	2	164
70.0-74.9	1,126	8	108	57	1,299
65.0-69.9	4,108	126	319	143	4,696
60.0-64.9	7,936	491	686	330	9,443
Total	13,322	625	1,124	532	15,603

Source: Eftec and others (2018)

Notes:

1. 5 dBA bands applied along with guidance in Defra's noise pollution: economic analysis published in 2014.

The asset value of noise mitigation from vegetation in Scotland was £34 million in 2019. Scotland made up around 4% of the £849 million asset value of noise mitigation across the UK. The asset value for noise reduction in Scotland is based on the estimated future flow of benefits over 100 years.

Many assumptions were made when estimating the future flow of value from noise mitigation by urban vegetation. For example, population affected was held constant and the impact of electric cars was not considered.

Urban Cooling

The urban heat island effect means that cities and towns are prone to higher temperatures than the rural environments surrounding them. Green and blue spaces, such as parks and lakes, can cool urban environments through the process of evapotranspiration and shading. This benefits the economy by avoiding labour productivity loss and reducing the use of artificial cooling (air conditioning).

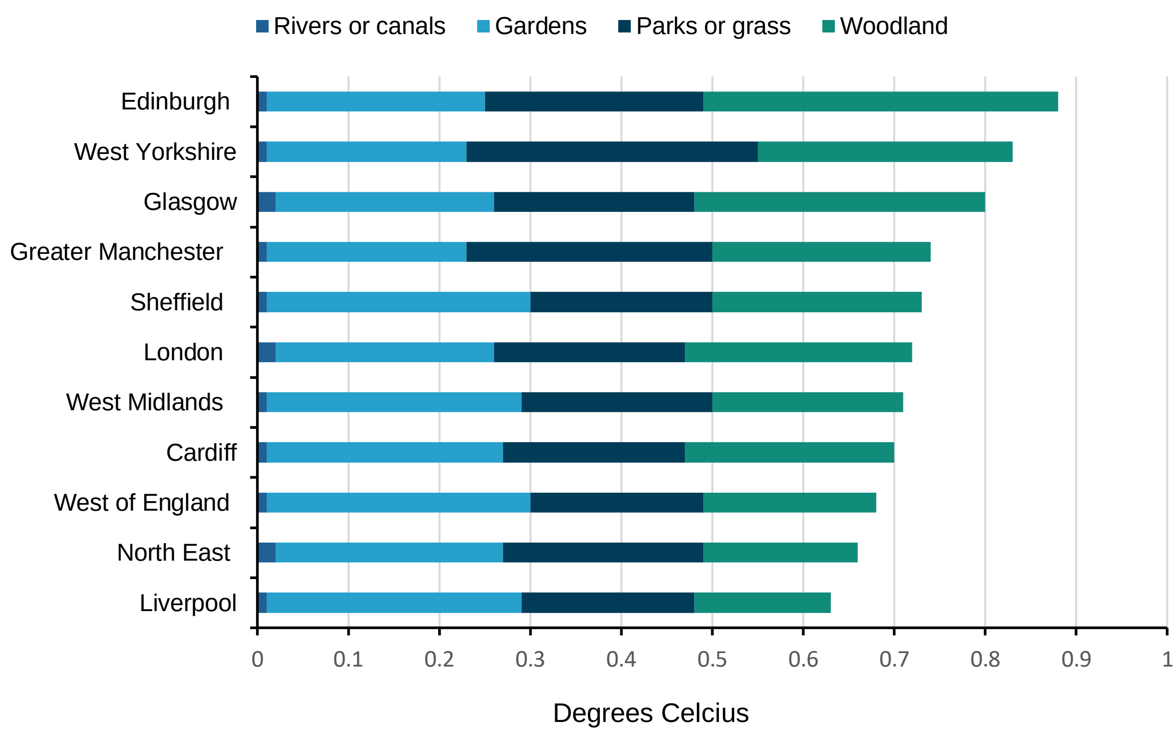
Eftec and others (2018) estimated the [cooling effect provided by natural capital for 11 city regions] across Great Britain, including two Scottish regions – Glasgow and Edinburgh. The cooling effect is based on reducing heat on hot days. “Hot days” refers to any day with a temperature between 28 degrees Celsius and 35 degrees Celsius, as defined by the Eftec and others (2018) report.

As shown in Figure 27, the cooling effect in both Glasgow and Edinburgh is similar, with Edinburgh’s green and blue space providing just 0.08 degrees more cooling. Cooling is dominated by green spaces as opposed to blue spaces.

[Edinburgh has a greater cooling effect than all other city regions] mentioned in Eftec and others (2018), closely followed by Glasgow. Figure 27 shows Edinburgh has a cooling effect 0.14 degrees Celsius greater than the average of the 11 Great British city regions covered. Scottish cities have the highest cooling effects because of the amount of woodland relative to the size of the city region.

Figure 27: Edinburgh city region has the largest area of woodland relative to city area and observed the greatest cooling effect of the 11 cities in Great Britain

Average annual cooling effect of green space and blue space in all Great British regions, degrees Celsius, 2014 to 2018



Source: Eftec and others (2018)

The value of green space in Scotland - measured in terms of avoided health costs – was £3.22 million in 2018 (Table 4). This value is low compared with other Great British city regions such as London, which had the highest avoided costs at £599.27 million in 2018. This is because London has the largest economy and highest number of hot days (see Table 3).

There was a significant increase in the number of hot days across the UK in 2018, nearly triple what was experienced in 2017, at 68 days. Scottish city regions experienced 1.5 hot days in 2018. This resulted in increased avoided costs for Scotland to £3.22 million from the £570,000 seen in 2016 (2019 prices). Between 2016 and 2017, most of the 11 city regions saw an increase in avoided costs. Unlike Edinburgh and Glasgow, many regions had an increase in the number of hot days (five more than 2016 overall).

Table 3: Number of hot days in each of the 11 Great British regions

City region	2016	2017	2018
Cardiff	1.3	3.1	5
Edinburgh	0.2	0	0.5
Glasgow	0.2	0	1
Greater Manchester	1	0.9	4.3
Liverpool	1	2.2	6.2
London	8.2	7.4	22.9
North East	0.4	0	0.1
Sheffield	2.4	1.9	5.7
West Midlands	2.8	4.6	10.6
West of England	1.6	4.6	8.5
West Yorkshire	1.1	1	2.8
Scottish Total	0.4	0	1.5
Total GB	20.2	25.7	67.6

Source: Eftec and others (2018) and Met Office

Notes:

1. In 2017 there were no days classed at hot days in Edinburgh and Glasgow.

Table 4: Total annual value of cooling from green/blue space in each of Great Britain’s regions (£ million, 2019 prices)

City region	2016	2017	2018
Cardiff	3.44	5.38	4.24
Edinburgh	0.24	-	0.39
Glasgow	0.33	-	2.83
Greater Manchester	8.00	1.47	9.50
Liverpool	4.32	0.88	4.65
London	242.43	212.55	599.27
North East	0.36	0.04	0.06
Sheffield	3.54	3.26	8.38
West Midlands	12.93	16.44	27.05
West of England	4.76	11.62	9.73
West Yorkshire	4.82	1.81	7.69
Total GB	285.18	253.46	673.79

Source: Eftec and others (2018) and Met Office

The asset value of urban cooling for Glasgow and Edinburgh city regions are £72.4 million and £33.94 million, respectively (2019 prices). These are calculated using the average number of hot days over the last five years and projected green space urban cooling increases over the next 100 years.

5. Cultural services

Cultural services are the non-material, experiential benefits people obtain from natural capital, such as recreation and aesthetic experience.

Nature provides us with several cultural services, the value of which can be understood by measuring engagement with the natural environment. This engagement involves visits to green and blue spaces, which are measured through survey responses, and desire to live near to these spaces or with a view of nature, which is measured by the value these features add to house prices. These two factors are related because living closer to green and blue spaces enables people to make "free trips" to the natural environment.

Recreation

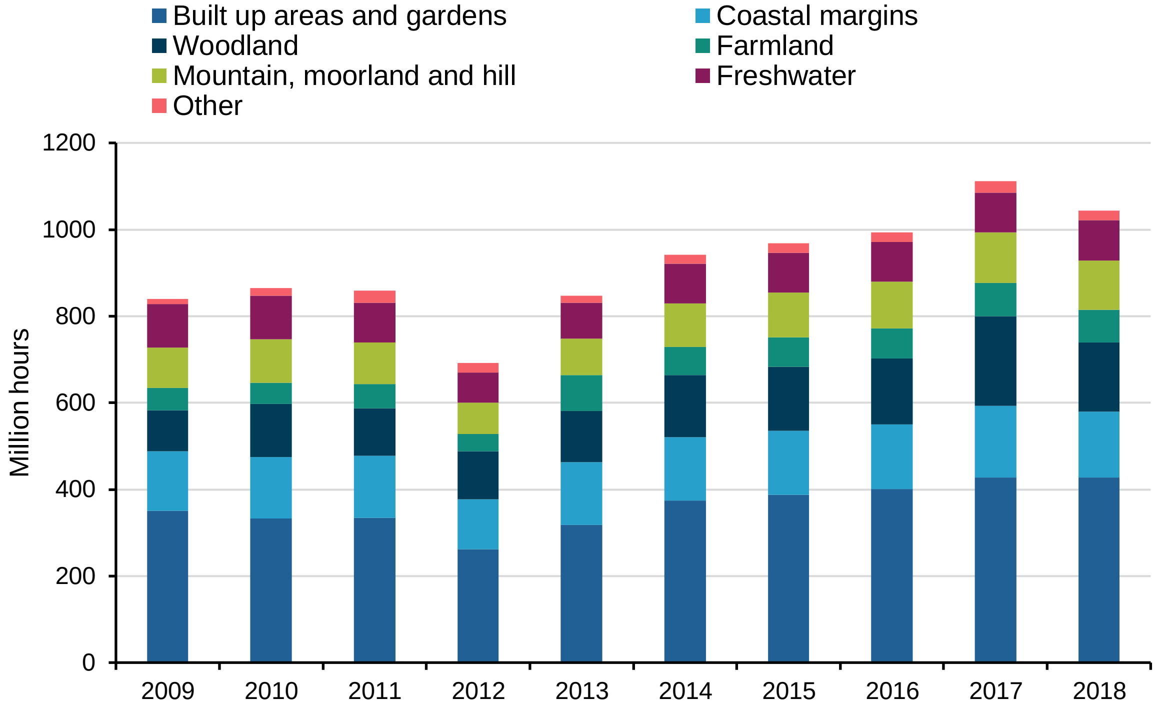
During 2018, over 1 billion hours were spent on Scottish outdoor recreation (including travel time) for an estimated 534 million visits. The time spent in Scotland's natural environment increased between 2012 to 2017, followed by a decline in 2018. However, 2018 still had the second highest amount of time spent on recreation across the time series. The largest year on year fall was between 2011 and 2012 where there was a 19% reduction in time spent in all Scottish habitat areas except woodland (Figure 28). The Scottish Recreation Survey summary report (PDF, 1.51MB) suggests that this may have been because of poor weather. This report estimated the number of visits to the Scottish outdoors was 25% lower during the summer months of 2012, compared with 2011. The total time spent on Scottish recreation fell by 6% from 2017 to 2018.

Visits to built-up urban green space areas in Scotland, such as local parks and gardens, made up the largest proportion of time spent in outdoor recreation between 2009 and 2018 (49% in 2018). An average trip to urban green space lasted an hour and 38 minutes, compared to an average of 2 hours 41 minutes for a trip to a mountain, moorland or hill habitat in 2018.

Estimates of outdoor recreation refer to people aged 16 years and over and excludes overnight and tourist visits. Since the survey is sampled on a residency basis, it does include day trips by Scottish residents which may have occurred outside of Scotland.

Figure 28: Over one billion hours were spent on outdoor recreation in Scotland in 2018, from 534 million visits

Time spent on recreation by habitat in Scotland, million hours, 2009 to 2018

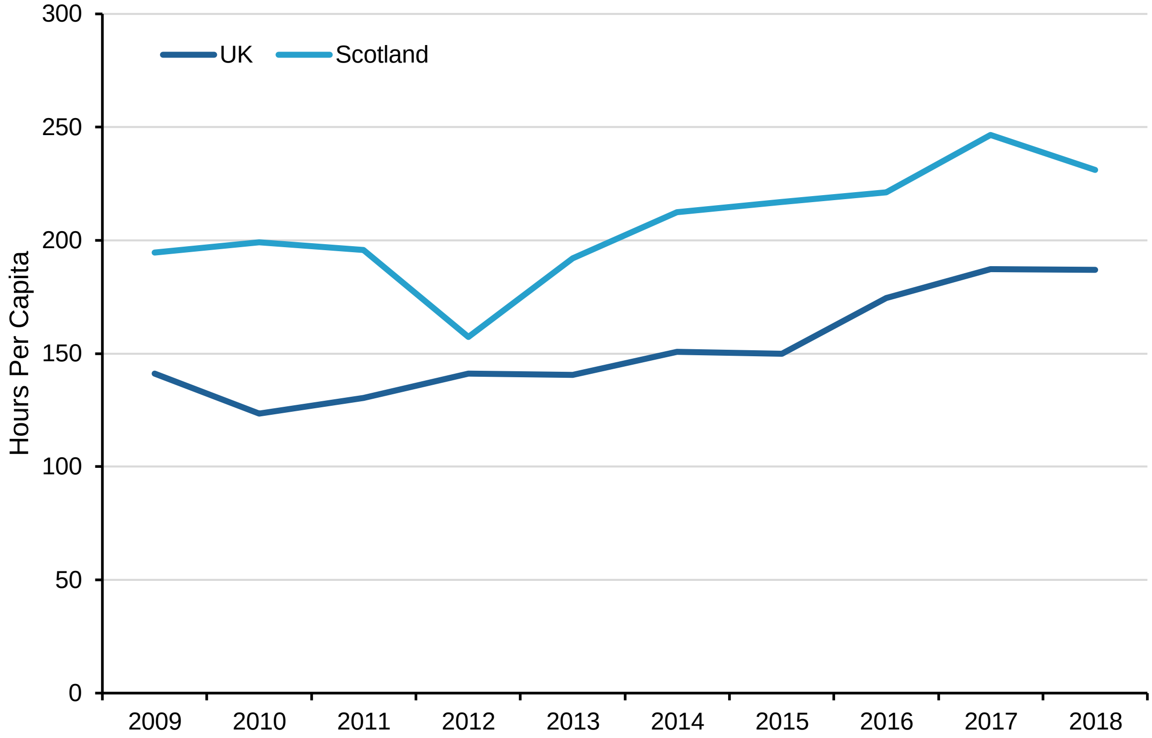


Source: Office for National Statistics, Monitor of Engagement with the Natural Environment (MENE) survey, Scottish Recreation Survey, and Scotland's People and Nature Survey

Scotland represented 10% of estimated UK time spent on outdoor recreation during 2018. In the same year, the average person in Scotland spent 231 hours on outdoor recreation. This was 24% higher than the UK average of 187 hours. There were also more outdoor recreation visits per person in Scotland; people in Scotland on average took 118 outdoor recreation visits in 2018, compared to the UK average of 95 visits.

Figure 29: Across the time series, individuals in Scotland spent more time on outdoor recreation than compared to the UK average individual

Total annual time spent (including travel) per person on outdoor recreation, 2009 to 2018



Source: Office for National Statistics, Monitor of Engagement with the Natural Environment (MENE) Survey, The Welsh Outdoor Recreation Survey, National Survey for Wales, Scottish Recreation Survey, and Scotland's People and Nature Survey

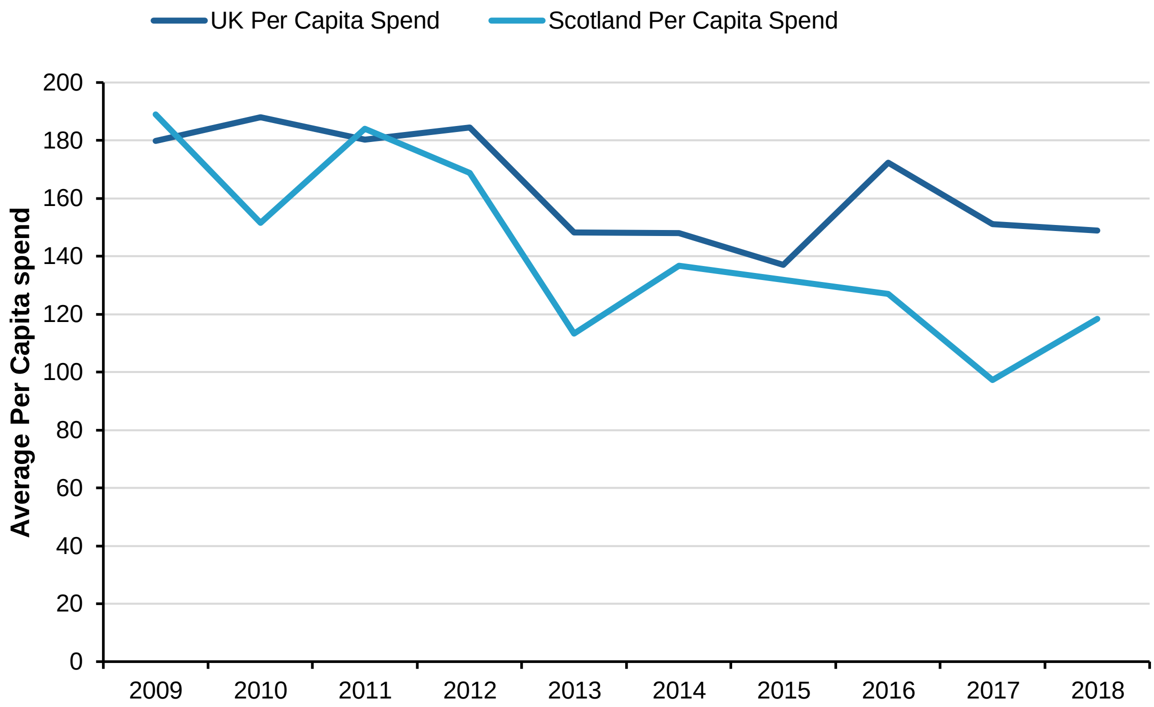
In 2018, UK outdoor recreation had an annual value of £8 billion (2019 prices). Scottish visits represented around 7% of this (£535 million). The value (2019 prices) of Scottish recreation decreased by 34% between 2009 (£815 million) and 2018 (£534 million), whereas the value of UK recreation fell by 12% between 2009 (£9.1 billion) and 2018 (£8 billion).

The fall in Scottish expenditure can largely be attributed to reduced car running costs from fewer and shorter distance drives to the outdoors. In 2018, outdoor recreation visits that were travelled to by car decreased to 26%, down from 30% in 2009. The average roundtrip distance also decreased from 22 miles to 18 miles. People were trading their cars for walking boots as the percentage of people walking to their visit destination increased from 65% to 68% between 2009 and 2018. In 2009, Scottish residents walked 593 million miles travelling for outdoor recreation. In 2018, they walked 493 million miles more, walking 1.1 billion miles to visit nature near their door.

Scottish people are staying longer and visiting the outdoors more, while opting for cheaper visits. In Scotland, the average spend on an outdoor recreation visit in 2018 was £1, compared to the UK average of £1.50. In Scotland, visits to urban green space had the lowest average spend in 2018 of £0.73 per trip, with £0.55 of that being travelling expenses. A lower travel cost is likely to reflect shorter journeys and so improved access to urban green space. Lower values could as easily reflect good provision of natural spaces as bad in this context. Visits in Scotland to mountain, moorland, and hill habitats in 2018 had the highest per trip average spend of £2.77, with £1.96 being travel costs.

Figure 30: With the exceptions of 2009 and 2011, people in Scotland spent less annually on outdoor recreation than compared to the average UK individual

Average Per Capita spend across all habitats, UK and Scotland, 2009 to 2018



Source: Office for National Statistics, Monitor of Engagement with the Natural Environment (MENE) Survey, The Welsh Outdoor Recreation Survey, National Survey for Wales, Scottish Recreation Survey, and Scotland's People and Nature Survey

As illustrated in Figure 30 above, the average per capita spend in Scotland across all habitats in 2018 was £118. The UK average equalled £148 for the same year. Across the time series, the average spend in Scotland has fallen by 37%, while the UK average has fallen by 17%.

The asset value of recreation in Scotland in 2018 was estimated to be £21.5 billion, 6% of the UK value.

Scottish House Prices: Recreation and Aesthetic Values

Living close to green spaces added, on average, £2,438 to Scottish property prices in 2016 (2019 prices).

The value of green and blue spaces measured by house prices at the UK level have previously been published. This analysis estimates what proportion of a house's price can be attributed to its views of or access to green and blue spaces, like parks and lakes. Access to and views of these spaces provide a range of benefits which are reflected through market prices for housing. From implementing a hedonic pricing method, we provide estimates for the value of green and blue spaces, relative to the value of properties within 500 meters of these spaces.

There are two important caveats to note before interpreting the estimates for Scotland. Firstly, we were unable to include data on Scottish schools, as Education Scotland only inspect a sample of schools and educational establishments are not given an overall inspection outcome in the same way that Ofsted and Estyn provide. Since there is a strong correlation between house prices and proximity to school, this lack of data will reduce the precision of the Scottish model.

Secondly, it is possible that our sample of urban property prices underestimates actual urban property prices in Scotland. This is because property price data from Zoopla captures the advertised price rather than the real selling price. Scottish properties, however, are marketed with either a fixed price or “offers over” – the minimum offer accepted by the seller. As bidding for “offers over” houses can drive up the selling price of properties, our data on advertised prices likely underestimate the real selling price.

The hedonic pricing approach analyses a range of other variables that affect house prices, in addition to willingness to pay for living close to green and blue spaces. Table 5 shows the variables included in this model. We can use this approach to measure the value of the “free” recreational trips to nearby green spaces, which are missing from the recreation account. It is worth noting that some of the differences we attribute to green or blue spaces may be because of additional characteristics of the property or the local area, which the model is unable to identify.

Table 5: Variables included in this model

Characteristic vector	Component variables	Sources
Structural	Number of bedrooms	Zoopla
Structural	Property area (square feet)	Zoopla
Structural	Property type, such as house, bungalow, flat	Zoopla
Structural	Property attributes based on description (for example, garage, double glazing)	Zoopla
Neighbourhood	Distance to railway station	Ordnance Survey
Neighbourhood	Distance to local labour market	Ordnance Survey
Neighbourhood	Distance to nearest transport infrastructure	Ordnance Survey
Neighbourhood	Distance to nearest retail cluster	Ordnance Survey
Socio-economic	Scottish Index of Multiple Deprivation, Output Area Classification	Scottish Government
Environmental amenities	Distance to green space	Ordnance Survey
Environmental amenities	Distance to blue space	Ordnance Survey
Environmental amenities	Area of Natural Features in 500 metres radius of property (square metres)	Ordnance Survey
Environmental amenities	Area of functional green space in 500 metres radius of property (square metres)	Ordnance Survey
Environmental amenities	Area of blue space in 500 metres radius of property (square metres)	Ordnance Survey

Environmental amenities	Function of green space	Ordnance Survey
Environmental amenities	Area of residential garden (square metres)	Ordnance Survey
Environmental amenities	Distance to railway line	Ordnance Survey
Environmental amenities	View over green or blue space	Zoopla
Environmental amenities	Air pollution	Department for Environment, Food and Rural Affairs
Environmental amenities	Noise pollution	Department for Environment, Food and Rural Affairs
Environmental amenities	Distance to coast	Department for Environment, Food and Rural Affairs
Environmental amenities	Distance to substation, tower, overhead lines	UK National Grid

Source: Office for National Statistics

Table 6 shows the split of the total stock value by recreational and aesthetic values for the years 2010 to 2016. The value of recreational services is based on the distance travelled to green and blue spaces and the total area these spaces occupy. The value of aesthetic services is based on the view individuals have of green and blue spaces. Recreational values are significantly larger than aesthetic values across this time series.

In 2016, recreational value equalled £5.7 billion and aesthetic value equalled £0.56 billion. Across the time series, the average combined value of access to and views of green and blue space has fallen from £4,767 per property in 2010 to £2,438 in 2016.

We have no data to suggest that these value changes represent genuine falls in the provision or quality of urban green space. However, we do believe the yearly statistics are robust. England and Wales saw similar falls over the same period. We are observing a change in the price the public are willing to pay for houses with higher access to public green space. We have not yet fully analysed the drivers of this change – however it is worth noting that overall house prices have been increasing over that period. One theory is that as buyers start to further stretch their budgets the ability to pay for lower priorities will fall as they increasingly focus on more fundamental needs such as enough bedrooms.

Table 6: In 2016, the total stock value of living within 500 metres of green and blue space was estimated to be £6.3 billion

Year	Average value (£)	Average value (%)	Stock value (£billion)	Aesthetic value (£billion)	Recreational value (£billion)	N properties (millions)
2010	4767	2.41%	11.83	1.28	10.55	2.48
2011	3565	1.92%	8.89	1.09	7.81	2.49
2012	4266	2.30%	10.70	1.01	9.69	2.51
2013	3839	2.24%	9.68	0.92	8.76	2.52
2014	3278	1.97%	8.30	0.87	7.43	2.53
2015	2678	1.90%	6.83	0.63	6.20	2.55
2016	2438	1.77%	6.26	0.56	5.70	2.57

Source: Office for National Statistics

For annual values, we can present an equivalent rental value of living within 500 metres of green or blue space (Table 7). “Imputed rent” is a national accounting term for what homeowners would receive if all homes were rented. It can be thought of as the amount that non-renters are willing to pay themselves for the housing services they produce. This must be imputed as homeowners do not receive payment on their property.

In 2018, the estimated rental value of living within 500 meters of green and blue space was approximately £301 million.

Table 7: Imputed rental values for green and blue space, £ million (2019 prices), Scotland, 2010 to 2018

Year	Total (£ million, 2019 prices)
2010	340
2011	277
2012	320
2013	322
2014	281
2015	275
2016	256
2017	303
2018	301

Source: Office for National Statistics

Travel to work areas (TTWA) are geographical areas created to approximate labour market areas. These are designed so that most people live and work within these defined areas, while relatively few people commute between areas. Table 8 presents the average effect of living near green and blue spaces in different TTWA.

Within the 10 most sampled travel to work areas, Edinburgh has the largest average effect with £6,928 of an average property's value being attributed to access and views of blue and green spaces (2.93% of the average property price).

Table 8: Average effect of living near green and blue spaces in different TTWA, £ 2019 prices, Scotland, 2009 to 2016

Travel to work area	Average Value (£, 2019 prices)	Average value of property price (%)	N Validation Set	Average distance to green spaces (m)	Average distance to blue spaces (m)
Glasgow	3,114	1.93%	5,911	276	334
Edinburgh	6,928	2.93%	2,415	254	390
Motherwell and Airdrie	2,094	1.65%	1,907	290	473
Falkirk and Stirling	2,363	1.56%	1,648	284	281
Livingston	2,562	1.77%	1,174	285	350
Kilmarnock and Irvine	1,880	1.71%	1,086	331	333
Ayr	1,626	1.09%	729	290	367
Dunfermline and Kirkcaldy	2,266	1.73%	601	315	355
Perth	3,010	1.75%	585	262	345
Inverness	2,529	1.36%	409	309	228

Source: Office for National Statistics

6. Asset valuation

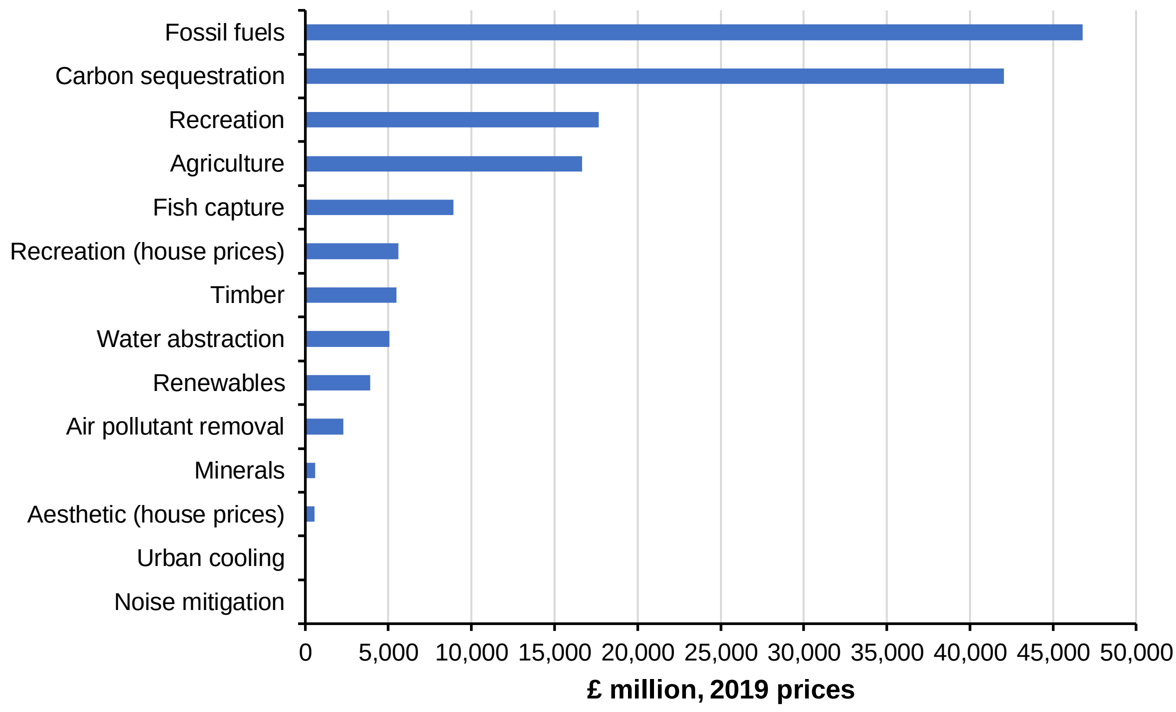
Here we present the asset values of Scottish natural capital by service. These values are estimated by capitalising the annual flow of services from the natural resource that are expected to take place over a projected period, known as the asset life. The annual environmental service flows provide the basis for the projected flows. This is a method known as Net Present Valuation (NPV), which is explained in more detail in the methodology section.

Some of the environmental services presented in this article are produced from renewable resources whose stock is not exhausted over time, such as Scottish woodland delivering carbon sequestration. For these renewable resources, a 100-year asset life has been assumed. The non-renewable abiotic resources presented in this article are minerals and fossil fuels, which have an assumed asset life of 25 years.

In 2017, fossil fuels were equivalent to 30% of the value of Scottish natural capital assets, which in total equalled £156 billion in 2017. The second and third largest services were carbon sequestration, making up 27% of Scottish natural capital assets, and outdoor recreation, making up 11%.

Figure 31: Scottish natural capital assets were valued at £156 billion in 2017

Asset value by service (£ million, 2019 prices), Scotland, 2017



Source: Office for National Statistics

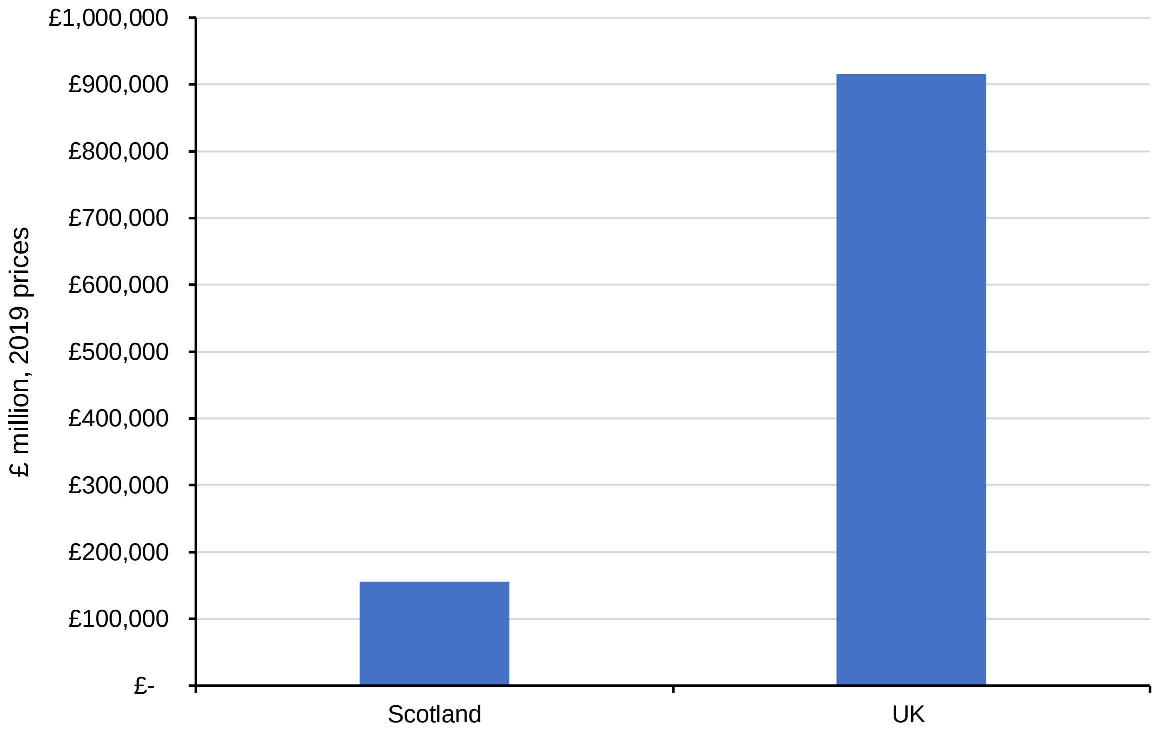
Notes:

1. Values for noise mitigation are from 2018.
2. Values for recreation and aesthetic (house prices) are from 2016.

The asset value of regulating and cultural services, which are not directly included in national accounts, amounted to £68 billion in 2017, or 44% of Scotland's total quantified natural asset value.

Figure 32: In 2017, Scotland's natural capital assets equalled 17% of the UK total natural capital asset value

Asset value (£ million, 2019 prices), UK and Scotland, 2017

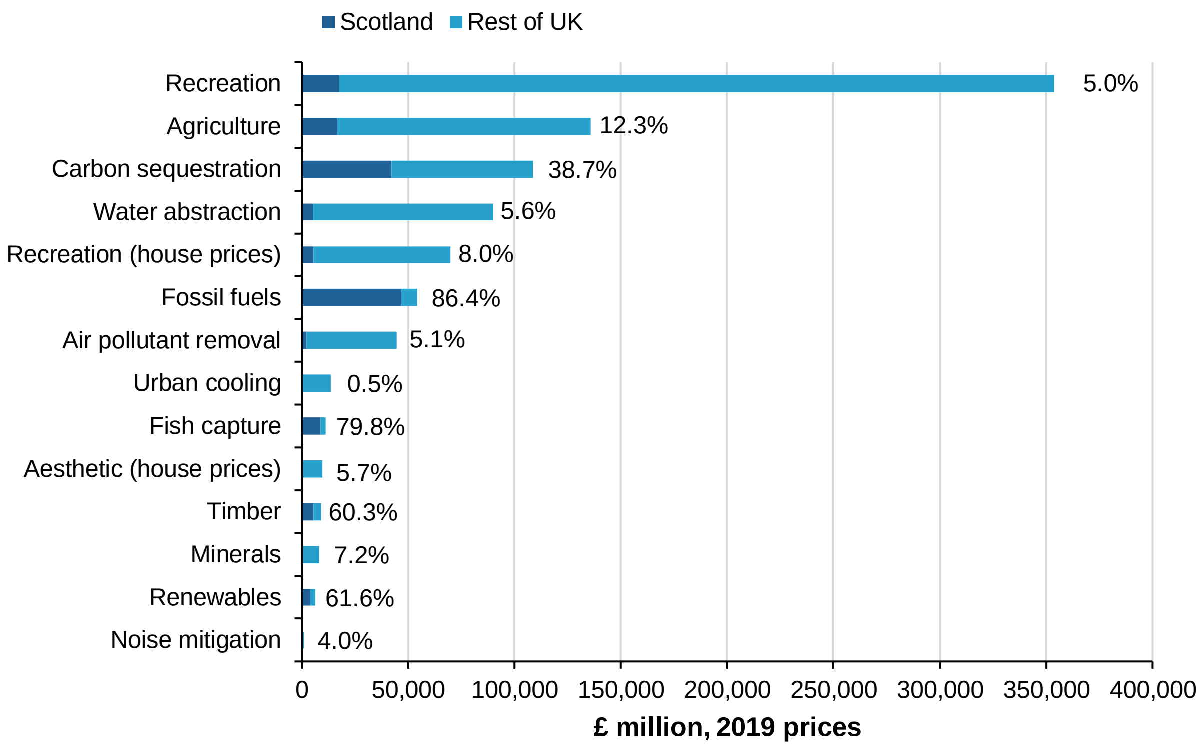


Source: Office for National Statistics

Scotland's contribution to the total UK asset value of each ecosystem service ranges from 0.5% (urban cooling) to 86.4% (fossil fuels). Scottish contributions to UK total asset values are particularly large across some provisioning services, with Scotland contributing 86.4% in fossil fuels, 79.8% in fish capture, 60.3% in timber and 61.6% in renewable energy.

Figure 33: Scotland makes a significant contribution to UK provisioning services

Ecosystem service asset values (£ million 2019 prices), UK, 2017



Source: Office for National Statistics

7. Methodology

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.

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 methodology section provides a detailed summary of the methodology used to develop the natural capital accounts. This summarises the broad approach to valuation and the overarching assumptions made, as well as giving a more detailed description of the methods 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 UK 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 currently 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.

We welcome discussion regarding any of the approaches presented via email at natural.capital.team@ons.gov.uk.

Overview of services

This section provides a high-level overview of the ecosystem services relative quality and future aims. For detailed information on the methods used please continue to the methodology by service section.

Table 9: Summary of service estimates quality

Service	Suitability	Coverage	Source data	Granularity	Timeliness	Timespan
Provisioning						
Agricultural biomass	3	2	1	3	2	1
Fish capture	1	2	2	1	2	1
Timber	1	1	1	1	1	1
Water	3	2	1	3	2	1
Minerals	2	1	1	3	2	1
Fossil fuels	1	1	1	3	2	1
Renewable energy	3	3	2	2	2	1
Regulating						
Carbon sequestration	1	3	2	2	2	1
Air pollutant removal	1	1	2	1	3	2
Urban cooling	1	3	3	2	2	2
Noise mitigation	1	2	2	1	3	3
Cultural						
Recreation	1	3	2	1	2	1
Recreation (house prices)	1	2	1	1	3	2
Aesthetic (house prices)	1	2	1	1	3	2

Source: Office for National Statistics

Notes:

1. 1/Green = relatively strong, 2/Amber = could be improved, 3/Red = needs improvement.
2. Suitability: Suitability of method in the valuation of natural capital asset, particularly considering the ability to integrate condition and sustainability measures. A suitable natural capital value has a clear logic chain where the impact of changes can be measured and sustainability influences asset valuation.
3. Coverage: The ability to provide a well-rounded and fair coverage of the full benefits the service provides.
4. Source data: The quality of the underlying data sources for estimating the ecosystem service.
5. Granularity: The ability to disaggregate the service, primarily by geography.
6. Timeliness: The ability to provide full up to date estimates.
7. Timespan: The ability to provide a consistent timeseries going back several years.

Service summary and future aims

Agricultural biomass

Estimates of the provisioning value of agricultural biomass based on a resource rent residual value of industry national accounts data does not offer a strong logic chain from extent through condition and flow to valuation. As a result, it is difficult observe how changes in agriculture impact its natural capital asset valuation. Further development and examination of alternative methods is required. The methodology for the valuation of agricultural biomass is likely to change substantially in the future.

Fish capture

Using net profit estimates of fish capture of individual species in different areas provides a clear logic chain from natural capital asset to valuation. As a result, we can now begin to integrate sustainability measures that directly influence the asset valuation, as seen in the annex and within the marine accounts. Although illustrated in the annex, to maintain consistency with the 2020 UK accounts, these methodological improvements are not included within this account.

Timber

Estimates of the provisioning value of timber provides a strong logic chain from flow to valuation, through stumpage prices, and integrate future projections of provisioning. We currently have no development plans for the near future.

Water abstraction

Estimates of the provisioning value of water abstraction based on a resource rent residual value of industry national accounts data does not offer a strong logic chain from flow to valuation. As a result, it is difficult observe how changes in the water industry affect its natural capital asset valuation. The methodology for the valuation of water abstraction is likely to change substantially in the future. Long term we hope to net off the costs of any water restrictions to society from overall industry income.

Minerals

Estimates of the provisioning value of mineral extraction based on a resource rent residual value of industry national accounts data does not offer a strong logic chain from flow to valuation. As a result, it is difficult observe how changes in the mineral extraction industry affect its natural capital asset valuation. Data for the minerals industry is relatively sparse. We currently have no development plans for the near future.

Fossil fuels

Estimates of the provisioning value of fossil fuels based on a wholesale price integrated resource rent residual value adaptation represent the best available practical approach to the valuation of the fossil fuels asset. There are unlikely to be any significant changes to this methodology in upcoming accounts.

Renewables

Estimates of the provisioning value of renewable energy based on a resource rent residual value of industry national accounts data does not offer a strong logic chain from flow to valuation. As a result, it is difficult observe how changes in the renewables industry affect its natural capital asset valuation. The methodology for the valuation of renewables is likely to change substantially in the future. We aim to use data on subsidies and levelized costs of operation to estimate the overall income for the renewable providers. The direction of the change is uncertain.

Carbon sequestration

Carbon sequestration largely suffers coverage issues as to the extent of land-based emissions (such as from degraded peatland) that are currently not fully covered within the greenhouse gas inventory. Potentially significant sequestration from marine habitats (covered in the annex) is also not included. There are also issues as the exclusion of 'natural' emissions, if sequestration moved from a gross to a net sequestration basis the value would fall. The valuation process for carbon sequestration is unlikely to change soon but the coverage of different habitats is likely to improve.

Air pollution removal

We hope to update the models and data to provide more accurate and timely values of air pollutant removal by vegetation. Direction of the change would be uncertain, but it is unlikely to be large.

Urban cooling

Longer term it is desirable to use remote sensing temperature data to ground truth our estimates of urban cooling. If we can move from a relatively simple model to a more precise site-specific prediction, we may also switch to a less conservative valuation price.

Noise mitigation

We hope to use other data to provide yearly estimates of noise production. This would allow us to see expected changes between years but should not impact on the scale of the service. There are also likely to be changes in the modelling for noise dispersion which may reduce benefits.

Recreation

Recreation largely suffers coverage, lacking overnight tourism, and timeliness issues. Day visit surveys across the UK are not consistent and, increasingly, lack the essential questions on expenditure needed for estimations of the recreational cultural service. We have recently published the tourism accounts, providing a different and consistent approach to estimating recreation, inclusive of overnight tourism. This will significantly increase the value of recreation in future accounts. To maintain consistency with the 2020 UK accounts, these methodological improvements are not included within this account.

Recreation (house prices)

The original data source for advertised house prices is no longer readily available. We will therefore move to actual recorded sale prices. In addition, we need to make more direct estimates of urban and rural house numbers but also include the value of recreation outside of formal parks. The overall impacts of these changes are unknown but could be significant.

Aesthetic (house prices)

See Recreation (house prices). However, in addition we would need to change the basis on which a, "view" is identified which again will have an uncertain impact on value.

Annual ecosystem service flow valuation

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

- identifying a price that relates, as closely as possible, to contributions provided by the ecosystem to the economy
- 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, water abstraction, minerals, fossil fuels, and renewable energy generation a “residual value” resource rent approach is used.

Resource rent definition and assumptions

The resource rent can be interpreted as the annual return stemming directly from the natural capital asset itself. This 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 10. 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 10: Derivation of resource rent

Calculation	Measure
Less	Operating costs
Less	Intermediate consumption
Less	Compensation of employees
Less	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 2017). 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 193) (PDF, 5.33 MB) acknowledges that the use of the method may result in 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 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

A principal 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 of data, up to and including the reference year in question.

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 a key 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 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

The following section provides an explanation of the data sources and methods used in each service.

As well as updated data and a newer price basis there have been some methodological improvements and underlying data source changes from the previous Scottish natural capital accounts: 2020. Results should not be compared across accounts. Please use the data available in this alongside this release for time series analysis. The scale of these changes varies across different ecosystem services. Table 11 provides a broad explanatory summary of these changes and the impact they have on service valuations.

Table 11: Percentage change in 2016 asset values by service because of methodological changes between 2020 and 2021 accounts

Service	Percentage change	Explanation
Fish capture	52%	Improved net profit estimations from Seafish
Water abstraction	56%	Updates to the Scottish input output tables for standard industry code 36/37
Minerals	-75%	Updates to the Scottish input output tables for standard industry code 08
Fossil fuels	-12%	Updates to the Office for National statistics capital stocks data for standard industry code 06
Other services	0%	No change
Total	-4%	

Source: Office for National Statistics

These experimental accounts are being continually revised to produce the best statistics with the available data and methods.

Agricultural biomass

Agricultural biomass relates to the value of crops, fodder and grazed biomass provided to support agricultural production. Agricultural statistics are published by the Scottish Government. Grazed biomass calculations are based upon livestock numbers and livestock annual roughage requirements provided in the Eurostat Economy-wide Material Flow Accounts (PDF, 2.96MB) (EW-MFA) questionnaire. This approach is also used in the UK Material Flows Accounts.

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 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.

For the primary 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 Input-output supply and use tables and capital stocks data do not provide further SIC breakdowns so the industry residual value includes animal production. 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.

While residual value resource rent approaches should be used for valuing provisioning services in the first instance (Principle 7.5) top-down industry-level estimates present difficulties in establishing clear ecosystem service logic chains and disaggregation. Condition indicators, or even physical flows of agricultural biomass, cannot readily be related to the estimated valuation of the service.

Fish capture

We have been working to improve our fisheries statistics and more work is needed. We rely on a range of external sources that all involve known uncertainties. For instance, Norway and Faroese landings are excluded from this analysis. The economic data are based on UK fleet data, which we also apply to foreign vessels that may face different costs and prices.

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.

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).

To calculate marine fish capture in the Scottish exclusive economic zone (EEZ) Marine Management Organisation ICES statistical rectangle factors were used. The overall fish capture provisioning service physical flow presented in this article represents landings (tonnage) from UK waters. UK boundaries do not perfectly align with the geographical areas of fish capture statistics. For more detail on how fish capture in UK waters is estimated, see the Marine Management Organisation Exclusive Economic Zone Analysis and associated publications.

Valuations are calculated using net profit per tonne (landed) estimates, provided by Seafish, for different marine species by marine areas. Net profit per tonne is calculated using Seafish economic estimates for fleet segments and Marine Management Organisation data on landings by stocks (landed value and landed weight) and landings by stocks and species (in cases where species are not managed by total allowable catches). Annual net profit per tonne (landed weight) is multiplied by tonnes of fish captured (live weight) for a specific species. The data are aggregated for overall annual valuations of fish provisioning from the UK EEZ.

Landed weight is the weight a product at the time of landing, regardless of the state in which it has been landed. Landed fish may be whole, gutted and headed or filleted. Live weight is the weight of a product, when removed from the water.

A notable limitation of the fish capture provisioning valuation methodology is that landed weight net profits were multiplied by live weight fish capture. Based on Marine Management Organisation data on live and landed weights of UK vessel landings into the UK, aggregate landed weight is around 7% less than live weight.

Net profit per tonne was not available for all fish species so not all the physical flow is valued. Based on available net profit per tonne annual data, 93% of fish provisioning (live tonnes) from Scottish waters was valued in 2018.

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.

Timber provisioning service asset valuations used Forestry

Commission forecasts of timber availability to estimate the pattern of expected future flows of the service over the asset lifetime.

Removals estimates are taken from Forest Research Timber Statistics and converted from green tonnes to cubic metres (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 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 data for water abstraction for public water supply are sourced from Scottish Water.

Monetary estimates are based on resource rents calculated for the Standard Industrial Classification (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.

In estimating the resource rent for the Scottish water abstraction provisioning service Input-output supply and use tables and capital stocks data are 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.

Further work is required to value the services relating to other uses of the water provisioning services, and to explore the roles of different ecosystem types in providing clean water.

Minerals

Physical estimates of mineral extraction are provided by the British Geological Survey (BGS) as a country-level breakdown of the United Kingdom Minerals Yearbook. Mineral extraction after 2014 are estimated.

Monetary estimates are based on the "residual value" resource rent approach calculated from the SIC subdivision class: Other mining and quarrying (SIC 08). This division includes extraction from a mine or quarry, but also dredging of alluvial deposits, rock crushing and the use of salt marshes. The products are used most notably in construction, such as stone and aggregates, and manufacture of materials, such as clay and gypsum, and manufacture of chemicals. This division does not include processing (except crushing, grinding, cutting, cleaning, drying, sorting, and mixing) of the minerals extracted.

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.

Fossil fuels

Physical estimates of oil and gas production are available from the Scottish Government. Country-level coal production were requested from the Department for Business, Energy, and Industrial Strategy (BEIS) Digest of UK Energy Statistics (DUKES).

Monetary estimates of oil and gas 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, from the Scottish Government, and user costs of produced assets, 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 capital expenditure.

For the valuation of coal, a “residual value” resource rent approach is used. This is based upon supply and use and capital stocks data for the Standard Industrial Classification (SIC) division: Mining of coal and lignite (SIC 05). 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 05) intermediate consumption at purchasers' prices.

For the asset valuation of fossil fuels 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 the last five years of 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.

Renewable generation

Energy generated by renewable sources is published in the Scottish Government Energy Statistics Database.

Monetary estimates are based on the “residual value” resource rent approach calculated from the SIC Group 35.1: Electric power generation, transmission, and distribution. UK capital stocks data are apportioned for Scotland based on relative installed capacity. These data are then apportioned using turnover from the ONS Annual Business Survey (ABS) to derive the resource rent of 35.11: Production of electricity. To estimate the renewable provisioning valuation, data were further apportioned using renewables proportion of total energy generation.

Carbon sequestration

Estimates relate to the removal of carbon dioxide equivalent (CO2e) from the atmosphere by habitats in Scotland. However, because of a lack of data we are unable to include the marine habitat, including those intertidal areas such as saltmarsh. Furthermore, peatlands are only partially covered. The UK Centre for Ecology and Hydrology estimates that damaged peatland in Scotland emitted 9.3 million tonnes of CO2 equivalent. This nearly completely negated the gross terrestrial sequestration of Scotland reported in the Greenhouse Gas Inventory (GGI).

The carbon sequestration data come from the UK National Atmospheric Emission Inventory (NAEI), which reports current and future projections of carbon removal for the land use, land use change and forestry (LULUCF) sector.

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

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

- land converted to cropland
- wetlands remaining wetlands
- land converted to wetlands

For the years 1990 to 2017, estimates of Scottish carbon sequestration are sourced from the Greenhouse Gas Inventory. In the asset valuation, projections of carbon sequestration are provided for the years 2017 to 2050 using the central values. This is produced by the National Atmospheric Emission Inventory (NAEI) in the LULUCF emission projections. For years used in the projections beyond 2050, the carbon sequestration rate is assumed to be constant as at 2050 levels.

To work out the annual value, we multiply the physical flow by the carbon price. 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 beyond 2100 are constant at 2100 levels.

The non-traded carbon prices are used in appraising policies influencing emissions in sectors not covered by the EU Emissions Trading System (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 (expected) development of a more comprehensive global carbon market, the traded and non-traded prices of carbon are assumed to converge into a single traded price of carbon.

Air pollution removal by vegetation

Air quality regulation estimates have been supplied in consultation with the UK Centre for Ecology and Hydrology (UKCEH). A very brief overview of the methodology will be explained here. A more detailed explanation can be found in the full methodology report published in July 2017.

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.

Air pollution data removal by Scottish vegetation has been modelled for the years 2007, 2011, 2015 and then scaled to create values in 2030. Between these years a linear interpolation has been used and adjusted for real pollution levels as an estimation of air pollution removal.

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 benefiting 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))

The damage costs were updated in February 2019. For a method of how the damage costs are calculated (PDF, 1.01MB) please see the report published by Defra.

Future flow projections used for asset valuation incorporate an average population growth rate and an assumed 2% increase in income per year (declining to 1.5% increase after 30 years and 1% after 75 years). Income elasticity is assumed to be one. Annual forecasts are discounted to 2018 present values using a 3.5% discount rate, reducing appropriately as per the Green Book methodology. More work is being conducted in this area.

Noise mitigation by vegetation

Please see the full methodology report published by Defra.

Urban cooling

A brief overview of the methodology of urban cooling will be provided here but for more detailed description please see Eftec and others (2018). To calculate the physical flow of local climate regulation services for the urban blue and green space assets, Eftec and others (2018) calculated the proportional impact on city-level temperatures caused by the urban cooling effect of blue and green space features and their buffers using the cooling values from various sources.

The monetary account measures the value of the cooling effect in pounds. The cooling effect is monetised through the estimated cost savings from air conditioning and the benefit from improved labour productivity. The benefit from improved labour productivity makes up most of the value, with avoided air conditioning energy costs only accounting for a small fraction.

This is assessed by non-financial business sectors, based on averaging temperature mitigation across urban areas, and applying temperature-output loss functions to estimate the gross value added (GVA) that would have been lost because of heat in the absence of the cooling effect, accounting for adaptation behaviours.

These adaptation behaviours consider the averted loss of labour productivity from air conditioning and behaviour change. A 40% reduction is applied to the estimated additional avoided productivity loss from urban cooling to more labour-intensive or non-office based sectors. For example, mining and utilities, and manufacturing are reduced at 40%. An 85% reduction is applied for less labour-intensive or office-based sectors for averted losses because of air conditioning (for example, information and communication; real estate activities).

These estimates represent exchange values as they are based on avoided losses in economic output and expenditure. Welfare values would be included if the valuation covered the non-market benefits to the public of urban cooling, for example, the value of tree shading. In principle, some of these non-market benefits may be captured within the recreational account, to the extent that the cooling and shading features of green and blue space generate more recreational visits to such sites on hot days.

Additionally, avoided air conditioning energy costs are based on estimates in London and extrapolated to other city regions. To extrapolate to other city regions, data on the relative air-conditioned office space and percentage green space in other regions are used. This figure is more tentative. The value of the service will fluctuate year to year reflecting the number of hot days (defined as over 28 degrees Celsius) experienced.

The monetary account of the future provision of the ecosystem service, or future benefit stream, accounts for the benefits received over a specified time period, in this case 100 years. The account incorporates a projection for an annual increase in working day productivity losses because of climate change, which increases the value of urban cooling over time. The assessment of future climate impact relies on broad estimation of the number and degree of hot days in future across Great Britain.

As well as including climate change impacts, an annual uplift is applied to the monetary values to account for year-on-year increases in gross value added (GVA) over the 100-year assessment period. For the first 30 years this uplift is 2% annually, decreasing to 1.5% for years 31 to 75, and 1% for years 76 to 100.

Further work is needed to measure this ecosystem more accurately, for example, adoption of a more granular, bottom-up approach to physical account modelling. For a full list of all the recommendations to update this service please see Eftec and others (2018).

Recreation

The recreation estimates are adapted from the “simple travel cost” method developed by Ricardo-AEA in the methodological report Reviewing cultural services valuation methodology for inclusion in aggregate UK natural capital estimate. 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 some 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.

Estimates for the cultural service of outdoor recreation in this publication use respondent data from two surveys in Scotland. The questions used from these surveys can be broadly summarised as:

- How many visits to the outdoors for leisure and recreation have you made in the last four weeks?
- On the last visit to the outdoors, what type of habitat did you go to?
- What was the main means of transport used on this last visit?
- How far did you travel to get to and from the main destination of this visit?
- How long was the visit, in terms of time (including travel time)?
- How much did you spend on [spending category]?

From 2003 to 2012, data from the Scottish Recreation Survey (ScRS) were used. The ScRS was undertaken through the inclusion of a series of questions in every monthly wave of the TNS 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.

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. Unlike ScRS, SPANS excludes questions relating to respondent expenditure during their last outdoor recreation visit. To produce estimates of Scottish outdoor recreation expenditure beyond 2012 we created a statistical model. Using comparable Monitor of Engagement with the Natural Environment (MENE) from Natural England and ScRS data, this model examined the relationship between English and Scottish per visit expenditure on a habitat basis. Linear interpolation was used to produce estimates of Scottish recreation from 2014 to 2016.

Habitat disaggregated estimations of expenditure and time spent may not sum to overall time spent. This is because habitat estimates may be based upon a different sample – those answering a question on habitats visited.

Table 12: Scottish recreation broad habitat classifications

Broad habitat	Scotland survey habitats
Built up areas and gardens	Village
Built up areas and gardens	Local Park or open space
Built up areas and gardens	Towns
Built up areas and gardens	Golf course/football stadium
Built up areas and gardens	Local urban
Built up areas and gardens	Local area
Built up areas and gardens	City
Built up areas and gardens	Country lanes
Built up areas and gardens	Castle/historical building
Built up areas and gardens	Garden/gardening
Built up areas and gardens	Local show/festival
Built up areas and gardens	Leisure/sports centre
Built up areas and gardens	Streets/roads
Coastal margins	Sea/Sea loch
Coastal margins	Beach/Cliff
Coastal margins	Beach
Coastal margins	Cliff
Coastal margins	Wildlife area
Woodland	Woodland/forest - managed by Forestry Commission/Forest Enterprise
Woodland	Woodland/forest - other type of owner
Woodland	Woodland/forest - do not know owner
Woodland	Wildlife area
Farmland	Farmland - fields with crops
Farmland	Farmland - fields with livestock
Farmland	Farmland - mixed crops and livestock
Farmland	Wildlife area
Farmland	Farmland unspecified
Farmland	Country/countryside
Mountain, moorland and hill	Mountain/moorland

Mountain, moorland and hill	Mountain/hill
Mountain, moorland and hill	Moorland
Mountain, moorland and hill	Wildlife area
Freshwater	Loch
Freshwater	River/Canal
Freshwater	River
Freshwater	Canal
Freshwater	Wildlife area
Freshwater	Reservoir
Other	Others
Other	None of these
Other	Do not Know/Not Stated

Source: Office for National Statistics, Scottish Recreation Survey, Scottish People and Nature Survey

For the asset valuation of outdoor recreation, projected population growth calculated from ONS population statistics and an income uplift assumption, 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. These assumptions project the annual value to increase over the 100 years.

It is acknowledged that the expenditure-based method provides an underestimation of the value provided by visits to 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 time spent by people in the natural environment is not itself directly valued because of the accounting and methodological challenges involved.

A considerable number of outdoor recreation visits have no expenditure as people take local visits, such as walking to a local park. The value of local recreation and the aesthetic benefit from living near green and blue spaces is estimated through house prices.

Recreation and aesthetic value in house prices

There is a detailed methodology note on how the recreation and aesthetic value in house prices was produced for the UK accounts, please see this 2019 House Pricing Methodology paper. There are two significant differences for consideration for Scotland.

First, we were unable to include data on Scottish schools as Education Scotland only inspect a sample of schools and educational establishments are not given an overall inspection outcome in the same way that Ofsted and

Estyn provide. Since there is a strong correlation between house prices and proximity to school[1], this lack of data will reduce the precision of the Scottish model. Future work might hope to use alternative data sources on the quality of Scottish schools.

Second, it is possible that our sample of urban property prices are underestimates of actual urban property prices in Scotland. We source property price data from Zoopla, which uses advertised price rather than the selling price. However, Scottish properties are marketed with either a fixed price or “offers over” – the minimum offer accepted by the seller. As bidding for “offers over” houses can drive up the selling price of properties, our data on advertised prices could underestimate the selling price.

Annex A: Fish capture provisioning and sustainability

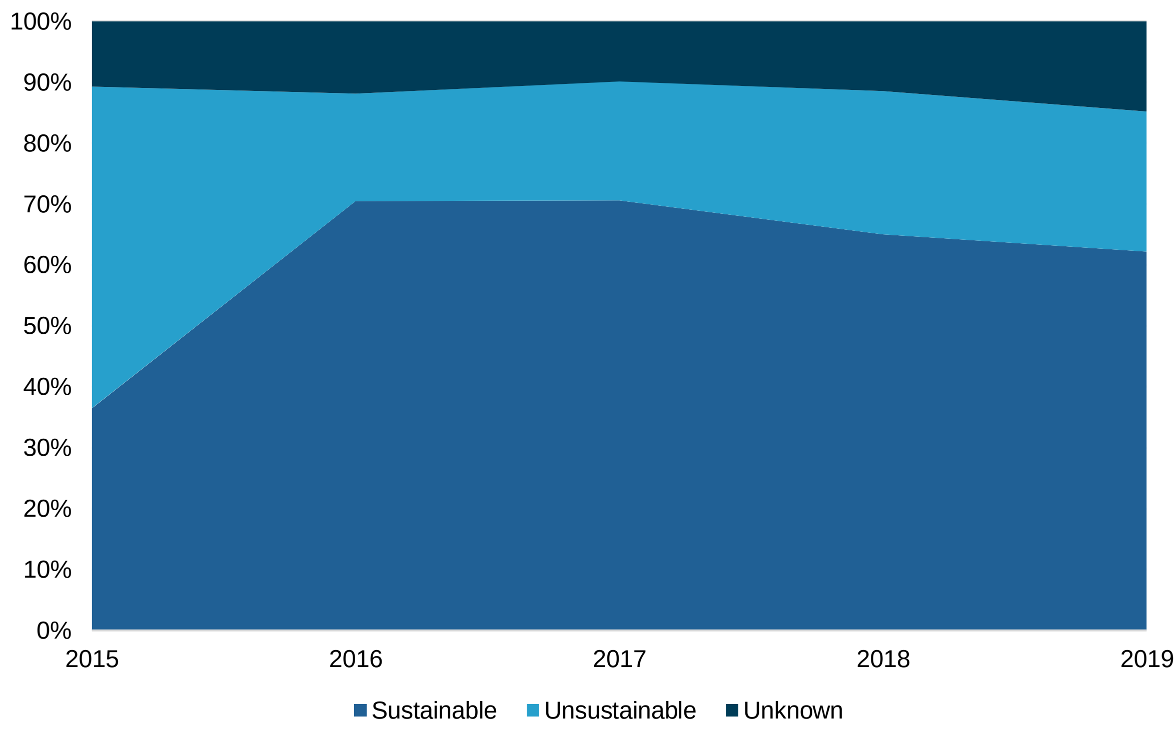
The sustainability of fish capture will be integrated into future UK and Scottish natural capital accounts. To maintain consistency with the UK 2020 accounts, this methodological improvement was not implemented for this account.

For all fish species across different areas in UK waters, we estimate whether fishing is sustainable using The International Council for the Exploration of the Sea stock assessments. This does not include wider externalities from fishing. For each stock we check that fishing pressure is at or below levels capable of producing maximum sustainable yield. We also check if each stock's spawning biomass is at or above the level capable of producing the maximum sustainable yield. Across the years in Scotland, we can determine stock sustainability for 88% of the fish capture tonnage, leaving 12% as unknown.

In Scotland, from 2015 to 2019, the percentage of sustainable fish capture increased from 37% to 62%. The percentage of fish caught where sustainability is unknown increased from 11% in 2015 to 15% in 2019. Within this time series, the largest year on year improvement on sustainable fishing occurred from 2015 to 2016, as a result of mackerel fishing becoming sustainable.

Figure 34: In 2019, 62% of Scottish fish capture was sustainable

Percentage of Scottish fish capture that is sustainable, unsustainable and fish capture where sustainability is unknown, Scotland, 2015 to 2019

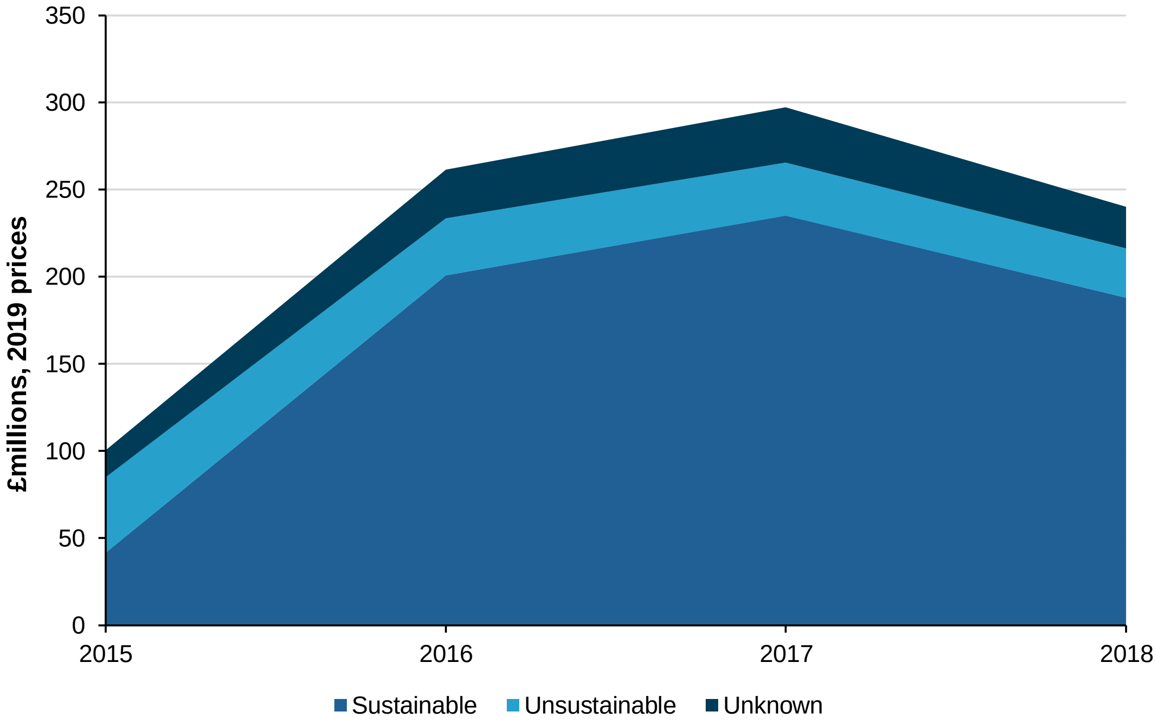


Source: Office for National Statistics, Marine Management Organisation, Seafish, Scientific, Technical and Economic Committee for Fisheries and The International Council for the Exploration of the Sea

In 2018, 78% of the value of fish capture from the Scottish EEZ was sustainable - around £188 million of £240 million. In 2018, 12% of Scottish landed fish value came from unsustainably sourced fish and 10% came from landed fish where sustainability is not known.

Figure 35: Sustainable fish capture is making up more of the catch value

Value of landed Scottish sustainable fish, unsustainable fish, and fish with unknown sustainability, £ million, 2019 prices, Scotland, 2015 to 2018



Source: Office for National Statistics, Marine Management Organisation, Seafish, Scientific, Technical and Economic Committee for Fisheries and The International Council for the Exploration of the Sea

Annex B: The Natural Capital Asset Index and the Natural Capital Accounts – How Do They Compare?

An alternative appraisal of Scottish natural capital is available through NatureScot's Natural Capital Asset Index (NCAI). The NCAI is a composite index which analyses the relative potential of nature to contribute to the wellbeing of Scotland's citizens. The NCAI and National natural capital accounts provide complimentary information about natural capital in Scotland This annex provides information on the similarities and differences between the NCAI and the Scottish natural capital accounts.

NatureScot has been producing the NCAI since 2007, and it is now part of the National Performance Framework as an economic indicator. The 2021 NCAI update was published on 26th May 2021. Adapted from the existing UK-wide accounts by the ONS in 2020, the Scottish natural capital accounts presented for the first time estimates of the value of Scotland's natural capital in monetary terms and has subsequently been updated on an annual basis. This will make it easier to incorporate natural capital into decision making and helps demonstrate the vast contributions that the environment makes to the economy and society in terms that are more comparable to other economic indicators.

The main difference between the NCAI and the accounts is the representation of value, the accounts look to measure nature's contribution to society and the economy through commeasurable monetary terms whereas the NCAI seeks to demonstrate the contribution of nature to the citizens of Scotland more directly. The accounts are able to demonstrate the contribution of select assets comparatively and in absolute values which is vital for demonstrating value when compared to other types of capital. The NCAI instead looks at the contributions provided by Scotland's terrestrial ecosystems relative to each other, in doing so it is able to include a wider range of benefits and habitats. The accounts include some abiotic benefits such as renewable energy, mineral and oil and gas deposits in their valuations, the NCAI focusses instead on living ecosystems and habitats.

It is impossible to wholly accurately model the full range of benefits derived from the environment and neither the accounts or the NCAI claims to be fully successful in doing so. Both models make considerable contributions to our understanding of the total benefits Scotland obtains from the environment and can be seen as complimentary to each other.

How they represent value

The NCAI tracks the changes in the potential of the natural environment to provide benefits to people. The accounts seek to measure these benefits directly through market and hypothetical market values and express them mainly as monetary values.

Many benefits cannot be accounted for or valued because of their intangible nature, even in hypothetical markets therefore many of these benefits remain unaccounted for in the accounts. As the NCAI does not measure benefits directly and seeks to assess the ability of habitats to provide benefits it is therefore more able to account for more intangible benefits.

There are issues surrounding value with both the NCAI and the accounts. The NCAI has value weightings within it based on academic studies and surveys of the Scottish public. These weightings are not updated annually and don't reflect changing attitudes within the Scottish public to inform valuation. The NCAI outputs are relative to themselves and cannot be directly compared to other forms of capital such as human or produced, meaning that comparison between them is difficult. The accounts use up to date valuation of benefits. However they often use current value to project expected benefits into the future; future values are also impacted by changing attitudes as well as by market forces which may change (e.g. oil prices).

The accounts value the stock of natural capital by forecasting the benefits and use into the future. There are issues here surrounding policy changes (e.g. banning sale of petrol/diesel cars and other climate change policies which would affect the projected demand of oil and gas, or increased woodland planting etc.) and how these will affect future value flows.

Abiotic services

The NCAI accounts only for biotic ecosystem services (e.g. those that are produced by habitats) with the exception of the provision and quality of water which is strongly influenced by ecosystem functions. The accounts on the other hand include many abiotic services, services that are still provided by nature but do not require organic input. These include renewable energy and non-renewable mineral, oil and gas reserves.

The accounts do not include livestock as they consider them to be produced or man-made capital. The NCAI uses livestock numbers as one of its indicators, as a proxy for potential to supply provisioning services, i.e. food.

Biodiversity

Biodiversity can be found at many points along the value chain: it supports the ability of habitats to function effectively, contributes directly to the benefits and is valued as a benefit in itself. This has meant it has always been difficult to value within the natural capital concept and complementary indicators are often used to ensure that biodiversity is not overlooked. In 2021 the UK treasury published a global review on the economics of biodiversity, know as ‘The Dasgupta Review’. The review advocated for incorporating natural capital into decision making to improve outcomes for biodiversity. The review highlighted the benefits in valuing national natural capital for the inclusion in national accounts and in tracking the changes in portfolios of natural capital stocks as the NCAI does. The NCAI includes some broad biodiversity indicators: bird and butterfly indicators. The accounts do not currently account for biodiversity either as inputs or outputs.

Timeframes involved

The NCAI tracks changes since the year 2000; the 2021 update provides results up to 2019. A more rudimental version of the NCAI is able to demonstrate trends back to 1950 although detailed data becomes less reliable prior to 2000. The accounts, where available provide monetary estimates of ecosystem service flows between 1997 and 2019, historical values are deflated using the HM Treasury June 2020 GDP deflators.

What is covered

The NCAI only accounts for terrestrial habitats and assets (to the high water mark). Whilst marine habitats were considered during the initial development of the NCAI, a lack of data meant it was not possible to include marine habitats. A recent feasibility study suggested a marine version of the NCAI is possible but may still be limited by data availability. The accounts include terrestrial and some marine assets in the form of fish capture from the sea.

Ecosystem disservices / costs

The Scottish natural capital accounts account only for benefits flowing from different habitats; they currently do not account for disbenefits arising from changes in the environment. Whilst the NCAI does not measure these disbenefits, it does use stress indicators to highlight negative changes to habitats (increases in fertiliser and pesticide use for example) which can be attributed to losses of habitats and places pressure on assets to provide benefits into the future.

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