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Towards the 2025 System of National Accounts:
Measuring intangible assets and natural capital in 2025 System of National Accounts

Developing estimates of depletion for the UK natural capital accounts: 2024

Prepared by Office for National Statistics, United Kingdom[1]

Summary

Depletion is the decrease in the quantity of the stock of a natural resource because of extraction exceeding rates of regeneration, affecting the asset's ability to deliver continued flows of services. Our estimates indicate physical rates of depletion have declined over time and in 2021 were 45 million tonnes of oil equivalent (mtoe) for oil, 31 mtoe for gas, 207 million tonnes for minerals and metals, and 0.7 mtoe for coal. The estimated monetary value of depletion has declined from levels in 2008, and in 2021 was £2.5 billion for oil and £2.6 billion for gas; monetary estimates are not available for minerals and metals or coal.The effect of depletion explained, on average, 34% of the year-on-year change in the oil and gas asset value, while the price effect explained 44% and other changes in stock 22%.

In our most recent UK natural capital accounts, the estimated annual value was £8.0 billion for oil and £5.6 billion for gas in 2021; when we adjust this value to account for the cost of depletion, estimates reduce to £5.5 billion and £3.0 billion for oil and gas, respectively. The depletion-adjusted annual value for oil and gas became negative in several years because the annual value fell faster than the price in situ; the price in situ of reserves in the ground is based on average resource rents so is less affected by short-term changes in price. Depletion estimates can help to produce adjusted macro-economic aggregates, such as net inclusive income and could in the future feature in net domestic product.

[1] Prepared by Aram Hawa and Ellen Clowser. Full paper can be found on the ONS website here. We welcome feedback on this research and the methods we have used to produce these estimates to Natural.Capital.Team@ons.gov.uk

I. Overview of natural capital accounts

1. Natural capital accounting provides estimates of the economic value of the natural environment. This is measured in terms of the stocks (asset value) and flows (annual value) of goods and services nature provides, also known as ecosystem and abiotic services.

2. We currently produce UK natural capital accounts statistical bulletins covering 16 ecosystem services that arise within the UK's exclusive economic zone, regardless of the nationality of the extractor or beneficiary of those services. Ecosystem services are generally grouped into three main categories:

- provisioning services – products from nature such as food, water, energy and materials
- regulating services – help to maintain the quality of the natural environment, including greenhouse gas and air pollution regulating
- cultural services – the non-material benefits we obtain from natural capital, such as tourism and recreation

3. Natural capital accounts form part of the environmental accounts, developed in line with United Nations (UN) System of Environmental Economic Accounting (SEEA) guidance. As such, they can be seen as an important complement or "satellite accounts" to the main UK National Accounts.

4. Our ambition is to adapt the natural capital accounts for inclusion in extended national accounts including producing estimates of depletion and degradation of natural assets where possible. The rationale for this is set out in our Natural capital accounts roadmap: 2022.

5. These initial estimates of depletion represent a first step towards this ambition.

6. We use the SEEA definition of depletion: *"Depletion, in physical terms, is the decrease in the quantity of the stock of a natural resource over an accounting period that is due to the extraction of the natural resource by economic units occurring at a level greater than that of regeneration."*

7. Depletion of natural resources relate to human-driven changes to the stock of a resource, for both non-renewable and renewable resources. For renewables, depletion occurs only when rates of extraction exceed rates of regeneration. This has a negative effect on the stock size and can limit the capacity for future harvests, potentially leading to population collapse.

8. Examples of depletion include the extraction of non-renewable mineral, metal, oil, gas and coal reserves, and for renewables include the over-exploitation of fish stocks and timber reserves.

9. Depletion can be considered a specific form of degradation: *"Degradation considers changes in the capacity of environmental assets to deliver a broad range of contributions known as ecosystem services (e.g., air filtration services from forests) and the extent to which this capacity may be reduced through the action of economic units, including households."*

10. Degradation encompasses a wider array of declines in the condition or quality of an ecosystem, which impact several ecosystem services. This goes beyond how much of the stock of natural capital would be consumed as part of the production process.

11. Examples of degradation include:

- deteriorating soil health, which affects agricultural productivity and water quality
- declining condition of natural woodlands, which reduces the volume of carbon sequestered and air pollution removed
- destruction of natural landscapes, which, among other effects, reduces the number of people making recreational visits

12. The main effect of depletion and degradation, from a natural capital accounting perspective, is to limit the natural asset's capacity to provide continued flows of services, reducing the current and future generation's ability to derive benefits from these services.

13. Production activities that lead to depletion create a temporary boost in income, output and expenditure. However, they are based on the result of reductions in the limited stocks of natural assets, which inevitably constrains future production. By quantifying how much of a natural resource has been exhausted, the longer-term consequences of relying on finite resource stocks or the excessive extraction of renewable resources, can be recognised and more sustainable development paths designed and targeted. This is particularly relevant as technological innovations in industry and rising demand have led to an increase in the volumes of physical output in certain provisioning services.

14. The SEEA and System of National Accounts (SNA) recommend the inclusion of measures of depletion in countries' balance sheets.

15. Estimates of depletion and degradation enable the production of net economic measures alongside the more widely used gross measures. It is widely acknowledged that gross domestic product (GDP) does not measure all aspects of economic well-being and current proposals for the 2025 SNA update suggest a greater prominence of net macroeconomic measures, see WS.6 Accounting for the Economic Ownership and Depletion of Natural Resources (PDF, 1.24MB). Our methodology article, Gross and net measures of the UK economy, discusses the recording of natural resource depletion within net economic measures in the context of production, welfare and sustainability.

16. In the SNA, depletion of natural resources can be viewed in a similar way to capital depreciation (or the consumption of fixed capital) for manufactured assets. Declines in the manufactured capital base arise because of physical deterioration and damage resulting from the use of capital in production. Consequently, the asset value of the manufactured capital declines over time and investment is required to maintain its productive capacity. The transformation of GDP into net domestic product (NDP) reflects the output generated by the capital, but deducts the capital consumed to enable that output. Comparing the two indicators gives a measure of the longer-term sustainability of the economy, as production can continue only if the capital stock is maintained.

17. Similarly, depletion of the stock of natural resources creates an increase in gross outputs, however, the use of the stock of those natural assets means it cannot be used again in the future. Therefore, similar justifications for considering consumption of fixed capital apply to natural resource depletion.

18. This aligns with the "inclusive wealth" concept as described in the Dasgupta Review of the Economics of Biodiversity. The drive towards more comprehensive economic measures forms part of our New Beyond GDP measures for the UK: a workplan for measuring inclusive income, which aims to present data under an extended economic production boundary to include, among other things, human and natural capital. The production of wider measures provides meaningful and useful information on the range of benefits people receive from both the market economy and other domains, including the environment.

19. Measuring and considering depletion in our new indicators, such as net inclusive income, helps to enable decision makers to better understand the full impact that current economic activity has both now and into the future, and potential trade-offs between resource depletion and economic growth. Synergies between nature and the economy, and how the services provided by nature enable industry output was a focus of our article Developing supply and use tables for UK natural capital accounts: 2023.

20. Other work on net economic metrics include the World Bank's The changing wealth of nations: measuring sustainable development in the new millennium, which outlines methods to adjust gross national income (GNI) to reflect the depletion of its natural resources.

21. Our work is the first step in exploring depletion in the UK natural capital accounts context, constructing depletion accounts in line with international statistical guidance. Our estimates consider only the depletion of non-renewable natural resources in the UK. They do not estimate global natural resource depletion resulting from UK consumption and business activity, nor do they estimate the cost of degradation of UK natural resources.

22. These estimates of depletion are published as innovative research using data from our UK natural capital accounts: 2023, which provides estimates of all the ecosystem services

that we are currently able to value. Our estimates of depletion are consistent with the methods described in our UK natural capital accounts methodology guide: 2023.

II. Understanding depletion

23. The United Nations System of Environmental Economic Accounts (SEEA) central framework (PDF, 2.69MB) provides detailed examples of the calculation of depletion, particularly in Annex A5.1, and our estimates are informed by these methods. Full details of our methods can be found in Section 9: Data sources and quality.

A. Reserves

24. Reserves are the commercially exploitable, physical remaining stock of a given resource. We have taken reserve data for coal from the Department for Energy Security and Net Zero (DESNZ) and we have worked with the North Sea Transition Authority (NSTA) to produce estimates for oil and gas. Further information on how oil and gas reserves are calculated can be found in Section 9: Data sources and quality.

25. Data on reserves are not available for minerals and metals, which limits our ability to estimate other changes in stock and monetary values of depletion for this service.

III. Physical changes in reserves

26. Estimates of the physical change in reserves can be split into depletion and other changes in stock. In the case of non-renewables, which we focus on here, depletion is simply the amount of the resource that is extracted in a given year. Other changes in stock include a variety of different events that cause changes in the reserves, such as new discoveries or catastrophic losses.

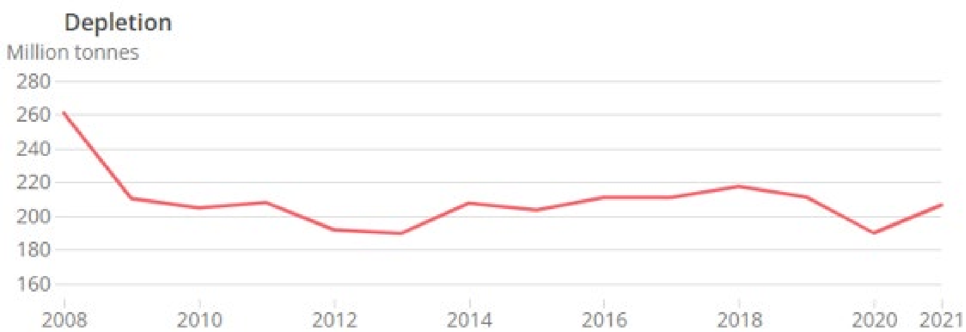
27. Estimates of physical depletion are the most readily available and we are able to provide estimates for oil, gas, coal, and minerals and metals. Other changes in stock are calculated based on the annual change in reserves minus the depletion.

28. The physical value of depletion in 2021 was 45 million tonnes of oil equivalent (mtoe) for oil, 31 mtoe for gas, 207 million tonnes for minerals and metals, and 0.7 mtoe for coal.

A. Minerals and metals

29. After high levels of depletion in 2008 for minerals and metals, the level has ranged between 190 and 218 million tonnes between 2009 and 2021.

Figure 1
Physical estimates of minerals and metals depletion, UK, 2008 to 2021



Source: Mineral production data from the British Geological Survey

30. Reserve data are not available for minerals and metals, which means we cannot calculate other changes in stock for this service.

B. Oil

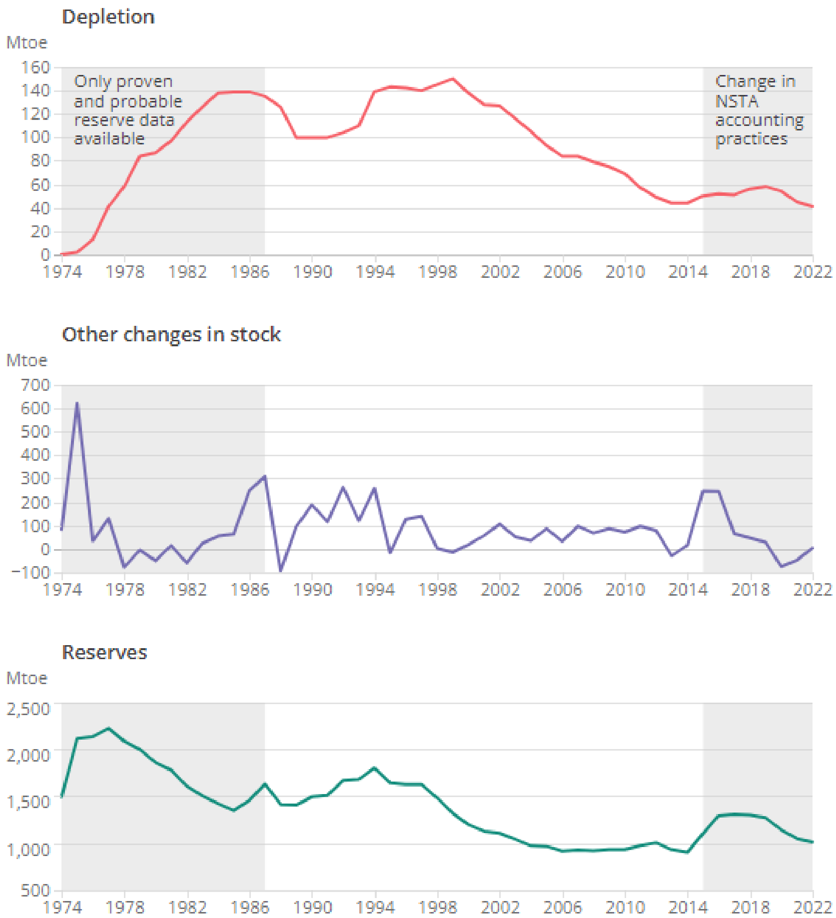
31. Oil reserves have declined over time, from 1,633 mtoe in 1987, to 1,014 mtoe in 2022, decreasing 38% over this period.

32. Oil depletion was greatest between 1982 and 2004, with annual extraction above 100 mtoe in each year, and 1999 had the largest annual production at 150 mtoe. There has been a steady decline since 2004, with a five-year average of 51 mtoe between 2018 and 2022.

33. Other changes in stock of oil fluctuate more and include both positive and negative results, with positive results in 80% of years between 1974 and 2022. The magnitude of upward re-appraisals and new discoveries in positive years are much greater than negative years, and over the period the net impact of other changes in stock was the addition of 3,967 mtoe of reserves. There was a notable change in 1975 where other changes in stock added 621 mtoe to reserve levels. This was a result of successful exploration in the North Sea, with one of the largest reserves discovered in the Forties Oil Field in 1970 and production beginning shortly afterwards in 1975.

34. Rates of oil depletion exceeded the other changes in stock in 61% of years, with 4,367 mtoe extracted between 1974 and 2022, which was 400 mtoe above the net effect of other changes in stocks.

Figure 2
Physical estimates of oil reserves, depletion and other changes in stock, UK, 1974 to 2022



Source: UK natural capital accounts from the Office for National Statistics and production and reserves data from the North Sea Transition Authority

Notes: (1) Before 1987, only proven and probable reserve data are available. After 1987, lower potential additional resources (PARS) is included. (2) From 2015 onwards, lower PARS is replaced with 2C contingent resources.

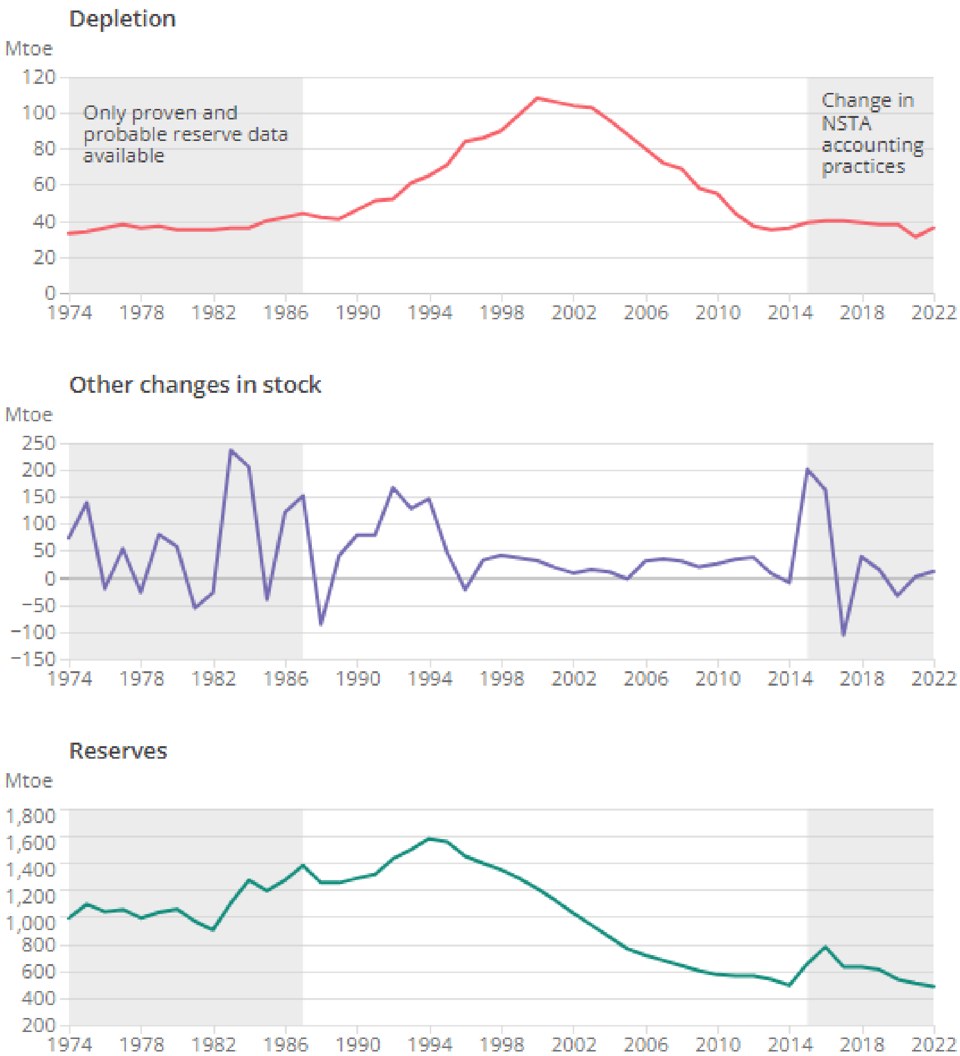
C. Gas

35. Gas reserves follow a similar trend to oil, with peak reserve levels in 1994 at 1,579 mtoe, declining by 69% to 484 mtoe in 2022.

36. Since 1974, gas depletion was greatest between 2000 and 2003, where extraction exceeded 100 mtoe each year, with peak production of 108 mtoe in 2000. Rates have since declined broadly to previous levels, with a five-year average of 36 mtoe between 2018 and 2022.

37. Other changes in stock of gas were positive in 78% of years between 1974 and 2022, with 2,230 mtoe added to reserve levels. Similar to oil, gas depletion exceeded the rates of new discoveries, with total depletion of 2,695 mtoe between 1974 and 2022, which was 465 mtoe above the net result of other changes in stock, leading to a decline in total reserves.

Figure 3
Physical estimates of gas reserves, depletion and other changes in stock, UK, 1974 to 2022



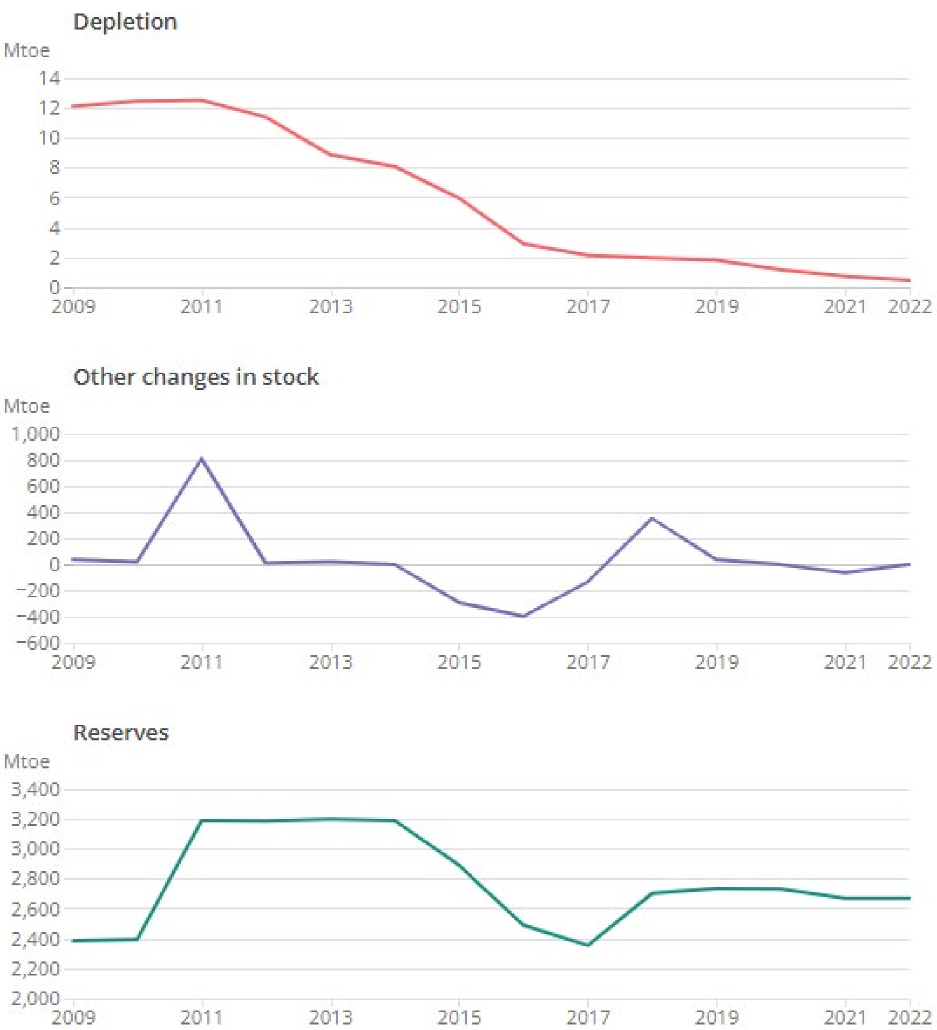
Source: UK natural capital accounts from the Office for National Statistics and production and reserves data from the North Sea Transition Authority

Notes: (1) Before 1987, only proven and probable reserve data are available. After 1987, lower potential additional resources (PARS) is included. (2) From 2015 onwards, lower PARS is replaced with 2C contingent resources.

D. Coal

38. Between 2009 and 2022, reserves of coal increased by 12%, despite 83 mtoe being depleted over the period. This is because of the net impact of other changes in stock amounting to 390 mtoe, with considerable boosts to reserves occurring in 2011 and 2018.

Figure 4
Physical estimates of coal reserves, depletion and other changes in stock, UK, 2009 to 2022



Source: UK natural capital accounts from the Office for National Statistics and coal reserve data from the Department for Energy Security and Net Zero

Notes: (1) Reserves data is only available from 2008 onwards.

IV. Monetary changes in asset value

39. In our UK natural capital accounts, we produce two types of monetary values: annual values (flows) and asset values (stocks).

40. For the services covered here, the annual value is produced using a resource rent methodology and can be interpreted as the annual return stemming from the natural capital asset. It is calculated from data available from the supply and use tables, or income and expenditure data from the North Sea Transition Authority (NSTA) in the case of oil and gas. Full details of our resource rent calculation can be found in our UK natural capital accounts methodology guide: 2023.

41. Asset values measure the stream of services of that natural resource in terms of future expected supply and use over a predicted time horizon. Methods vary by service, but for the services covered here, prices are projected forward based on a five-year average of annual values.

42. The change in the asset value can be broken down into depletion, other changes in stock and the price effect. The price effect estimates the impact of changing prices and industry profitability on the asset value, independent of changes in the physical stock.

43. While the price effect is considerably affected by the prevailing market prices of the commodity, changes to any of the other economic parameters in the resource rent can also play a part in determining the overall price effect. For example, if prices rise while the unit cost increases by more, this reduces the resource rent and the overall price effect will be negative.

44. The prices used to value depletion, other changes in stock, and the price effect refer to the price in situ of reserves left in the ground, calculated by dividing the total asset value from our UK natural capital accounts: 2023 by the total reserves. This reflects the opportunity cost of extracting reserves now rather than in the future.

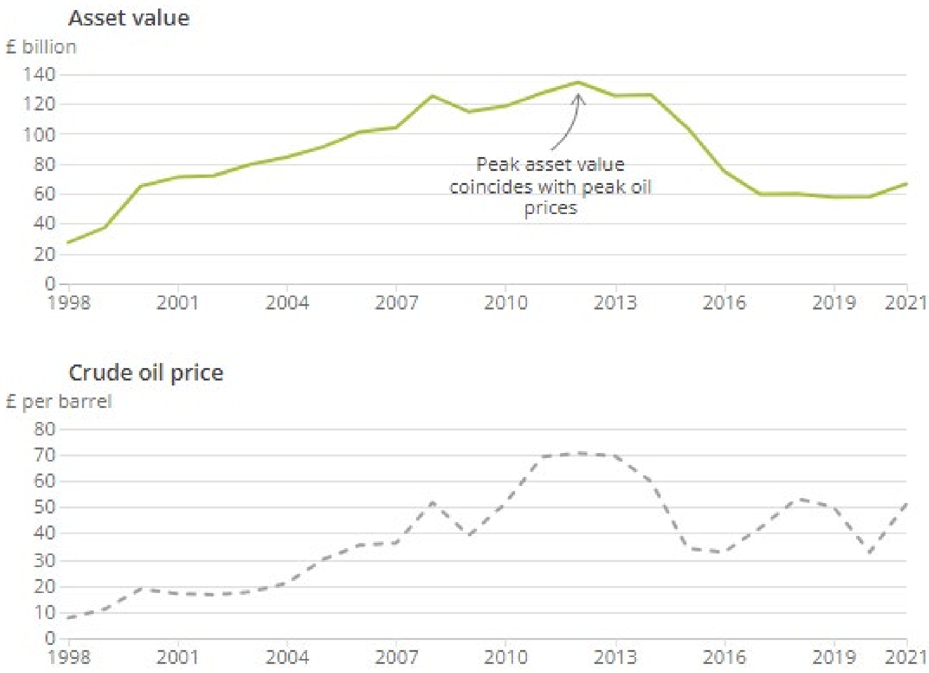
45. A requirement of this approach, therefore, is the need for complete reserve data. As we do not have reserve data for minerals and metals, we are not able to estimate the monetary values for this service.

46. Our current method for valuing coal provisioning in the natural capital accounts means that estimates are negative across the data time series. This is a result of the industry generating low levels of gross operating surplus, which after deducting the opportunity cost, produces negative results. In the context of depletion this is not sensible as it would mean extracting resources adds to the value of the asset. Therefore, until alternative means of estimating the value of this service are developed, we are unable to provide monetary estimates. The problem of negative results in the resource rent calculation are discussed in section 5.4.4 of the System of Environmental Economic Accounts (SEEA).

47. Monetary results are available for oil and gas. However, a limitation is the lack of data on the respective production costs of oil and gas. Our prices are therefore calculated using aggregate industry economic data with the same unit resource rent derived for oil and gas. As a result, monetary estimates between the two are highly correlated.

48. Generally, oil prices and industry profitability have risen over time, as shown in Figure 5 and the NSTA's income and expenditure data. This increases the value of the asset, with the patterns of the asset value and price mirroring one another. This relationship weakens between 2016 and 2020 because of the effect of lower prices in 2015 to 2016 persisting in the asset calculations.

Figure 5
Oil asset value and crude oil price, UK, 1998 to 2021



Source: UK natural capital accounts from the Office for National Statistics and crude oil price data from the North Sea Transition Authority

49. Depletion detracts from the value of the asset as once some of the reserve is extracted, it is not available again. In monetary terms, oil depletion rose from £3.5 billion in 1999 to its peak in 2008 at £9.8 billion, which occurred because of a combination of high output and prices, before diminishing to £2.5 billion in 2021.

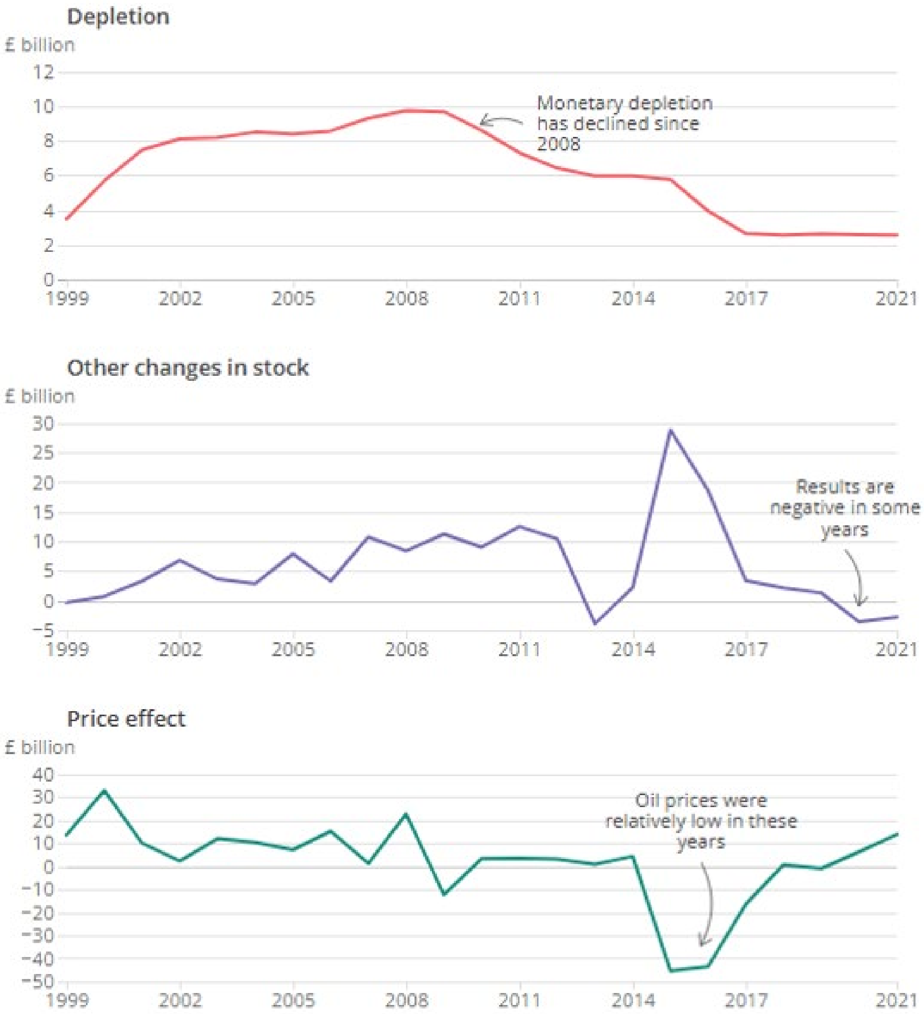
50. The value of other changes in stock of oil mirrors its physical profile, with negative monetary values occurring when the physical results are negative. In most years other changes in stock was positive, and between 1999 and 2021 £137.1 billion was added to the asset value.

51. The price effect is the least stable of the three effects, in part reflecting the volatility of oil prices. The pattern correlates with the changing price of oil, most notably in 2008 and 2015 to 2016. However, the relationship is not perfectly correlated for two reasons.

52. Firstly, the asset value is derived through estimates of the resource rent, which is affected by prices, but also other industry economic variables such as operating expenses and decommissioning costs, along with external factors such as interest and inflation rates. Secondly, lags persist in the price effect, which mean that it is not always immediately responsive to changes in the price of oil. This is because our asset values are calculated using the five-year average of resource rents, further muting the effects of rapidly changing oil prices.

53. The price effect is positive in most years, and between 1999 and 2021, added £46.4 billion to the value of the asset.

Figure 6
Monetary estimates of oil depletion, other changes in stock and price effect, UK, 1999 to 2021



Source: UK natural capital accounts from the Office for National Statistics and crude oil price data from the North Sea Transition Authority

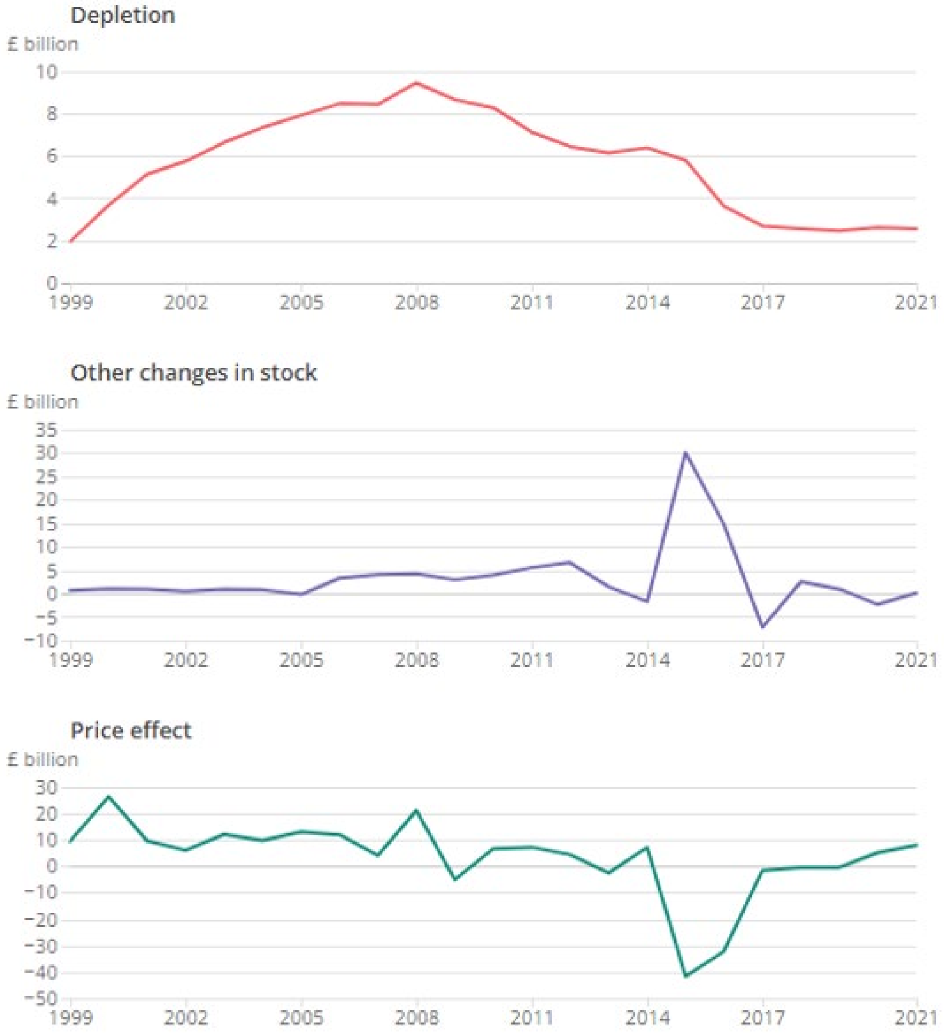
Notes: (1) From 2015 onwards, lower potential additional resources (PARS) is replaced with 2C contingent resources.

54. The monetary value of gas depletion follows a similar pattern to oil, with the value rising from £2 billion in 1999 to a peak of £9.5 billion in 2008 before declining to £2.6 billion in 2021.

55. Other changes in the stock of gas are smoother compared with oil, and between 1999 and 2021 added £74.4 billion to the value of the asset.

56. The gas and oil price effects are nearly perfectly correlated, which is a result of the same unit resource rent being calculated for the two products.

Figure 7
Monetary estimates of gas depletion, other changes in stock and price effect, UK, 1999 to 2021



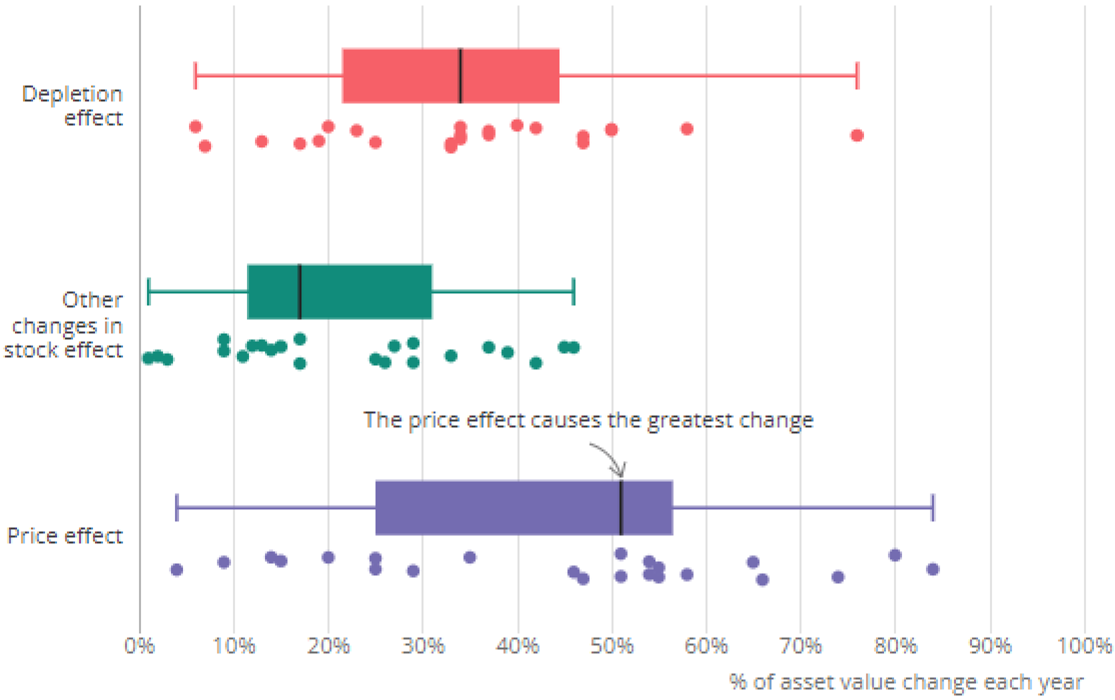
Source: UK natural capital accounts from the Office for National Statistics and crude oil price data from the North Sea Transition Authority

Notes: (1) From 2015 onwards, lower potential additional resources (PARS) is replaced with 2C contingent resources.

57. The change in the asset value can be broken down into the three effects, and across the data time series, the price effect dominates, on average explaining 44% of the change in the combined oil and gas asset value between 1999 and 2021. The average depletion effect accounts for 34% and other changes in stock 22% of the change in asset value. Of the three effects, other changes in stock shows the least variation.

Figure 8

The depletion, other changes in stock and price effect on the oil and gas asset value, UK, 1999 to 2021



Source: UK natural capital accounts from the Office for National Statistics

V. Depletion-adjusted annual values

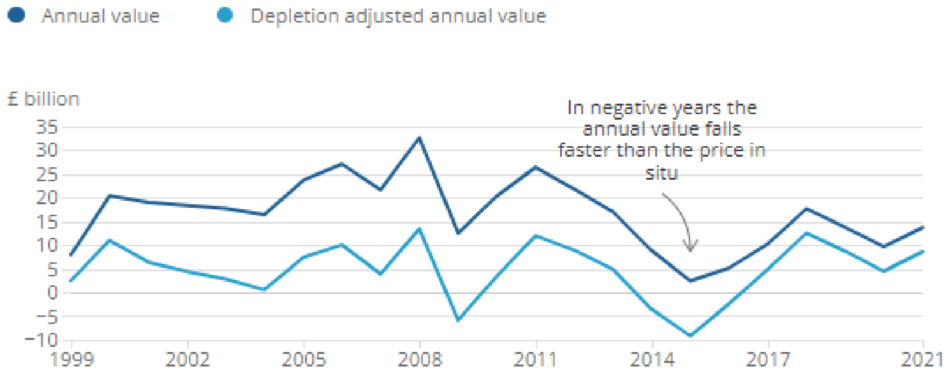
58. Our annual value estimates the flow of a service within a particular year and by deducting depletion from this, we are able to produce a net, depletion-adjusted annual value. This reflects the natural capital that was consumed in the process; the cost of generating this in the short term is the loss of the natural reserve, which diminishes the volume that can be extracted in the future and therefore negatively impacts the asset value.

59. Annual values for oil and gas of £8.0 billion and £5.6 billion, respectively, in 2021 indicate the value produced in the economy by these services. After taking account of depletion, the values decline to £5.5 billion for oil and £3 billion for gas.

60. Deducting depletion from the annual value of oil and gas reduces the value by £4.8 billion on average between 1999 and 2021. Results move into negative territory in several years, including 2009 and 2014 to 2016. The main reason for this is the drop in the annual value in these years relative to previous years. Annual values are sensitive to financial circumstances, including the prevailing market price, and so rapid changes in the resource rent impact annual values immediately. The price in situ of reserves is determined by averaged resource rents, therefore volatility in resource rents is slower to take effect. In negative years, the annual value falls faster than the price in situ.

Figure 9

Annual values and depletion adjusted annual values over time, UK, 1999 to 2021



Source: UK natural capital accounts from the Office for National Statistics

61. Depletion estimates can help to produce adjusted macro-economic aggregates, such as net inclusive income and could in the future feature in net domestic product. These economic aggregates consider the natural resources consumed in the process of generating income and output, therefore providing better information on the sustainability of economic growth. Current proposals suggest net indicators are set to become a more prominent focus in the 2025 System of National Accounts (SNA) update.

VI. Natural capital accounts data

62. Estimates of the financial and societal value of natural resources to people in the UK: UK natural capital accounts: 2023 (released 27 November 2023)

63. Detailed data breakdowns of the financial and societal value of natural resources to people in the UK: UK natural capital accounts: 2023 – detailed summary (released on 27 November 2023)

VII. Glossary

Degradation

Degradation considers changes in the capacity of environmental assets to deliver a broad range of contributions known as ecosystem services (for example, air filtration services from forests) and the extent to which this capacity may be reduced through the action of economic units, including households.

Depletion

Depletion, in physical terms, is the decrease in the quantity of the stock of a natural resource over an accounting period that is because of the extraction of the natural resource by economic units occurring at a level greater than that of regeneration.

Ecosystem services and abiotic flows

Ecosystem services and abiotic flows estimate the contribution of natural assets in the UK to the economy and society. This includes provisioning services such as food and water, regulating services such as flood protection and pollution removal, and cultural services such as recreation.

Non-renewable resource

A non-renewable resource is a natural resource which does not regenerate over human relevant time spans.

Other changes in stock

A catchall term to encompass the net effect of new discoveries, reappraisals, reclassifications, normal and catastrophic losses, and natural growth rates on the physical stock size.

Price effect

The impact of changing prices and industry profitability on the natural resource asset value.

Price in situ

The price in situ is the value of reserves in the ground, calculated by dividing the asset value by physical reserves.

Renewable resource

A renewable resource is a natural resource with the capacity to regenerate over time.

Resource rent

The resource rent can be interpreted as the annual return stemming directly from a natural capital asset. This is the value accruing to the extractor or user of a natural capital asset calculated after all costs, including opportunity costs, have been considered.

VIII. Data sources and quality

64. We have used a wide variety of sources for estimates of depletion, this includes data from our UK natural capital accounts: 2023. Additional data were provided by the North Sea Transition Authority, the Department for Energy Security and Net Zero, and the British Geological Survey.

65. These accounts have been compiled in line with the guidelines recommended by the United Nations (UN) System of Environmental Economic Accounting (SEEA) (PDF. 2.7MB) Central Framework and the UN SEEA Experimental Ecosystem Accounting principles. UN guidance in this area continues to develop.

A. Reserves

66. Reserves are the commercially exploitable, physical remaining stock of a given resource and several factors can lead to changes in the reserve levels beyond depletion.

67. We group these into five types:

- new discoveries arise through the exploration and evaluation of new reserves
- reappraisals occur when there are changes in the commercial environment, such as the price of the product, which influences how much of the resource is profitable to extract; it also reflects greater accuracy in the measurement of physical reserves as new measurement instruments are developed, these can have a positive or negative impact on reserve levels
- reclassifications arise when the government extends or retracts licences for the extraction of reserves or when a natural asset is used for a different purpose
- normal and catastrophic losses include any expected loss to reserves through production along with non-human induced events, which leads to a loss of reserves, such as floods, earthquakes, or wildfires
- for renewable resources, the stock or population also changes because of natural growth rates and this is determined by the net result of birth and death rates, with many factors influencing this, including the species type, population age structure and wider environmental conditions; in its most basic form, the sustainable yield is equal to the natural growth rate and depletion is only said to occur if extraction exceeds the sustainable yield

68. Estimating the portion of oil and gas reserves which are or will become, commercially exploitable is challenging because of the uncertainties inherent in estimating how future technology, costs, demand and government policy will shift the incentives oil producers face to extract reserves.

69. Several options are available when calculating reserves for finite resources, from conservative methods of considering only proven reserves (where the probability of being commercially extracted is above 90%), to more sophisticated statistical techniques, which consider the various reserve categories and probabilities of extraction.

70. Definitions of the various categories of reserves and resources can be found in the North Sea Transition Authority (NSTA) Reserves and Resources 2022 report (PDF, 1.1MB).

71. After engaging with the NSTA, we have adopted the following calculation, which informs the NSTA's future production estimates, and so is consistent with the other physical parameters used in the asset calculation:

$$Total\ reserves = Proven + Probable + Lower\ PARS\ (1987\ to\ 2014) + 2C\ Contingent\ Resource\ (2015\ onwards)$$

72. The switch from using lower potential additional resources (PARS) to 2C contingent resource was based on a change in NSTA accounting practices in 2015. Before 1987, lower PARS data are not available.

B. Physical depletion

73. Adapting SEEA notation, the change in the physical stock (ΔXt) for a resource between years t and $t{-}1$, is broken down into the following:

$$\Delta X_t = (X_t - X_{t-1}) = I_t + R_t + C_t - L_t - S_t + G_t$$

where I relates to new discoveries, R to reappraisals, C to reclassifications, L to normal and catastrophic losses, S to extraction or harvest levels and G to the sustainable yield.

74. Most available data sources do not contain the detail needed to estimate all of these variables separately. Extraction or harvest values are most commonly available, while accurate estimates of stock values over time are difficult to obtain. We do not have data sources for distinguishing between new discoveries, reappraisals, reclassifications, and normal and catastrophic losses for any of our services. Therefore, in the case of non-renewables we will refer to "other changes in stock" (Ot) as a catchall to encompass the net effect of these variables.

$$O_t = I_t + R_t + C_t - L_t$$

75. For renewables, natural rates of population growth are dependent on the population size, with an upper and lower limit for growth rates. A sustainable yield occurs when rates of harvest equal natural population growth rates. Along the frontier of the growth rate and population curve exists a spectrum of sustainable yields, which imply a stable population size in posterity and indicate the sustainable management of the resource.

76. Depletion (Dt) can be defined as the rate at which harvests exceed the sustainable yield:

$$D_t = S_t - G_t$$

77. Non-renewable resources, which we focus on here, can be seen in this model as a limited case where Gt=0.

C. Monetary depletion

78. To understand the wider monetary impacts of depletion on the changing asset value of a natural resource, we estimate the monetary value of three relevant factors:

- depletion – the value of physical depletion
- other changes in stock – the value of other changes in the physical stock
- the price effect – the impact of changing prices and industry profitability on the asset value, independent of changes in the physical stock

79. When calculating monetary depletion estimates, the price in situ of reserves in the ground (P) is calculated by dividing the total asset value from our UK natural capital accounts: 2023 by the total reserves. This differs from our standard price basis which relates to the resource rent, with the price in situ better reflecting the opportunity cost of extracting reserves now rather than in the future.

80. The SEEA states that the change in the asset value of the resource stock (ΔVt) can be calculated as follows:

$$\Delta V_t = (V_t - V_{t-1}) = P_{t-1}\Delta X_t + X_t \Delta P_t$$

where $Pt{-}1\Delta Xt$ is the quantity effect and measures the change in the quantity of the resource valued at the price (P) of the beginning of the period, whereas $Xt\Delta Pt$, the price effect, captures the price change of the resource, multiplied by the quantity at the end of the period.

81. The quantity effect considers all the factors that lead to a change in the physical reserve levels, including depletion and other changes in stock, for which we estimate the monetary values separately.

82. Another way to calculate the change in the asset value of the resource stock is by using the end of year prices for the quantity effect, and the beginning of year stock for the price effect:

$$\Delta V_t = (V_t - V_{t-1}) = P_t \Delta X_t + X_{t-1}\Delta P_t$$

83. As neither of these approaches are superior, an average of the two approaches is taken to generate the final values.

84. Drawing out the depletion component of the quantity effect, the final calculation for the monetary value of depletion (DV) becomes:

$$DV_t = 0.5(P_t + P_{t-1})\, D_t$$

85. By using the average price of the period, depletion is assumed to occur mid-year. This ensures consistency with the System of National Accounts (SNA) for the valuation of consumption of fixed capital.

IX. Future developments

86. This is the first step towards estimating UK natural resource depletion accounts in line with international statistical guidance. As seen across the services covered, the level to which we can estimate depletion depends upon the data availability and the suitability of the methods used to estimate the physical, annual and asset values.

87. We are not able to produce estimates for renewable services. These are more challenging to estimate, even at a physical level, because of the impact of regeneration and natural rates of population growth. Further work would be required to source suitable datasets to accurately estimate growth rates of stock for services such as timber and fish provisioning.

88. An improved ability to calculate estimates of depletion for all ecosystem services would better enable the production of aggregate estimates of depletion for all assets we include in our main UK natural capital accounts. These aggregate results would in turn enable the adjustment of existing gross economic metrics into their net equivalents.

89. Furthermore, the production of degradation estimates could be included in wider inclusive wealth accounts. Degradation estimates are more challenging because of the lack of data linking habitat condition to flows of ecosystem services. Developments in this area

would require quantitative estimates as far as possible while exploring the possible usefulness of a qualitative approach.