Environment and Rural Affairs Monitoring & Modelling Programme (ERAMMP)

ERAMMP Report-27: Valuation Methodologies

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Abbreviations Used in this Report

ABS	Annual Business Survey
APS	Annual Population Survey
BEIS	Department for Business, Energy & Industrial Strategy
CBA	Cost Benefit Analysis
CO_2e	Carbon dioxide equivalent
COMEAP	Committee on the Medical Effects of Air Pollutants
CV	Contingent Valuation
DCE	Discrete Choice Experiment
DICE	Dynamic Integrated Climate-Economy model
eftec	Economics for the Environment Consultancy
EMEP4UK	European Monitoring and Evaluation Program Unified Model for the UK
ENCA	Enabling a Natural Capital Approach
ERAMMP	Environment and Rural Affairs Monitoring & Modelling Programme
ESC	Ecological Site Classification
GDP	Gross Domestic Product
GHG	Greenhouse gases
HMT	Her Majesty's Treasury
IMP	Integrated Modelling Platform (an ERAMMP product)
IPBES	Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
LULUCF	Land use, land-use change, and forestry
MENE	Monitor of Engagement with the Natural Environment
MMH	Mountains, moorlands and heathlands
NO_2	Nitrogen dioxide
NRW	Natural Resources Wales
NSW	National Survey for Wales
NWEBS	National Water Environment Benefits Survey
O_3	Ozone
ONS	Office for National Statistics
PM2.5	Particulate Matter - less than 2.5 micrometres in diameter
PVB	Present Value of Benefits
PVC	Present Value of Costs
QALYs	Quality Adjusted Life Years
SEEA-CF	System of Environmental Economic Accounting - Central Framework
SEEA-EEA	System of Environmental Economic Accounting - Experimental Ecosystem Accounting framework
SIC	Standard Industrial Classification
SNA	System of National Accounts
SoNaRR	State of Natural Resources Report
TEV	Total Economic Value
UKCEH	UK Centre for Ecology & Hydrology
USEPA	United States Environmental Protection Agency
WFD	Water Framework Directive
WORS	Welsh Outdoor Recreation Survey
WTA	Willingness to Accept
WTP	Willingness to Pay

Contents

1 SUMMARY

Economic valuation is used within ERAMMP to help assess policy impacts in line with the project objectives, as guided by policy requirements such as the Well-being of Future Generations Act (2015). Assessment of impacts on well-being means the boundary of what is valued and the data used in economic valuation should be broad enough to inform policy makers about all impacts across society, not only those that arise in markets.

To assess the impacts on future generations, long appraisal timescales (75 and 100 years) should be used, and zero discount rates should be tested in sensitivity analysis. The Welsh National Natural Capital Accounts show: the value of different ecosystem services; their relative value to each other and to the market economy; and they inform policy and impact assessments. In due course they will provide trends in ecosystem service values over time.

1.1 Scope

This report compares economic valuation methods that have been used in the ERAMMP programme providing information to the Welsh Government. It reviews the valuation work contained in ERAMMP Report-12 *QuickStart* (Cosby et al. 2019), Report-24 and Report-28A *Welsh National Natural Capital Accounts* (Engledew et al. 2019; Dutton et al. 2020) and in the Integrated Modelling Platform work's Report-13 *Integrated Modelling Platform (IMP) Progress* (Harrison et al. 2019)[1].

Comparisons are also made to the State of Natural Resources Report[2] (SoNaRR) and across the categories of ecosystem services used. Other uses of economic valuation, such as in natural capital accounts for organisations or making business cases for investment, are not covered in this report.

Economic valuation estimates the value individuals place on the natural environment – in other words, their preferences for changes in the environment.

Different valuation methods represent different aspects of the individuals' preferences. Their commonality is that the results are expressed in monetary terms. The key distinction is between: data that reflect the economic activity in the markets ('exchange values'); or data that reflect the benefit a person gets from something, including but not limited to consumption in the markets ('welfare values')[3]. Both these types of value can be estimated for a specific 'marginal' change (e.g. an increase in purchases, or in visits to a recreational site), or in 'aggregate' (e.g. the total value of market purchases, or of all visits to a recreational site – which is equivalent to a change from zero - i.e. no market or no asset).

Applying any economic valuation method to the environment is a three step process:

1. Qualitative assessment (understand the environmental goods and services and the change in these to be valued)

[1] Available at: https://erammp.wales/12, https://erammp.wales/13, https://erammp.wales/24, and https://erammp.wales/28 respectively.
[2] https://naturalresources.wales/evidence-and-data/research-and-reports/the-state-of-natural-resources-report-assessment-of-the-sustainable-management-of-natural-resources/?lang=en
[3] Under some conditions exchange values are a good measure of welfare, but this is often not the case for environmental goods and services, nor in relation to public goods for which there are no exchange values because no market exists. For example, outdoor recreation or benefits to human health from better air quality can often be free to access, but nevertheless have high welfare.

2. Quantitative assessment (measure the change to be valued in biophysical or socio-economic terms), and
3. Monetary valuation (collect and analyse economic value data).

Ecosystem services approaches are widely used to organise relevant qualitative and quantitative data, without which valuation would not be possible to undertake and interpret.

Marginal or aggregate welfare or exchange values all have valid uses to inform policies and decisions:

- National accounts give aggregated measures of exchange values (as in GDP). The Welsh National Natural Capital Accounts (as in ERAMMP Report-24) use exchange values, some from market data, others are imputed or otherwise estimated;
- Cost-benefit analyses (CBA) compare the costs and benefits of achieving a given objective to the affected population (sometimes the entire society). Policy CBA incorporates costs and benefits for both market goods (using prices, with adjustments) and for non-market goods (using welfare values - as in ERAMMP Report-12 and the IMP).

System of National Accounts (SNA) is primarily concerned with measuring market exchanges, whereas policy appraisal is also interested in changes in the welfare of the affected population. This is the main reason why the economic values used in accounts are different from those used in appraisal/CBA. It also means that GDP, which only measures the economic activity in the markets, is not a good measure of welfare (SNA 2008[4]) even though it is often interpreted as if it were.

1.2 Valuation Methods used in ERAMMP

A range of valuation methods can be used to estimate the value to individuals of changes to the natural environment. The use of these methods in Reports 12 and 24/28A is summarised in Table 1-1. It shows that the scope of services covered in Reports 12 and 24/28A are significantly different. Only three services are valued in both reports; two (climate change mitigation and air pollutant removal) use the same (UK Government developed) valuation methods.

The major difference is between the methods used to value recreation in the natural environment. Their valuations are both based on individuals' travel choices, but they use very different data:

- Report-24 estimates the total expenditures by individuals (e.g. on fuel, entry fees) to make recreation visits. This aligns to data recorded in GDP, but omits the (large) number of visits to the natural environment that are made without any monetary expenditure.
- Report-12 uses data from modelling of individuals' choices to visit recreation sites. It estimates the welfare they gain from these visits by analysing the time, travel and other costs they incur to do so. It is comprehensive in covering all visits, but not equivalent to market economic data.

As the Quickstart (Report-12) and the IMP (Report-13) are policy appraisal instruments, they are akin to CBA. They assess the total benefits and costs of a policy or change to the natural environment to society, in particular changes to the value and distribution of public goods.

[4] https://unstats.un.org/unsd/nationalaccount/docs/SNA2008.pdf

Therefore they aim to measure welfare, so prefer to use welfare values, but sometimes use exchange values where they are an acceptable a proxy for welfare.

The Welsh Natural Capital Accounts, and the UK Natural Capital Accounts they draw on, are designed in line with UN system of environmental-economic accounting guidelines that favour use of exchange values to enable comparability to other national economic data, such as GDP. There are no exchange values for most public goods, because such goods are not exchanged in the markets, and the exchange values environmental goods would have if there was a market is not always known. Therefore, while these national accounts aim to use exchange values, they sometimes use welfare values as a proxy for exchange values.

These two areas of work are doing different types of analysis and so use different methods. This difference is starkest for recreation because it has a major non-market element - this means that the estimated values from travel expenditures (Reports-24/28A) and recreation demand model (Report-12) methods may be very different. **As they each have limitations and give decision-makers different information, it is better to use both exchange and welfare values.** Using only exchange values increases the risk that benefits from non-market environmental goods will be missed in decision-making, resulting in under-allocation of spending or sub-optimal management of the environment. This leads to an under-provision of public goods.

Table 1-1: Valuation Methods Used in Reports 12 and 13 (IMP) & 24 and 28A

Ecosystem service	**Report-12 (Quickstart) & Report-13 (IMP)**	**Reports 24 and 28A (Welsh National Natural Capital Accounts)**	**Comparison**
Climate / carbon	Shadow Price	Shadow Price	Same
Air pollutant removal	Welfare Value of Life Years Lost	Welfare Value of Life Years Lost	Same
Recreation	Recreation demand model	Travel Expenditures	Major difference
Water quality (Report-13 (IMP) only)	Stated Preference	-	n/a
Agricultural Biomass/ Water abstraction/ Freshwater fish	-	Resource Rent	n/a
Timber	-	Market Price	n/a
Renewable energy (Report-28A only)	-	Resource Rent	n/a

2 INTRODUCTION AND PURPOSE

The Welsh Government has commissioned the Environment and Rural Affairs Monitoring & Modelling Programme (ERAMMP) to inform policy development (including for the EU exit process and the design and evaluation of programmes delivering to the Natural Resources Policy) and to evaluate programme implementation.

The overall aim of ERAMMP is to deliver a programme of monitoring and modelling which collects data across the Welsh landscape, and establishes the links between the changes in land use, environmental impacts and their values society. The programme will also be a key source of data for future editions of the State of Natural Resources Report (SoNaRR).

This report compares and explains the differences between the economic valuation work undertaken under the ERAMMP. This includes the categories of ecosystem services valued, and the valuation methods applied to deliver the objectives of the different reports. It explains the differences between methods, and describes the sources of uncertainty in the estimates to enable the interpretation of results for policymakers.

2.1 Background

The purpose of economic valuation is to provide understanding of how the changes to the environment affect individuals' welfare. Monetary values are useful to assess trade-offs in policy design and to justify resource allocation (e.g. public spending) especially when implications are experienced outside market economy.

Economic valuation is used in the following ERAMMP work[5]:

Report-12 (Cosby et al. 2019): In Phase 1 of ERAMMP, 'Quick Start' Modelling was produced (October 2019), focused on the potential impact of Brexit on the farming sector and wider environment. Modelling explored potential changes in agricultural land use and new land management options, and the resulting changes to ecosystem services and the value of the benefits they provide.

Report-13 (Harrison et al. 2019): The **Integrated Modelling Programme** (IMP) undertakes more complex modelling of the land use changes covered in Report-12. Although not an end-product, the design and features of the IMP are detailed in ERAMMP Report-13 (Harrison 2019).

Report-24 (Engledew et al. 2019): Welsh Ecosystem Service Accounts for Woodland, Farmland and Freshwater habitats (September 2019). These accounts aim to measure the total value of the ecosystem services provided by these habitats in Wales.

Report-28A (Dutton et al. 2020): Welsh Ecosystem Service Accounts for Mountain, Moor and Heath habitats[6] (June 2020). These accounts aim to measure the total value of the ecosystem services provided by these habitats in Wales.

[5] Available at: https://erammp.wales/12, https://erammp.wales/13, https://erammp.wales/24, https://erammp.wales/28A and https://erammp.wales/28B respectively.
[6] ERAMMP Reports-28A & 28B provide a Welsh Accounts for Mountains, Moorlands and Heath habitat and where possible take account of the rich condition data available for these Welsh ecosystems. Further accounting work on Food production, and to incorporate ecosystem services from Acid Grassland, is planned within the ERAMMP work programme.

The Welsh State of Natural Resources Report (SoNaRR) is produced by NRW under the requirements of the Environment (Wales) Act 2016 to show the conditions and trends of natural resources in Wales and the pressures acting on them.

The remainder of this Section considers how economic values are used in decision-making, and the ecosystem services framework used to enable such analysis. Section 3 summarises the methods available to obtain economic values for the environment, which are described further in Annex D of this report. Section 4 compares and explains the valuation methods used in the ERAMMP studies and SoNaRR.

2.2 The Process of Economic Valuation[7]

We live in a world in which resources are limited and choices are inevitable. So it helps to understand the relative pros and cons of the different choices. Economics is the study of how to allocate limited resources – be it environmental or time or money or other – amongst our unlimited needs and wants. The objective of allocation is the improvement of human welfare.

Economic valuation is a way to understand how much something is worth to particular individuals or to society as a whole. The two major conceptual bases for economic valuation both use monetary units, but differ in the way they define and measure value. The **exchange value** framework focuses on the revenues, i.e. quantities and prices in the market economy – so mainly cover 'use values'. The **welfare framework** focuses on all changes to welfare whether they are delivered through the market economy or not.

Although under certain conditions exchange values can be similar to welfare values, often they are quite different. Exchanges in the market place allocate resources: one party's money is exchanged for the other party's goods and services. The amount of money given up to purchase something is an indication of its value to the buyer – in other words, the welfare benefit enjoyed through the purchase – but in most cases there will be additional welfare over and above the price paid. Welfare values are the foundation for economic appraisal, reflecting individual preferences for provision of goods and services. They are measured by individual 'willingness to pay' (WTP), which derives from several possible motives making up Total Economic Value (see Figure 2-1). The most obvious is the use value to the individual, which can be consumptive ("used up": e.g. food) or non-consumptive (used but left intact, e.g. outdoor recreation). There may also be non-use values, associated with existence of natural environments and their availability for other people and future generations, as well as option values associated with uncertainty and keeping future options open.

While market prices guide individual choices, there are no markets for many environmental and other goods and services. Markets fail to account for changes that happen outside them: the key example here is 'externality' - meaning environmental changes impact on other people or future generations. Therefore, using exchange values/ market prices alone will not tell us about the values of environmental goods and services; or the changes in their contribution to human welfare. Reliance on market data severely underestimates how dependent our existence, society and economic activities are on nature, particularly in relation to public goods, which have no markets and so no exchange values. Economic valuation methods are applied to the environment to address this imbalance – gathering biophysical, market and non-market data to estimate the value individuals place on environmental goods and services.

[7] This section draws from Ozdemiroglu & Hails (2016)

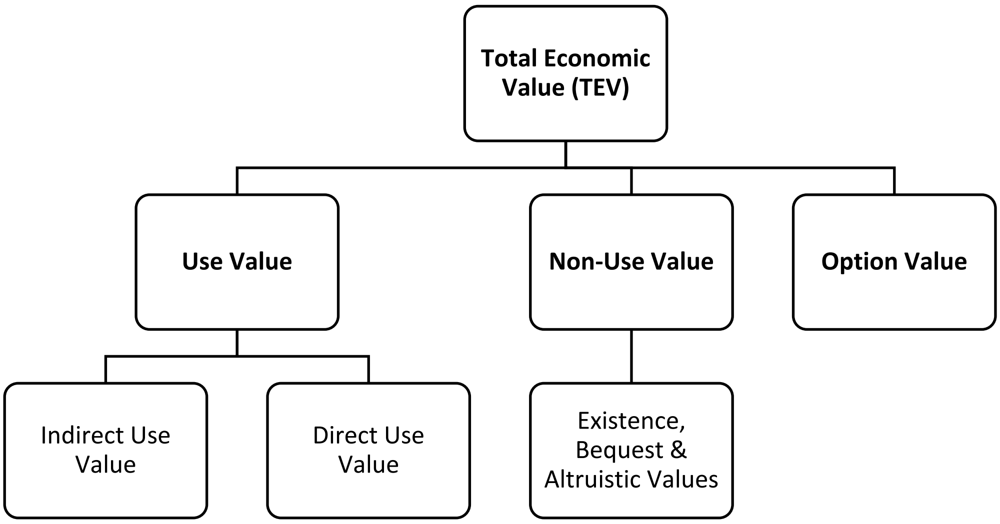

Figure 2-1: Figure 1: The Total Economic Value framework

2.3 Ecosystem Services as a Framework for Valuation

Economic valuation involves three stages:

1. Qualitative assessment: the mechanisms by which a decision will influence the environment and the goods and services it provides needs to be understood
2. Quantitative assessment: the change in the environment and the related benefits need to be measured in appropriate metrics
3. Monetary valuation: only when (1) and (2) are complete can the third step of valuation in monetary terms take place.

Organising data for the qualitative and quantitative steps can be challenging, and is an important source of uncertainty to consider when interpreting valuation (and other) results.

ERAMMP uses ecosystem services as a framework for organising the required qualitative and quantitative data.

Ecosystem services classifications provide economics with a basis for identifying the benefits to people from the environment. Several different approaches to classification have been developed over recent years and continue to evolve. There is broad agreement over the main categories of provisioning, regulating and cultural services[8], but many differences in the classification of individual ecosystem services. Furthermore, there is some disagreement over the semantics of “ecosystem services”, with some favouring the IPBES framing of “Nature’s contributions to people”, and the separation of that in to Material and Non-material contributions. In practice, ecosystem services concepts are most commonly used, but any

[8] Supporting services are also covered in some but not all classifications. This is not because they are unimportant, but because (a) they are only indirectly consumed or used and (b) may simultaneously facilitate many final services. Therefore, where those final services are valued, valuing the supporting services would entail double counting.

given analysis will cover only some of the affected ecosystem services, usually because others cannot be adequately measured and/or valued.

The reports reviewed here are no exception and indeed cover different ecosystem services, reflecting the different purposes of the ERAMMP analyses for Wales (see Annex A). In ERAMMP's *Quick Start* modelling (ERAMMP Report-12) and in the IMP (ERAMMP Report-13) fewer services are measured and valued. This is because the detailed spatial modelling they provide requires spatially explicit values, and these do not exist for all ecosystem services. The natural capital accounts in Reports-24 & 28A (and SoNaRR) cover a broader range of services but at a higher level of aggregation, drawing on national level data and estimates for Wales.

2.4 Using Economic Valuation in Accounting and Appraisal[9]

The key reason for using economic valuation is to present better information on the importance of nature[10] to support decision making. This is particularly important when decisions have both market and non-market environmental costs and benefits. In ERAMMP, economic valuation is used in accounting and appraisal.

Accounting framework. The System of National Accounts (SNA) framework is used by government statisticians to measure Gross Domestic Product (GDP). GDP omits non-market activity, it only measures the size of economic activity in markets and therefore includes value of natural capital assets and services only so far as they are traded. Given this scope, national accounting uses exchange values ('prices') and not welfare values even though GDP is often, mistakenly, used as a measure of welfare (SNA 2008). National ecosystem accounts are guided by the UN's System of Environmental Economic Accounting. Its Central Framework (SEEA-CF) is an international statistical standard, but has a restricted coverage that stops short of full ecosystem accounting. The Experimental Ecosystem Accounting (SEEA-EEA) framework, as the name suggests, is not yet a fully agreed standard, with UN guidelines currently being revised[11]. The UK and Wales national natural capital accounts follow the SEEA-EEA guidelines and also implement Defra's accounting principles[12]. It should be noted that natural capital approaches and accounting are also used in other contexts (see Box 1).

Welsh Natural Capital Accounts are estimating economic values of the services provided by several habitats to help understand the value the environment provides to society. They aim to measure the total value of annual flows of benefits, and of natural assets based on the total flows they can provide into the future. They improve our understanding of the value of benefits to society from an ecosystem or ecosystems. They provide additional information to what is already measured through systems of national accounts (such as GDP), by valuing the contributions of ecosystems to the benefits used in economic and other human activity. 'Logic chains' are created to link ecosystem assets; enabling factors and human inputs; ecosystem services; and benefits, explaining the way ecosystem services are provided and generate benefits. Benefits can be goods and services traded in the markets, as measured in

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[9] For further discussion of natural capital accounting and appraisal, see Table 9 in Defra (2020).
[10] Nature in this context can be understood through natural capital assets, ecosystem services or any other approach.
[11] https://seea.un.org/content/seea-experimental-ecosystem-accounting-revision
[12]https://www.ons.gov.uk/economy/environmentalaccounts/methodologies/principlesofnaturalcapitalaccounting#basic-valuation-principles-in-natural-capital-accounting

the SNA, or the non-SNA benefits that are outside the markets such as many cultural and regulating services.

Through these steps, national natural capital accounts aim to capture the services provided by nature, which GDP excludes in part, as it only covers the economic activity in the markets. Including natural capital assets and their services in the national accounts makes them a fuller, but still incomplete, reflection of national welfare.

Box 1: Natural Capital

Natural capital is that part of nature which directly or indirectly underpins value to people, including ecosystems, species, freshwater, soils, minerals, the air and oceans, as well as natural processes and function (NCC 2019). The stock of natural capital assets provide (with other capital stocks), flows of benefits in the form of ecosystem services, and abiotic goods and services (e.g. minerals).

Natural capital accounts show the stocks of assets and the flows of services and values they provide. Distinguishing stocks and flows is a key aspect of a natural capital approach, along with considering both impact and dependencies, and use of measurement and valuation[1]. Natural capital accounting applies the key features of the natural capital approach in a consistent structure that links together physical and economic data, and enables more consistent analysis over time (Dickie & Neupauer 2019).

Natural capital accounts can be applied at national, regional or an organisational level. At the organisational level, the approach taken is determined by its purpose and decision-making context (Natural Capital Coalition 2016). Accordingly a variety of approaches exist (for example using a value chain or spatial asset account boundary), but the principles involved are becoming standardised[1].

National capital accounting is discussed further in Section 2.4.

Appraisal framework. The aim of cost benefit analysis (CBA) – as practiced for public decisions at least - is to weigh up all the impacts of a policy or the project (financial, environmental, social) to determine if, on balance, the benefits outweigh the costs. In CBA, some of the costs and benefits can be related to markets (for which prices, or exchange values, would be used – with necessary adjustments); and others can be related to changes in welfare (for which non-market values would be used).

Comparing impacts involves aggregating individuals' costs and benefits over the affected population, space and time so that allowing different policy or project options (including 'do nothing') can be compared. Comparison can be expressed as net present value (NPV: total benefits discounted over time net of total discounted costs) or as a benefit:cost ratio (BCR). Positive NPV means benefits outweigh costs and BCR greater than one means each unit of cost generates more than one unit of benefit. However, as CBA sums costs and benefits across society, in practice appraisals allow gains to some individuals to offset losses to others. Therefore, care must be taken interpreting CBA results since the distribution of values is important.

As well as trade-offs between individuals, appraisals usually assume that capitals are perfectly substitutable – that is, that a loss in one kind of capital (for example natural) can be fully compensated for by increasing some other kind of capital (for example manufactured) with no overall loss of productive capacity or welfare. However, this should not be assumed to always be true. If some important services flowing from a capital stock have no substitutes (like a stable climate), the stock can be essential to human well-being. The idea of 'critical natural capital' refers to resources that we must conserve at all costs, and that cannot be traded off against other forms of capital.

3 Applied Economic Valuation Methods for ERAMMP

This Section compares the valuation approaches used in the different ERAMMP outputs and describes the reasons for the differences in their methods. Different economic valuation methods are developed to deliver the third step in economic valuation – monetary valuation (as described in Section 2.2). All methods rely on the first two steps: qualitative and quantitative assessment, but differ in the data they used and hence the economic values they cover.

Table 3-1 summarises the different valuation methods used in ERAMMP Reports 12 and 24, with their application described in more detail in Annexes B and C. The methods applied are briefly described below, and Annex D gives more detail on them and others that could potentially be used in similar work. The ecosystem service categories used are compared in Annex A. It is also noted that the SoNaRR uses some aggregate ecosystem service valuations, but it doesn't provide a comprehensive ecosystem service account, so the valuation methods used in SoNaRR are not examined in further detail here.

Table 3-1: Comparison of Valuation Methods Used in Reports 12, 13, 24 and 28A

Ecosystem service	Reports 12 & 13	Reports 24 & 28A	Comparison
Climate mitigation/ carbon sequestration	Shadow Price	Shadow Price	Same
Air pollutant removal	Welfare value of a Life Years Lost	Welfare value of a Life Years Lost	Same
Recreation	Recreation demand model (welfare value)	Travel Expenditures (exchange value)	Major difference
Water quality (Report-13 (IMP) only)	Stated Preference	-	n/a
Agricultural Biomass	-	Resource Rent	n/a
Water abstraction	-	Resource Rent	n/a
Freshwater fish	-	Resource Rent	n/a
Timber	-	Market price	n/a
Renewable energy (Report-28A only)	-	Resource Rent (Report-28A only)	n/a

3.1 Typology of valuation methods applied in ERAMMP

The key difference between valuation methods is the data they use, that in turn determine the kind of values they can capture:

A. Data from actual markets:

   i. market values (or exchange values) for environmental goods and services that are traded in markets

   ii. adjusted market values (or shadow prices) especially when environmental goods and services are an input to a production process

B. Data from 'surrogate markets' that reveal how individuals value environmental goods and services (revealed preference) and

C. Data from 'hypothetical markets' that enable individuals to state the values they hold for environmental goods and services (stated preference methods).

There is a 'valuation hierarchy' in economics that suggests the starting point for economic valuation should be **market values** and other observed (rather than modelled or hypothetical) data. This is because such data are observable and repeatable. However, as discussed above, many ecosystem goods and services (especially public goods) are not traded in markets therefore there is no market data about them. Market prices can be used directly as exchange values. In some cases, these are the same as welfare values. Often, however, some form of market imperfection (such as pollution) means that they need to be adjusted to derive **shadow prices** that reflect social benefits and costs. Shadow prices try to reflect the true (marginal) social value of a good or service, where the actual price does not do this. In other words, shadow prices are a way of adjusting an exchange value (price) to give a welfare value. The most common adjustments in standard economics approaches are adjusting for taxes and subsidies that affect market prices but do not reflect exchange or welfare values, and adjusting for unemployed labour via a shadow wage. The UK social cost of carbon, discussed in Annex B, is another example.

Some ecosystem services lead to marketed goods – for example food, timber, and water – but the exchange value of these goods captures more than the ecosystem service. To separate out the contribution of the ecosystem service from the other inputs – manufactured capital, human labour, energy - the **Resource Rent** approach is often used. This calculates the exchange value of an ecosystem service by taking the gross value of the final products and then deducting the cost of all other inputs (labour, produced capital and intermediate inputs). The residual can be considered the value of the ecosystem service (UN Statistic Division, in prep).

Similar methods underpin the production function approach (see annex D) that can be combined with either a market exchange value or a welfare value depending on the analytical purpose. **Cost of illness** methods are a particular class of production function where environmental services are linked to health impacts – such as the health damage of pollution, or the health benefits of a cleaner environment. The valuation can be based on medical costs (incurred or avoided), productivity (work days lost or gained), and/or pain and suffering (for a standardised unit of health impacts such as a Life Year Lost or QALYs (Quality Adjusted Life Years) lost/saved)[13].

Where market values cannot be used or adjusted, there are two main approaches to valuation: revealed preference and stated preference.

Revealed preference methods analyse relationships between demand for some market goods and preferences for related non-market goods/services. These methods only work if changes in provision of the non-market good have an observable impact on the demand for a market good. The example used in ERAMMP is a recreation demand model. This examines survey data of actual household behaviour in selecting and visiting outdoor recreation sites, taking account of the sites available and the costs of reaching them. Analysis of the data allows estimation of a demand curve for outdoor recreation and that can be used to estimate the welfare values of recreation.

ERAMMP also uses a travel expenditures approach. This is much simpler, only involving the step of calculating the travel expenditures associated with accessing the recreation sites. This is an exchange value that is already included in the national accounts, but that can be "reattributed" to the natural capital involved (the sites). Recreation demand modelling and travel expenditures are superficially similar, but in fact very different, measuring different things, and with no clear relationship between them. This is explained via a worked example in annex E.

Where there are no actual or surrogate markets, the only option is to ask individuals to state their preferences. **Stated preference methods** do this through surveys which create hypothetical markets in which respondents trade off money against changes in the ecosystem goods and services. The methods vary depending on how the surveys are designed whether using more direct trade off questions (contingent valuation) or more indirect questions about choices between trade off scenarios (discrete choice experiments). The water quality value used in ERAMMP is based on a combination of these approaches.

3.2 Comparisons and Discussions of Methods Used

Table 3-1 shows that the scope of services covered in Reports 12 and 24/28A are significantly different. Only three services are valued in both reports. Of these three services, two (climate change mitigation and air pollutant removal) have the same valuation methods, both of which stem from UK Government appraisal guidance (BEIS's carbon values and Defra's 2016 air pollution appraisal guidance, respectively). There are small differences between Reports 12 and 24 in the physical modelling/ measurement of these services, due to the different spatial scale and purpose of their respective analyses.

The major difference between the methods shown in Table 3-1 is in respect to recreation. Report-24 uses data from analysis of travel expenditures relating to recreation. The travel expenditures used in Report-24 are part of the data that is summed to give GDP figures in the SNA – they effectively identify what part of expenditures within GDP are made in order to undertake trips for recreation. This gives an indicator of recreation expenditures over time, but does not measure the welfare value of recreation activity in the natural environment, which is a key component of the societal value of public goods. Furthermore, since most

[13] UK Government provides various estimates of The Value of Life Year Lost or QALY values. ERAMMP uses a willingness to pay (welfare) value from Chilton et al. (2004). There are also estimates of the welfare value of a QALY (willingness to pay to avoid a unit decline in QALY) and the exchange value of a QALY (the marginal cost spent to save a QALY in clinical practice).

recreation trips do not involve direct expenditures, it may significantly underestimate both the total value to society from recreation in the natural environment, and the value changes that arise as a result of changes in land management (see Annex E).

Report-12 uses data from the ORVal Tool, a model built from survey data in England and extended to Wales using the Welsh Outdoor Recreation Survey (WORS). It estimates values for recreation activity based on a recreation demand model, which uses data on recreational travel costs and trip-making decisions to estimate demand for recreation amongst all visitors, including those who are able to visit for free (see Annex E).

Thus, travel expenditures in Report-24 are costs incurred by individuals in travelling to undertake recreation, and this is not at all the same as the recreation demand model-based values used in Report-12. This comparison is summarised in Table 3-2.

Table 3-2: Recreation Valuation Methods Used in Reports 12 and 24, and the IMP

	Report-12 & IMP	**Reports 24 and 28A**
Method	Recreation demand model (welfare value)	Travel Expenditures (exchange value)
Basis	Welfare from visits net of costs.	Spending to access recreation.
Coverage of trips with zero expenditures	Captured through estimation of demand for recreation	Not included

3.3 Interpreting values

Valuation is one manifestation of a model of how aspects of the natural world influence human well-being. Like any model, the important issue is whether or not valuation is useful as a decision support tool, in a particular context. Contexts can range from specific local decisions, to national or even global strategic planning. In all cases, economics offers different frameworks focused on the impacts on human welfare (the welfare values used in social CBA) and on the impacts on economies and markets (the exchange values framework used in national accounting like GDP). Both can be useful and indeed complementary, in that they focus on different aspects of the management and monitoring problem.

Thus, the exchange and welfare economic valuation data used in Reports 12 and 24 within the ERAMMP programme measure different things and are useful in different ways:

- Caution is needed in adding together values derived under different valuation frameworks: although expressed in monetary terms, they measure different things.
- Exchange values tell us about monetary flows in a form comparable to other data from the market economy.
- Welfare values tell us about welfare benefit to society.
- Welfare values can measure public goods. Exchange values are usually not available for public goods, though in principle they could be simulated (see annex D).
- Comparing market exchange values and welfare values gives an indication of the inaccuracy of the SNA as an indicator of welfare. This will better inform decision-

makers than if they are provided with data on only exchange values. For example, much outdoor recreation is free of charge, but has substantial welfare value. Decision-makers need to know about those values to make good decisions about investments in public goods.

3.3.1 Differences in purpose

Reports 12 and 24/28A serve different purposes within ERAMMP. As a result, the physical and economic data needs of the studies are different. The Welsh ecosystem accounts in Reports 24 and 28A aim to provide aggregate measures of value at a national scale. They make this measurement in a way that best enables comparisons to other national economic data, such as GDP, and that can be consistently applied over time. They still need to be sensitive to spatial and other changes in ecosystem services in order to measure national changes accurately. However, their primary purpose is to track national outcomes, rather than the distribution of those outcomes.

Report-12 (QuickStart) and the IMP, are designed to understand the extent, type, value and distribution of potential impacts of environmental changes in Wales. Therefore, they require physical data on environmental changes that are spatially explicit measures of change. For example, when assessing potential impacts of woodland creation, spatially explicit physical data includes the slope, climate and other characteristics of land that will influence the resulting changes in ecosystem services, and contextual data that will influence the changes to public goods resulting from changes to those services. For QuickStart and IMP, the valuation data (except for GHG emissions) also needs to be spatially explicit and related to changes. The range of physical environmental data, and the need to connect it to valuation evidence is what makes applied spatially explicit valuation of changes to the natural environment complex.

3.3.2 Interpreting differences in values

Values for the same service can be very different depending on the context and location. There can be services where this is not the case – notably climate regulation, since carbon dioxide is a globally mixing pollutant – but more generally, context is key. Provision of outdoor recreation access is a good example: the value will depend on the quality of the site, but even more on the location and the availability of alternative sites and users' socio-economic characteristics and social norms and habits. The value of a visit to a remote natural area may be higher, but more visits may be made to urban parks.

To be useful for decision-making, value concepts and methods should be sensitive to these contextual differences, and should be able to estimate how values change in response to how a good or service changes as a result of decisions. In this context, the interpretation of monetary value changes in accounts is a particular concern. A higher figure in accounts might be thought 'better', as implying that more people benefit and/or there's an improved quantity or quality of service. But in fact there are other possibilities: increased scarcity (overfishing, crop failure…); decreased competition; loss of substitutes or increase in their prices; 'marketisation' (where previously free resources become traded); increased environmental pressures that require more of a regulating service (e.g. increased air pollution). For recreation values, when travel becomes more expensive the travel expenditures method may show increased value, but a recreation demand model will show reduced consumer surplus (See Annex E, example 2). Therefore is it important that policy makers do not equate increased travel expenditures with greater benefits. To understand the figures properly, it is vital that the physical data be considered alongside monetary.

The different methods used in ERAMMP for valuing recreation make a good case in point. Both travel expenditures and values from the recreation demand model can vary due to a number of factors, including for example changes in the provision or quality of recreation sites, and changes in populations, incomes or other determinants of recreation demand. However, as explained in Annex E, the interpretation of changes in expenditures can be difficult. Indeed it is possible that welfare values could increase while travel expenditures decline – this would be the case, for example, if new recreation sites were provided, allowing people to enjoy more recreation opportunities while also reducing expenditures on accessing sites.

4 Conclusion

All economic valuation methods used in ERAMMP have similarities in that they combine physical environmental data (often organised as ecosystem services) with socio-economic data to estimate the monetary values of changes to individuals. However, they generate monetary values using different types of data and representing different aspects of the value individuals hold for the natural environment. A key distinction is between:

- Data measuring market values, and proxies for these that reflect exchanges in the economy ('exchange values'); and
- Data representing the benefit a person gets from something ('welfare values').

Both these types of value are calculated for changes: either smaller 'marginal' change (e.g. an improvement to a recreational site), or an 'aggregate' value reflecting the change from zero (e.g. the total value of a recreational site compared to if it did not exist).

4.1 Uncertainty

As with all modelling and transfer of data, there are uncertainties in the identification and application of economic values for the environment. These uncertainties can relate to any of the qualitative, quantitative and monetary stages of valuation described in Section 2.2. Quantitative physical measurement of some ecosystem services (e.g. mitigation of downstream flood risk) is complicated and context-specific. If physical measurement is inaccurate, then any related monetary values will have similar inaccuracy, irrespective of the accuracy of the monetary stage.

The applications of economic valuation methods within ERAMMP, are described in Annexes B and C and given a High/ Medium/ Low confidence rating. This describes the confidence in their monetary valuations given the data available within the project. When certainty is low, conservative assumptions are usually adopted in the analyses, meaning results are more likely to be underestimates of value. Low confidence is also an important signal to the need for more research.

While confidence levels should be borne in mind by decision-makers, they should not prevent uses of monetary values in decision-making. Even with low levels of confidence, it is better to take available information into account than ignore it (which can imply a zero value for the environment). Furthermore, if measurements over time are consistent, as per the purpose of the National natural capital accounts, then low-confidence data still gives a useful time-series. Sustained reporting over time is essential for incorporating nature into the way governments set policy and allocate resources.

4.2 Recommendations

Policy and business decisions are best informed using both market and non-market data to allow comparisons of relative values across impacts, people, time, and decisions. Where care is needed is in adding together values derived under different valuation frameworks: although expressed in monetary terms, they measure different things. For various reasons, including exchange value's deficiencies as a proxy for welfare from non-market (i.e. many environmental) goods and services, they can have major differences in what they show.

The benefit of being informed by welfare *and* exchange values is to understand the limitations of market economic data. Using only exchange values increases the risk that benefits from non-market environmental goods will be missed in decision-making, resulting in under-allocation of spending or sub-optimal management of the environment. This will lead to an under-provision of public goods.

Economic valuation is used within ERAMMP to help assess policy impacts in line with the project objectives, as guided by policy requirements such as the Well-being of Future Generations (Wales) Act 2015. Assessment of impacts on well-being means the boundary of what's valued and the data used in economic valuation should be broad enough to inform policy makers about all impacts across society, not only those that arise in markets. To assess the impacts on the future generations, long appraisal timescales (75 and 100 years) should be used, and zero discount rates should be tested in sensitivity analysis. The Welsh National Natural Capital accounts show the relative value of different ecosystem services to each other and the market economy, giving context for policy impacts and assessments. In due course they will provide trends in ecosystem service values over time.

5 GLOSSARY

Altruistic value	Non-use benefit derived from the knowledge that contemporaries are able to enjoy the goods and services related to natural resources.
Bequest value	Non-use benefit associated with the knowledge that natural resources will be passed on to future generations.
Biodiversity	The variability among living organisms from all sources, including terrestrial, marine, and other aquatic ecosystems and the ecological complexes of which they are part. Biodiversity includes diversity within species, between species, and between ecosystems (Convention on Biological Diversity, Article 2)
Choice modelling	An umbrella term for a variety of stated preference techniques that infer willingness to pay or accept indirectly from responses stated by respondents (as opposed to directly asking as in a contingent valuation survey). Includes choice experiments, contingent ranking, and paired comparisons. .
Contingent valuation	Determination of willingness to pay through use of structured questionnaire in which respondents answer yes/no to suggested prices (dichotomous choice or payment ladder) or provide a willingness to pay number themselves (open ended).
Cost of alternatives	A market pricing approach that considers the cost of providing a substitute that would provide a similar function to a resource.
Cost of illness	A market pricing approach for assessing the costs of illness (e.g. medical treatment, loss of earnings from work days lost, etc.). It does not include aspects related to pain and suffering from illness.
Cultural services	Cultural services relate to the intellectual and symbolic benefits that people obtain from ecosystems through recreation, knowledge development, relaxation, and spiritual reflection.
Defensive/ avertive expenditure (method)	This method can be applied in cases where an environmental good can be substituted by a form of defensive expenditure incurred in avoiding damages from reduced environmental quality (e.g. expenditure on water filters and bottled water which is indicative of the value people place on clean water).
Direct use value	Economic value associated with use of a resource in either a consumptive manner or non-consumptive manner.
Discounting	The technique of applying a discount rate to convert future monetary amounts to their equivalent value in today’s terms.
Discount rate	The discount rate is used to adjust the value of a stream of future flows of revenue, costs or income to account for time preferences and attitudes to risk.
Economic value	The monetary measure of the well-being associated with the change in the provision of some good or service.

Ecosystem accounting	An integrated approach to the assessment of the environment through the measurement of ecosystems, and measurement of the flows of services from ecosystems into economic and other human activity.
Ecosystem condition	The overall quality of an ecosystem asset in terms of its characteristics.
Ecosystem services	Ecosystem services are the contributions of ecosystems to benefits to economic and other human activity.
Exchange value	For a traded good or service, equal to the market price multiplied by the quantity transacted. Exchange values are those that underpin national and business accounting frameworks.
Existence value	Non-use value derived from knowing that a resource continues to exist, regardless of use made of it by oneself or others now or in the future.
Hedonic pricing method	A revealed preference valuation method that estimates the use value of a non-market good or service by examining the relationship between the non-market good and the demand for some market-priced complementary good (e.g. property or land prices).
Marginal change	An incremental change (ordinarily a 'unit change') in the provision of a market or non-market good or service.
Market goods	Goods and services traded in formal markets.
Market price	The price for which a good is bought and sold in a market. See 'exchange value'.
Market price methods	Approaches to economic valuation that provide proxy estimates - which may be observed directly from actual markets - for use values.
Natural capital	The elements of nature that directly and indirectly produce value or benefits to people, including ecosystems, species, fresh-water, land, minerals, the air and oceans, as well as natural processes and functions.
Net Present Value	NPV is calculated as the difference between present benefits (PVB) and present value costs (PVC). A positive NPV indicates that benefits outweigh costs; a negative NPV, vice versa.
Non-market goods and services	Goods and services that are not traded in markets and are consequently 'un-priced' (e.g. environmental goods and services).
Non-use value	Economic value not associated with any use of a resource, but derived altruistic, bequest and existence values. (Passive use value)
Non-users	Population group(s) that derives economic value from a resource even though they do not make direct or indirect use of it (i.e. non-use value).
Opportunity cost	The value of the next best alternative use of a resource.

Option value	Benefits associated with retaining the option to make use of resources in the future.
Present value	The discounted value of a stream of future costs or benefits.
Production function	A production input method which relates the output of a given good (e.g. agricultural products) to its factor inputs (e.g. land area and quality, machinery, labour quantity and quality of water etc.).
Provisioning services	Provisioning services reflect contributions to the benefits produced by or in the ecosystem, for example a fish, or a plant with pharmaceutical properties.
Public good	A good or service that is non-rival and non-excludable. Consumption of the good by one individual does not reduce availability of the good for consumption by others, and no one can be effectively excluded from using the good.
Regulating services	Regulating services result from the capacity of ecosystems to regulate climate, hydrological and bio-chemical cycles, earth surface processes, and a variety of biological processes.
Revealed preference methods	Economic valuation methods that estimate the use value of non-market goods and services by observing behaviour related to market goods and services (e.g. recreation demand model and hedonic pricing method).
Replacement cost method	This approach approximates the value of an ecosystem service from the cost of mitigating actions required if the service is lost or if its productivity decreases.
Shadow price	The opportunity cost to society of some activity, relating to situations where market prices do not reflect the scarcity value (i.e. opportunity cost) of the use of a good or service.
Stated preference methods	Economic valuation methods that use questionnaire surveys to elicit individuals' preferences (i.e. willingness to pay and/or willingness to accept) for changes in the provision on non-market goods or services.
Supporting services	A category of ecosystem services which are necessary for the production of all other ecosystem services, such as soil formation and retention, nutrient cycling, water cycling and the provision of habitat.
Total economic value (TEV)	The economic value of a good or service comprised of its use, non-use and option values.
Recreation demand models	These approaches are revealed preference methods. They use information on costs and time spent by individuals travelling to reach sites, costs and time spent at sites, and decisions about which sites to visit, to estimate the value of recreation benefits.
Use value	The economic value that is derived from current and future use of a resource.
Users	Population group(s) that composed of individuals making direct use of a resource or indirect use of a resource.

Value transfer	Process by which readily available economic valuation evidence is applied in a new context for which valuation is required. A more common term for value transfer used to be ‘benefits transfer’.
Welfare (well-being)	A measure of satisfaction or ‘utility’ gained from a good or service.
Willingness to pay (WTP)	The amount of money individuals are willing to pay for avoiding a deterioration in the valued goods and services; or for securing an improvement

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7 Annex A: Ecosystem Categories

Table 7-1 compares some of the reports prepared to support environmental policy making in Wales in terms of their use different classifications of ecosystem services to measure and value benefits. The differences between reports can largely be explained through the differences in the reports' objectives – such as the type and spatial scale of the policy decisions they seek to inform, and the constraints such as data availability that they faced.

Table 7-1: Comparisons of Ecosystem Services classifications

	SoNaRR	UKNEA	Quickstart & IMP	ONS Wales Accounts
Regulating	Pollination	pollination		
	Air quality	regulation of water, air and soil quality	Air pollutant removal by vegetation	Air pollutant removal by vegetation
	Climate	climate regulation	Climate mitigation (agricultural emissions, carbon sequestration)	Carbon sequestration
	Water quality	regulation of water, air and soil quality		
	Water quality	water cycling (FROM SUPPORTING SERVICES)		
	Water quality	fresh water	Water quality	
	Soil quality	soil formation (FROM SUPPORTING SERVICES)		
	Hazard	hazard regulation		
	Disease and pests	disease and pest regulation		
Supporting	-	nutrient cycling		
	-	primary production		
Provisioning / Materials & assistance	Noise	noise regulation		
	-	-		Peat extraction
	Crops	Food		Agricultural biomass
	Livestock/aquaculture	Food		
	Fish	Food		Freshwater fish

	SoNaRR	UKNEA	Quickstart & IMP	ONS Wales Accounts
	Trees, standing vegetation, peat	Fibre		Timber
	-	genetic resources		
	Water supply	-		Water abstraction
Non-material / Cultural	Wild species diversity	-		
	Environmental settings: landscapes/seascapes	spiritual or religious enrichment		
		aesthetic experience		
	Environmental settings: local places	cultural heritage		
		recreation and tourism	Peri-urban recreation	Outdoor recreation

8 Annex B: Report-12 (Quickstart) and Report-13 (IMP) Methods

This section describes the methods used to value three ecosystem services covered in ERAMMP Report-12 (*Quickstart*) and Report-13 (*IMP)*, and to value water quality impacts in the IMP.

Quickstart used 2018 prices and IMP values are in 2020 prices. The calculations present values over 75 years. ONS uses a 100 year time period to calculate asset values in the Welsh Natural Capital Accounts. Both studies use HM Treasury recommended discount rates.

Each method is given a confidence rating as follows:

- High: there is good confidence in the data, which can be used to support specific decision making and spending choices.
- Medium: there is reasonable confidence in the data as estimates to guide decisions and spending choices.
- Low: there are weaknesses in the data such that they provide only order of magnitude estimates of value to inform decisions and spending choices.

8.1 Climate mitigation, emissions reduction and climate mitigation, sequestration

Method: Shadow Price

Confidence: Medium - High

Quantitative assessment: quantity of CO_2 equivalent (CO_2e) emitted or sequestered

Ecosystems, such as peatland or wetland restoration, have varied emission and sequestration profiles over time, and take a long time to return to a steady state in response to management.

Monetary valuation: shadow price based on mitigation costs

The values for a tonne of CO_2e for emissions reductions and sequestration are the same – they are both marginal changes in the concentrations of CO_2e in the atmosphere. The expected changes in carbon emissions have been valued according to latest Government Guidance, adopting the non-traded price of carbon (BEIS)[14], which escalates from £68 in 2020 (the baseline year) to £319/tonne in 2095.

This is an established valuation approach across the public sector in the UK, and is widely used in policy analysis and decision-making across Government departments. However, the values have not been updated since UK commitment to zero carbon emissions.

[14] BEIS guidance (2013). https://www.gov.uk/government/collections/carbon-valuation--2 2017 update

8.2 Air Pollutant Removal

Method: Avoided health damages

Confidence: Medium

Quantitative assessment: changes in air pollutant concentration and the resulting change in human health impacts

Calculation of the physical amount of pollutant removal uses the European Monitoring and Evaluation Program Unified Model for the UK (EMEP4UK) atmospheric chemistry and transport model, which generates pollutant concentrations directly from emissions and dynamically calculates pollutant transport and deposition, considering meteorology and pollutant interactions. The role of vegetation is through interaction with the atmospheric pollutants, in particular in removing pollutants either through deposition on vegetation surface (especially particulates), or chemical absorption (some gases). The role of vegetation is calculated as the difference between the results from the model with the current vegetation cover in the UK, and a model in which the vegetation is replaced by an inert surface.

The difference (reduction) in pollutant loads is then translated into lower population exposure to the atmospheric pollutants, taking into account the distribution of the resident population. The benefit of reduced population exposure to atmospheric pollutants is estimated based on the Government's COMEAP[15] guidance. This results in reduced morbidity and mortality as a result of lower exposure, which are summarised as Life Years Lost, and welfare costs associated with respiratory and cardiovascular hospital admissions.

As UKCEH estimated pollution capture for years 2007, 2011, 2015 and 2030, a linear adjustment index was calculated to obtain a full time series, from 2007 onwards. The linear adjustment index was determined by taking actual air pollution data and calculating the percentage of pollution capture, for the aforementioned years, as a proportion of actual air pollution levels. A trend of the percentage of pollution capture was then calculated and the estimated percentages of pollution capture were used to obtain values of pollution capture for the missing years.

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.

Monetary valuation: avoided damage to human welfare from illness

Damage costs per unit exposure were then applied to the benefitting population at the local authority level for a range of avoided health outcomes:

- respiratory hospital admissions
- cardiovascular hospital admissions
- loss of life years (long-term exposure effects from PM2.5 and nitrogen dioxide (NO_2))
- deaths (short-term exposure effects from ozone (O_3))

[15] Committee on the Medical Effects of Air Pollutants https://www.gov.uk/government/groups/committee-on-the-medical-effects-of-air-pollutants-comeap

The value of impacts is adjusted according to the degree of health impacts from different pollutants. For example, the life years lost are valued at different levels in line with existing Defra models. This values a life year lost at £35,000 (2012 price), but is adjusted based on assumptions of the number of life years lost for deaths from different pollutants.

8.3 Recreation

Method: Recreation demand model

Confidence: Medium – High

Quantitative assessment: from ORVal tool, a model of outdoor recreation choices in England and Wales, built from survey data.

Monetary valuation: recreation demand model using costs of travel and time.

The welfare value of recreation can be drawn from modelling of known patterns of recreation in England and Wales, through the ORVal tool[16]. The modelling uses long-term Government survey data[17] on recreational behaviour, combined with the location of people and accessible paths and open spaces. The values are based on the cost of travel and time taken to access the recreation opportunity. This cost of time approach is the same as that used by the Department for Transport to value time savings from transport projects[18], as part of assessments as to whether those projects should be supported by Government, so is an established welfare valuation approach.

The use of the ORVal model in England is well established, is recommended in ENCA, has been compared to observed data for individual sites, and its limitations are understood. It only captures day visits by adult residents (so excludes overseas visitors, overnight stays and visits by under 16s). The extension of the ORVal model to Wales is more recent and so further testing would be useful. ORVal provides evidence on the overall value of recreation and changes to recreational access provision at individual sites. It does not readily model changes at multiple sites. There is also greater uncertainty for larger changes to the resource of footpaths and accessible open spaces.

8.4 Integrated Monitoring Platform

The IMP is using eight models, taking an integrated approach, as it is recognised that policy effects in one sector have indirect effects in other sectors. There are nine areas in which the IMP output variables will be aligned to that include air quality, public health, greenhouse gas balance, biodiversity, water quality, productivity, conservation of heritage, improvement of the natural landscape and social outcomes (e.g. public access, outdoor recreation). Ecosystem services and public good valuation occurs in the final stage of the IMP using a range of valuation methods such as market prices, avoided costs, revealed preference and stated preference approaches in line with their application within the cost-benefit analysis context.

However, estimates of physical changes to some services are calculated in a different way to that of ONS Natural Capital ecosystem services. For example, in the IMP Ecological Site Classification (ESC) and CARBINE (an analytical model developed to address questions about the carbon and GHG balances of forestry systems) are collectively used to estimate

[16] http://www.exeter.ac.uk/leep/research/orval/
[17] https://www.gov.uk/government/collections/monitor-of-engagement-with-the-natural-environment-survey-purpose-and-results
[18] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/603254/webtag-tag-unit-a1-3-user-and-provider-impacts-march-2017.pdf

the productivity and carbon storage of potential forestry, based on scenario information and management options, whereas ONS use estimates that relate to the removal of carbon gas from the atmosphere, separated into different land use and land-use change categories (LULUCF) and the central non-traded price of carbon. The IMP also calculates outputs with and without policy management interventions.

8.5 Water quality risks (Report-13 (IMP) only)

Method: Stated preference

Confidence: Medium

Quantitative assessment: changes (or the risk of changes) in Water Framework Directive (WFD) status

The modelling identifies expected increases in emissions of pollutants that create pressures on water body chemical status as defined under the Water Framework Directive (WFD). The modelling cannot predict whether these increased pressures will actually cause a deterioration in status[19]. Therefore, the analysis identifies the risk of deterioration, defined where there is a certain % increase in a pollutant that is already known to be a pressure on the receiving water body.

There are also areas where pressures on waterbodies will decrease and WFD status may improve. This has not been valued, partly because if factors other than chemical status (e.g. morphology) are determining status, the Directive’s ‘fail one fail all’ criteria would mean status would not change.

Monetary valuation: welfare values for improvements in waterbodies’ status.

Deterioration in water body chemical status is valued using the NWEBs values for water framework directive status. The values represent an estimate of the costs of potential reductions in water body status as a result of the agricultural changes modelled.

The NWEBs values have been extensively used in UK implementation of the Water Framework Directive over the last decade. The value is for deterioration from a given status and is based on the National Water Environment Benefits Survey (NWEBS) values (Metcalfe 2012).

This valuation represents people’s total economic value for maintaining the health of rivers/ waterbodies. It thus captures several aspects of value, including for:

- Direct uses of abstracted water.
- Enjoyment of those who may use waterbodies or adjacent land for recreation, and
- Knowing the environment is being maintained in good condition.

This is a detailed and peer reviewed evidence base, but is also over 15 years old, and interpolates national data to local waterbodies. Care needs to be taken because of the range of benefits captured in these values may double-count other benefits assessed separately (e.g. recreation). Adjustments to the data can be made to accommodate this.

[19] Note: improved data may allow monitoring data to replace this assumption in the IMP.

9 Annex C: Reports 24 and 28: Welsh National Natural Capital Accounts methods

This report presents ecosystem service accounts for woodland, farmland and freshwater habitats. Seven ecosystem services are covered, giving estimates of the quantity and value of services being supplied by Welsh natural capital. The valuation methods used to calculate the ecosystem service accounts are outlined below. Work has also been undertaken in ERAMMP to provide an ecosystem account for mountain, moor and heath (MMH) (Report-28A) and methods applied in that work are also described.

Each method is given a confidence rating as follows:

- High: there is good confidence in the data, which can be used to support specific decision making and spending choices.
- Medium: there is reasonable confidence in the data as estimates to guide decisions and spending choices.
- Low: there are weaknesses in the data such that they provide only order of magnitude estimates of value to inform decisions and spending choices.

9.1 Carbon sequestration

Method: Shadow price

Confidence: Medium to high

Quantitative assessment: quantity of CO_2 equivalent (CO_2e) sequestered

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

The LULUCF sector breakdown identifies carbon sequestration activities in the following subcategories of land uses and changes:

- forest land remaining forest land
- land converted to forest land
- cropland remaining cropland
- land converted to cropland
- grassland remaining grassland
- land converted to grassland
- wetlands remaining wetlands
- land converted to wetlands
- settlements remaining settlements
- land converted to settlements
- harvested wood products remaining harvested wood products
- land converted to harvested wood products

To apportion these values to calculate estimates of carbon sequestration within mountains, moorlands and heath (MMH), LULUCF categories were mapped to the Land Cover Map 2007 and 2015 class categories. From the mapping exercise it was concluded that, under the LULUCF categories, MMH corresponded to grassland and wetlands. The extent of the Land Cover class categories, that corresponded to MMH and LULUCF classes 'grassland' and 'wetlands', was taken and used to apportion the LULUCF estimates for grassland and wetlands. This then enabled us to calculate an estimated physical flow, annual value and asset value for carbon sequestration in MMH.

Monetary valuation: shadow price based on mitigation costs.

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

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

9.2 Air pollution removal

Method: Avoided health damages

Confidence: Medium-High

Quantitative assessment: changes in air pollutant concentration and the resulting change in human health impacts

Air quality regulation estimates have been supplied in consultation with UKCEH - for a more detailed explanation please see the full methodology report. The underlying UKCEH model is the same as used in ERAMMP Report-12, based on the study by Jones et al. (2017). This is very detailed and peer reviewed modelling process. This model uses data on the sources of key atmospheric pollutants and atmospheric conditions to predict pollutant dispersal patterns.

Calculation of the physical amount of pollutant removal uses the European Monitoring and Evaluation Program Unified Model for the UK (EMEP4UK) atmospheric chemistry and transport model, which generates pollutant concentrations directly from emissions and dynamically calculates pollutant transport and deposition, considering meteorology and pollutant interactions. The role of vegetation is through interaction with the atmospheric pollutants, in particular in removing pollutants either through deposition on vegetation surface (especially particulates), or chemical absorption (some gases). The role of vegetation is calculated as the difference between the results from the model with the current vegetation cover in the UK, and a model in which the vegetation is replaced by an inert surface.

The difference (reduction) in pollutant loads is then translated into lower population exposure to the atmospheric pollutants, taking into account the distribution of the resident population. The benefit of reduced population exposure to atmospheric pollutants is estimated based on the Government's COMEAP[20] guidance. This gives results on reduced morbidity and

[20] Committee on the Medical Effects of Air Pollutants https://www.gov.uk/government/groups/committee-on-the-medical-effects-of-air-pollutants-comeap

mortality as a result of lower exposure, which are summarised as Life Years Lost, and welfare costs associated with respiratory and cardiovascular hospital admissions.

As UKCEH estimated pollution capture for years 2007, 2011, 2015 and 2030, a linear adjustment index was calculated to obtain a full time series, from 2007 onwards. The linear adjustment index was determined by taking actual air pollution data and calculating the percentage of pollution capture, for the aforementioned years, as a proportion of actual air pollution levels. A trend of the percentage of pollution capture was then calculated and the estimated percentages of pollution capture were used to obtain values of pollution capture for the missing years.

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.

Monetary valuation: avoided damage to human welfare from illness

Damage costs per unit exposure were then applied to the benefitting population at the local authority level for a range of avoided health outcomes:

- respiratory hospital admissions
- cardiovascular hospital admissions
- loss of life years (long-term exposure effects from PM2.5 and nitrogen dioxide (NO_2))
- deaths (short-term exposure effects from ozone (O_3))

The value of impacts is adjusted according to the degree of health impacts from different pollutants. For example, the life years lost are valued at different levels in line with existing Defra models. This values a life year lost at £35,000 (2012 price), but this figure is adjusted based on the degree of life years lost for deaths from different pollutants.

Some years generated negative values for the economic value of NO_2 removal. In cases where a net disservice is presented the economic value is adjusted to zero.

9.3 Recreation

Method: Travel expenditures

Confidence: Low - Medium

Quantitative assessment: number of visits and time spent in habitat, taken from survey data

Monetary valuation: travel expenditures method, using expenditure on things such as fuel, transport costs and parking fees

The recreation estimates are adapted from the ‘simple travel cost’ method developed by (Ricardo-AEA 2016). This method was originally created for use on the Monitor of Engagement with the Natural Environment (MENE) survey which covers recreational visits by respondents in England.

The method looks at the expenditure incurred to travel to the natural environment and expenditure incurred during the visit. This expenditure method considers the market goods consumed as part of making the recreational visit (that is, fuel, public transport costs, admission charges and parking fees). This expenditure is currently assumed as a proxy for a marginal price for accessing the site. We therefore refer to this method as **‘Travel Expenditures’** to avoid confusion with ‘Travel Cost’ Methods, which is often used to refer to specific forms of recreation demand modelling.

The 2014 Wales Outdoor Recreation Survey (WORS) was the primary data source for ERAMMP Report-24, however, for ERAMMP Report-28A it is likely that the National Survey for Wales (NSW) will be the primary data source. Included in the survey are questions related to the most recent visit to the natural environment within the last 4 weeks; the distance travelled to the visit, costs associated with the visit and the habitats visited are asked. The visits numbers are taken directly from the habitats that each respondent reported. The visit weighting is split equally across all habitats reported by each participant.

For ERAMMP Report-24, the time spent in the habitat is calculated by taking the total time (including travel time) which is asked in the survey and subtracting an estimated travel time. Travel time is calculated using the reported distance travelled to get to the visit which is multiplied by the average speed relating to the form of transport used, taken from the Ricardo report. However, for ERAMMP Report-28A, the NSW question around time only considers time spent at the habitat, not including travel time, and so no further calculations need to be done.

The travel expenditures method used on the WORS data forms a monetary estimate for the amounts that are spent visiting the natural environment. This is done by adding the reported costs on admissions, car parking and bus/train/ferry fares; for participants who travelled by car, motorcycle or taxi the cost was calculated and added (because reported fuel costs from the survey data were deemed to be unreliable for the purposes of this estimation). The fuel costs for these vehicles is estimated using the mileage multiplied by a cost per mile value, taken from the Ricardo report. The expected values of recreational expenditures over time are adjusted in line with ONS population projections.

9.4 Agricultural biomass

Method: Resource rent

Confidence: low to medium (physical – medium; monetary - low)

Quantitative assessment: volume of agricultural biomass produced in Wales

Agricultural biomass relates to the value of crops, fodder and grazed biomass provided to support agricultural production in Wales. Physical production on wheat, barley, oats and potatoes estimates are published by Welsh Government.

Monetary valuation: residual value resource rent

For the valuation of agricultural biomass a “residual value” resource rent approach is used. This is based upon data for the Standard Industrial Classification (SIC) subdivision class: Crop and animal production, hunting and related service activities (SIC 01). Source-level apportioning of ONS UK supply and use tables and UK capital stocks is used. The factor used for apportioning gross operating surplus and taxes less subsidies from the UK supply and use tables is the proportional relationship between Wales and UK aggregate agriculture accounts gross output. To apportion net capital stocks and consumption of fixed capital from the UK capital stocks the factor used is the proportional relationship between Wales and UK aggregate agriculture accounts consumption of fixed capital.

The separation of the services provided by the farmland ecosystem from other economic inputs to agricultural production is challenging because of the degree to which the activity of farming manages and interacts with those services, for example, through sowing, irrigation, fertiliser spreading and livestock management. With very intensive arable farming, natural inputs may be limited to the provision of a medium for growing, with nutrients, light and water provided by the farmer, whilst intensive livestock farming may even take place entirely indoors. At the other extreme, livestock may be allowed to roam freely over semi-natural grassland with very limited human intervention.

An alternative approach which is being trialled involves applying land rental values to the total areas being farmed. The benefit of this simple approach is that it values the land itself – its soil and access to water or pollinators and its wider context; rather than the technology or economic decisions made by the farmer. Rental value however may be influenced by other economic factors such as the use of land as a store of value or farm incentive payments. Rental values are also relatively slow to change given long term contracts and may not be sufficiently sensitive to environmentally driven productivity changes.

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.

9.5 Water abstraction

Method: Resource rent

Confidence: Low

Quantitative assessment: total water abstraction in million cubic metres

Monetary valuation: residual value resource rent

Monetary estimates are based on the “residual value” resource rent approach calculated for the SIC subdivision class: Water collection, treatment and supply (SIC 36). In estimating the resource rent for the Welsh water abstraction provisioning service apportioning of ONS UK supply and use tables and UK capital stocks is used. The factor used for apportioning all components of the resource rent, using the “residual value” approach, is the proportional relationship between Wales and UK annual business survey local unit total turnover at basic prices.

The definition of SIC 36 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.

Future work is required to better value the range of services relating to water provided by the natural environment. The residual value method has in our experience to date generated a relatively high resource rent for public water supply which could be considered inconsistent with the concept of a price regulator and normal returns. In future, water may be traded between water companies although the prices charged may depend more upon covering the overheads of delivery than on the value of the resource in situ. It is also possible that abstraction licence charges may provide an estimate of the amount of resource rent captured by the Government. This requires further research.

9.6 Freshwater fish

Valuation method: Resource rent.

Confidence: Low

Quantitative assessment: freshwater fish capture estimates

Monetary valuation: residual value resource rent

Monetary estimates are based on the “residual value” resource rent approach calculated for the SIC subdivision class: freshwater fishing (SIC 03.12). This industry class includes: fishing on a commercial basis in inland waters, taking of freshwater crustaceans and molluscs, taking of freshwater aquatic animals, and gathering of freshwater materials.

In estimating the resource rent for the Welsh freshwater fish capture provisioning service apportioning of ONS UK supply and use tables and UK capital stocks is used. The factor used for apportioning all components of the resource rent is the proportional annual relationship between Wales and UK annual business survey local unit total turnover at basic prices for the Fishing and Aquaculture industry (SIC 03) multiplied by the proportional annual relationship between UK Fishing and Aquaculture (SIC 03) and UK freshwater fishing (SIC 03.12) annual business survey reporting unit (RU) total turnover at basic prices.

9.7 Timber

Method: Market price

Confidence: High

Quantitative assessment: timber production calculated by the physical amount of timber removed in million cubic metres

Monetary valuation: stumpage price

The method used to value the provisioning services related to timber supply requires two inputs: the stumpage price[21] and the physical amount of timber removed. Annual flow values are then generated by multiplying the two factors together.

Removals estimates are taken from Forestry Commission Timber Statistics and converted from green tonnes to metres cubed (m^3) overbark standing, using a conversion factor of 1.222 for softwood and 1.111 for hardwood.

9.8 ERAMMP Report-28A: Renewable energy

Report-28A covers the carbon sequestration, air pollutant removal and recreation services as per the methods described above. In addition it will cover the value of renewable energy from wind power.

Method: Resource Rent

Confidence: High

Quantitative assessment: electricity generated

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[21] The stumpage price is the price paid per standing tree, including the bark, for the right to harvest timber from a given land area.

Monetary valuation: residual value resource rent

Energy generated by renewable sources is published by BEIS in the Digest of UK Energy Statistics. Total renewable generation and bioenergy generation presented exclude generation from co-firing with fossil fuels.

Monetary estimates are based on the “residual value” resource rent approach calculated from the SIC Group 35.1: Electric power generation, transmission and distribution. 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.

10 Annex D: Valuation Methods[22]

This annex provides more detail of the valuation methods outlined in Section 3.1 and other methods that could potentially be applied to value ecosystem goods and services to inform policy decisions, such as in ERAMMP. There are many different approaches, applicable in different circumstances. All methods for ecosystem services valuation have advantages and disadvantages, with different levels of time and resource costs, data requirements, accuracy, acceptability to stakeholders, and applicability to specific contexts.

Table 10-1: Summary of valuation methods

Valuation method	Value captured	Points to note	Ecosystem services	Value type
Market based approaches: based on market prices and other data				
Market prices	Direct use values	Adjust for costs, subsidies, taxes	Provisioning services, provided these are marketed.	Exchange value
Market proxies	Direct use values	Adjust for costs, subsidies, taxes	Where service is not marketed, market value can sometimes be a proxy.	Exchange value
Resource rent	Use values	Depends on market context	Exploitation of natural resources	Exchange value
Production functions	Use values	Data hungry	For example, nursery habitat for fisheries is often valued via a production function	Choice of exchange value or welfare value
Cost of illness	Varies depending on how health impact valued	Production function linking change to health impact	Any ecosystem change that impacts on human health or mortality	Choice of exchange value or welfare value
Avoided costs	Use values		For example, estimate of avoided damage and/or avoided flood defence costs due to natural flood defence	Choice of exchange value or welfare value
Replacement costs	Cost not value	Presumes replacement would be appropriate	For example, the cost of recreating coastal wetlands to compensate for losses	Exchange value

[22] This section draws from Tinch et al. (2019)

Valuation method	Value captured	Points to note	Ecosystem services	Value type
Revealed preference methods: based on actual behaviour in surrogate markets				
Hedonic property pricing	Use values associated with home location	Depends on awareness of impacts	Views, amenities, peace and quiet, general environmental quality.	Welfare value
Recreation demand modelling	Use values for recreation	Based on visits to a site or choice among sites	Recreation and ecosystem services that contribute to it.	Welfare value
Stated preference methods: based on behaviour in hypothetical markets				
Contingent valuation	All use and non-use	Based on pricing single option	All services. The only methods able to estimate non-use values. Often used for biodiversity, cultural and heritage values.	Welfare value
Choice modelling	All use and non-use	Based on choice from options		

Exchange values are generally drawn directly from observations of market prices and quantities, though in some cases imputed values are used in order to estimate what the market price would be if a market existed. These are needed in some specific cases where markets do not exist, either because of social conventions regarding how services are provided (in the UK, most health and education is free at the point of supply) or because the 'transaction' is internal to an organisation ('fixed capital consumption', more commonly termed 'depreciation'). In other cases, this could be done but is not, in order to avoid swamping the national accounts with information (services produced and consumed by households: housework, gardening, childcare, cooking…) though these are services that are increasingly traded (cleaners, childcarers) and thereby brought inside the accounts – giving the appearance of GDP growth for no increase in actual output.

Natural capital accounting seeks to bring environmental services inside the accounting boundary and uses estimates of the exchange values of ecosystem services to do this. Some ecosystem services lead to marketed goods – for example food, timber, and water – but the exchange value of these goods captures more than the ecosystem service. The issue here is the need to separate out the contribution of the ecosystem service from the other inputs – manufactured capital, human labour, energy - used in producing the marketed service. The **Resource Rent** is often used in accounting to achieve this, applying a residual value method to individual natural resources. The exchange value of an ecosystem service is calculated by taking the gross value of the final products and then deducting the cost of all other inputs (labour, produced capital and intermediate inputs). The residual can be considered the value of the ecosystem service (UN Statistic Division, in prep).

Technical guidance on SEEA Experimental Ecosystems Accounting (p.107) acknowledges that the use of the method may result in very small, or even in some cases negative, resource rents. This in turn is often a reflection of market failures. Obst, Hein and Edens (2016) 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. Furthermore, 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.

One alternative approach is to estimate "simulated exchange values". Welfare based approaches value not what people actually pay, but the maximum they would pay if they had to. The simulated exchange value is different: it seeks to estimate the price individuals would pay if providers of public goods could charge for them – a price depending on the interaction between the quantity available, the benefits to buyers and the costs to sellers. These simulated exchange values have been proposed for use in environmental and ecosystem accounting, because they are compatible with the exchange value framework. However, estimates of simulated exchange values are not available for the public goods considered within ERAMMP.

For appraisal/welfare purposes, valuation methods break down in to market-based, revealed preference and stated preference techniques.

Market-based techniques use evidence from markets in which environmental goods and services are traded, markets in which they enter into the production functions for traded goods and services, or markets for substitutes or alternative resources.

- **Market prices** can be used for traded goods, for example food. However prices are not values:
    - it is necessary to correct for 'distortions' such as subsidies or taxes;
    - prices do not reveal the 'consumer surplus', the profit or value to the consumer over and above the price paid;
    - prices include the resource cost (for example the cost of farm machinery, fuel and labour) that do not form part of value (this is often dealt with by reporting 'value added', i.e. price net of costs);
    - prices arise in markets by the interaction of demand and supply, and an environmental change that alters this balance – for example, changing supply – will usually cause price to change;
    - a full analysis using markets therefore requires estimation of a demand curve and a supply curve, explaining how values and costs change with quantity;
    - in many cases, it may also be necessary to assess whether or not the exploitation of a resource is sustainable (and if not, there is an additional 'resource cost' associated with reducing natural capital stocks).

  At the margin, the welfare and exchange values are the same (equal to price) unless there is market failure. Where there is no market, or where the market exists but is imperfect, we may need to estimate values compatible with either the appraisal/welfare framework or the national accounting/exchange framework. For marginal changes, the calculation is straightforward in the exchange value framework (total revenue is price times quantity) while in the welfare value framework the estimation of total values requires more complicated analysis.

- **Market proxies** can be used for some goods, where there is no direct market but there is a market in a closely related good. Similar caveats apply as for 'market prices' above.

- Production functions use statistical analysis to determine how changes in some ecosystem function affect production of another good or service which is a traded resource, or can be valued using another technique. The primary difficulty in this method is the availability of scientific knowledge and/or data, necessary to allow estimation of the production function.
- Cost of illness methods are a particular class of production function where environmental services are linked to health measures, as part of estimating the health damage of pollution, or the health benefits of a clean environment. To give a monetary value, the health impacts need to be valued using additional methods such as costs of treatment avoided, and/or estimates of willingness to pay to avoid illness.
- Avoided cost methods value a service through the reduction in costs that would have been incurred in the absence of those services.
- Replacement cost methods estimate a value based on the cost to replace an ecosystem function or service. Can be applied to entire ecosystems (for example, the cost of providing new habitat to compensate for habitat losses) or more often to replacing specific ecological functions with human-engineered alternatives (cost of alternatives).

Where market values cannot be used or adjusted, there are two main approaches to valuation: revealed preference and stated preference.

Revealed preference methods analyse relationships between demand for some market goods and preferences for related non-market goods/services. These methods only work if changes in provision of the non-market good have an observable impact on the demand for a market good. Examples include:

- Where non-market good or service is an attribute (or characteristics) of a market good or service. These are property and labour markets. Hedonic property pricing method estimates the premium people are willing to pay for higher levels of environmental goods (like nice view, peace & quiet, good air quality) or to avoid lower levels (e.g. living near a landfill). Hedonic wage method estimates the wage premium workers are willing to accept to compensate for increases in occupational risk;
- Where non-market good or service is a complement to a market good or service (or vice versa). The key example is recreation, via recreation demand modelling methods which use data on what people spend in the travel market and the value of their time (exchange values) to estimate the welfare benefits of recreation; and
- Where spending in markets compensate for losses in ecosystem goods and services (averting behaviour). Examples include spending on water filters to compensate for poor quality water; or double glazing to reduce noise.

Averting behaviour approaches involve estimating household ‘production functions’ that allow calculation of values for risks and disamenities via the expenditures households incur to avoid them – for example to avoid exposure to pollution or risks associated with groundwater contamination. Problems include for example joint impacts (e.g. double glazing will impact both noise and thermal comfort), ‘lumpiness’ in investments and transactions costs and imperfect information about risks, effectiveness of measures, and the endogeneity of risk perceptions.

Hedonic pricing has a similar theoretical background. Common applications seek to value environmental quality aspects of housing via statistical analysis of property markets. Sale/rental values of properties are modelled as a function of property ‘attributes’ including environmental quality (such as noise nuisance, air pollution, or proximity to desirable/undesirable features, such as an urban green space or landfill sites). The method only accounts for use values associated with occupation of the property and does not cover values to non-residents. The method assumes markets are perfectly functioning, though people may have poor knowledge regarding both the levels and the impacts of some attributes (e.g. air pollution), and housing markets generally have high transactions costs (taxes and moving costs) and may therefore respond slowly to changed conditions. Hedonic wage methods use a similar approach to value risks to health/life, via the wage premium for dangerous jobs.

Recreation demand models use costs incurred travelling to and at a site, including the cost of time, as a proxy for the price of recreation. This is combined with information about visit rates to derive an estimate of the value of recreation at the site. The main methodological concerns include the valuation of travel time, the analysis of multi-site and multi-purpose trips, and accounting for substitute sites and activities. Early applications focused on single sites, but modern methods use Random Utility models focusing on individuals' choices from a set of alternative sites, modelled as a function of site characteristics and individual factors including income and costs of travel. The basic principles, and the clear distinction from simple calculation of travel expenditures, are explained through a worked example in Annex E.

Stated preference methods are based on surveys which create hypothetical markets for respondents to express their preferences:

Contingent valuation (CV) asks directly how much respondents are willing to pay to secure the change presented, or willing to accept compensation to avoid it, via open-ended questions or different forms of bidding formats.

Discrete choice experiments (DCE) are based on respondents' choices for their preferred scenario among alternatives. Scenarios are described by different combinations of the goods and services in terms of their environmental as well as cost attributes, each taking different levels in each scenario. Information on the values that people assign to improvements in the different goods and services are indirectly inferred from the trade-offs that people are willing to make when choosing their preferred alternatives.

Both CV and DCE formats enable estimation of welfare values for the good or service as a whole; DCE also allows for the calculation of implicit prices of specific attributes. One advantage of stated preference (over revealed preference) methods is that they can elicit preferences for scenarios that are yet to occur, therefore providing ex-ante information on expected WTP to inform the design of future policies. Another is the ability to capture non-use values as well as use values. Responses in stated preference surveys may show high sensitivity to factors that should not matter (according to economic theory) and/or insensitivity to factors that should.   Critics argue that hypothetical questions generate hypothetical, invalid responses. However, many decades of research have led to strategies to limit these potential biases through careful study design and testing.

These are the main types of valuation method available. The choice of economic valuation method, and in particular whether to use exchange or welfare values, depend on context-specific factors. The main issue is the context of the analysis, as explained above: exchange values are appropriate for national accounting and financial appraisals, welfare values are appropriate for social cost benefit analysis and wealth accounting.

Data, time and budget considerations are also important. The expense and effort of valuation needs to be commensurate with the level of confidence and accuracy required for the context. This in turn will depend on how the value evidence will be used. There are many applications for valuation evidence that may call for different methods, coverage, accuracy and research expenditure. Applications range from demonstrating the existence of values, to methods of using values to support decision making, to direct uses of values for setting prices, taxes, or compensation payments.

Primary valuation studies are expensive and time-consuming, so in the vast majority of applications, they are not used directly - the exception being market prices, where they are available. In the other cases, the expense, time and expertise needed for primary studies mean that almost always **value transfer methods** are used.to draw values from existing studies to use as proxies in analysis. Value transfer is the process of reviewing available evidence, selecting the most suitable estimates, and adjusting them for differences between the original studies and the context in which they are to be applied – for example adjusting for population sizes, wealth, and differences in ecosystems.

The simplest type, unit transfer, directly applies an estimate of value made for one site or location to another. A more sophisticated approach uses a value function describing the relationship between value and key environmental and population factors influencing it. Meta-analysis can be used to estimate a composite value function based on several studies. Value estimates based on careful meta-analysis of several good-quality studies may produce narrower confidence intervals than a single study, provided the meta-analysis take sufficient account of variability in socioeconomic and biophysical factors (Schmidt, Manceur & Seppelt 2016). Guidance for value transfer is available (e.g. eftec 2010 as formal guidance from UK Defra).

11 Annex E: Example comparing recreation demand modelling and travel expenditures

To illustrate the differences between these approaches, it may be useful to consider a highly simplified example of a zonal recreation demand model. It interprets data on visit numbers and the costs of travel as reflecting the total welfare (utility) that people get from visiting the site. Part of this is offset by the costs people face to get there – measured as travel expenditures. The remainder is surplus, measured as the net welfare.

Example 1

Firstly, imagine a major recreation site that is visited by people from across a wide catchment area. For both recreation demand modelling and travel expenditures, we can start by dividing the catchment into zones according to the cost of travel from that zone to the site. This is the basis of the simplest form of recreation demand model – more modern approaches use individual costs of travel or random utility models, but for the purposes of explaining the difference between recreation demand modelling and travel expenditures, the zonal model is easiest to understand.

The analysis then uses survey evidence, either from on-site surveying asking visitors where they travelled from, or through surveys of the populations in the outset zones asking if and how often they visit the site, to estimate the visit rate from each zone. The zones are defined around the site in terms of gradually increasing cost of travel, as an ‘average’ cost for travel from each zone. Calculating the travel expenditures for the site is then straightforward: multiply trip rate by population by cost. For example, we might have seven zones and data as follows:

Table 2: Example of zonal travel data for a recreation demand model.

Zone	Cost	Trips/100	Population	Trips	Expenditure
Zone 1	£0	57	10000	5700	£0
Zone 2	£10	43	10000	4300	£43,000
Zone 3	£20	34	10000	3400	£68,000
Zone 4	£30	27	10000	2700	£81,000
Zone 5	£40	16	10000	1600	£64,000
Zone 6	£50	5	10000	500	£25,000
Zone 7	£60	2	10000	200	£12,000
				18400	**£293,000**

In practice it would be very unusual to have such an even spread of population, given that people tend to live in urban concentrations and the concentric zones increase in area the further you go from the site. We’ll return to the importance of this shortly.

The recreation demand model method is rather more complex. The next step is to use regression analysis to estimate the relationship between the cost of travel and the trip rate. The (made up) data here show a highly linear relationship with cost, so we can use linear regression to estimate the relationship

Trips/100 = 54.04 – 0.925*cost

This can then be used to estimate the demand curve for the site – i.e. what people are willing to pay for it. The basic approach is to imagine an entry fee, and to assume that people would react to such a fee in the same way as they react to the cost of travel. So, for example, a £10 fee would make people in zone 1 behave like those in zone 2 did before the fee. A £30 fee would make them behave like those in zone 4 did. And so on. For price 0, we use the observed data, for other prices, we use the estimated regression to predict the demand.

Table 3: Calculating the number of trips for different hypothetical entry prices

Price	**£0**	**£5**	**£10**	**£15**	**£20**	**£25**	**£30**	**£35**	**£40**	**£45**	**£50**	**£55**	**£60**
Trips zone 1	5700	4941	4479	4016	3554	3091	2629	2166	1704	1241	779	316	0
Trips zone 2	4300	4016	3554	3091	2629	2166	1704	1241	779	316	0	0	0
Trips zone 3	3400	3091	2629	2166	1704	1241	779	316	0	0	0	0	0
Trips zone 4	2700	2166	1704	1241	779	316	0	0	0	0	0	0	0
Trips zone 5	1600	1241	779	316	0	0	0	0	0	0	0	0	0
Trips zone 6	500	316	0	0	0	0	0	0	0	0	0	0	0
Trips zone 7	200	0	0	0	0	0	0	0	0	0	0	0	0
Total trips	**18400**	**15771**	**13143**	**10830**	**8664**	**6814**	**5111**	**3723**	**2482**	**1557**	**779**	**316**	**0**

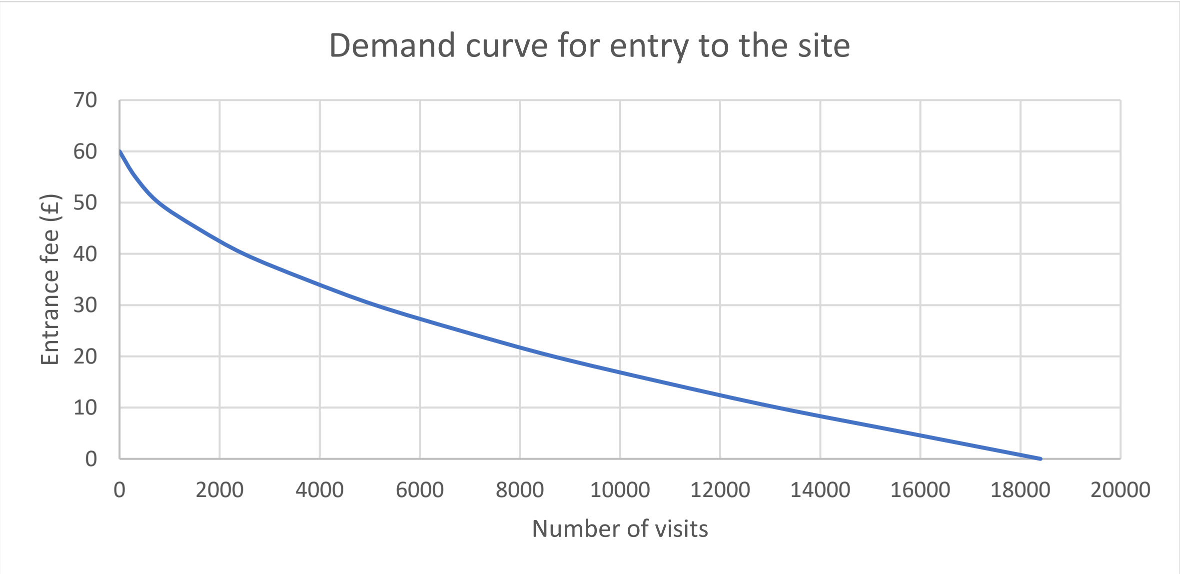

Figure 2: Recreation site demand curve estimated from the zonal demand model

The welfare value or surplus arising from the site can then be calculated as the area under the demand curve. In this case, that is £392,000, quite a bit higher than the expenditures of £293,000.

Example 2

Recall that we have assumed equal population size for each zone, which is very unlikely. Instead, let's assume rather few people live very close to the site, but there is a large town in zone 4, and distribute the same 70000 people in the catchment as follows:

Table 4: Example of zonal travel data with more realistic population distribution

	Cost	Trips/100	Population	Trips	Expenditure
Zone 1	£0	57	1000	570	£0
Zone 2	£10	43	2000	860	£8,600
Zone 3	£20	34	4000	1360	£27,200
Zone 4	£30	27	45000	12150	£364,500
Zone 5	£40	16	5000	800	£32,000
Zone 6	£50	5	6000	300	£15,000
Zone 7	£60	2	7000	140	£8,400
				16180	**£455,700**

We see immediately that the expenditure estimate goes up substantially, even though there are fewer trips overall; this is simply because most of the trips are now coming from the heavily populated zone 4 and costing £30/trip, with many fewer of the cheaper trips from the less populated areas near the site.

The welfare calculation also changes. There is very little demand at prices above £30, because people from zone 4 would stop visiting. The area under the demand curve, the welfare value or surplus associated with the site, is substantially smaller than before: £245,000. So with this population distribution, the welfare value is substantially less than the expenditures. People (on average) have to pay more to travel to the site, and therefore derive less surplus from it.

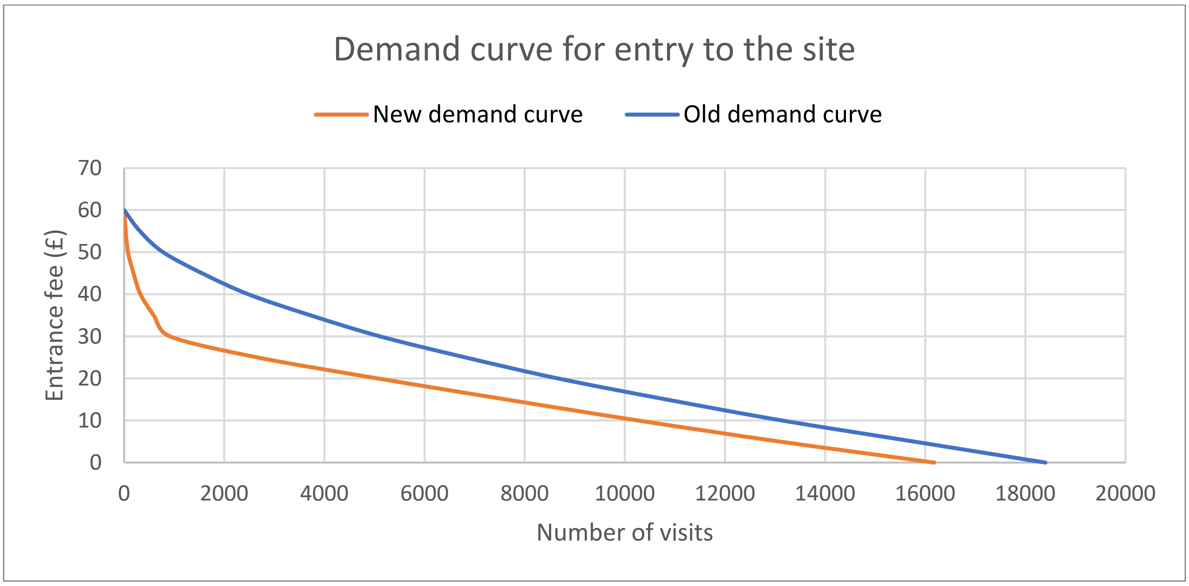

Figure 3: Comparison of demand curves for the different hypothetical population distributions

Interpretation

This simple example illustrates that there is no clear relationship between the travel expenditures and the welfare values estimated in the recreation demand model. This holds a fortiori for changes in provision (quality, quantity) of recreation sites, or for changes in the cost of travel, when the two methods can give not only different measurements but different signs:

- Example 1: fuel prices fall. People can travel more cheaply to the site, and so get more surplus from it. Also, more people will visit – those for whom it was previously just too expensive. For both reasons, surplus increases. However, total expenditures will probably fall.
- Example 2: imagine a new equivalent site located near the big town in zone 4. People there will now switch to that site – it's much cheaper to get there. And more of them will visit. People in other zones may also change behaviour. Again, total expenditures will fall, while total surplus will rise (though we have ignored any cost of providing the new site).

Note that there is a further complication, in that usually, a recreation demand model uses a more inclusive estimate of the costs of travel that include the value of time spent travelling, and in some cases on-site time, as well as the financial cost. These time costs can also be included in expenditure methods, however that is less common. If that is not done, it is another source of difference between the approaches. We note also that the value of time assumed can have an important impact on the welfare values estimated.

Discussion

The examples here should be sufficient to demonstrate that the travel expenditures and the recreation demand model are very different: they measure different things and there is no particular reason to suppose any particular relationship between the figures in general, and especially not for analysing the consequences of changes in provision/quality of sites, population characteristics or costs of travel. While the travel expenditures may be relatively straightforward to measure, they relate to spending already measured in the SNA. They tell us what part of existing spending is motivated by demand for recreation visits.

Travel expenditures have essentially no relationship with the welfare value of sites, and very little relationship with the theoretical exchange value in the sense of what people would pay if there were a market. One reason for this is the number of visits that involve no direct expenditures (i.e. are undertaken for free). The travel expenditures analysis could be expanded to include the costs of travel time (something the Ricardo-AEA (2016) study considered but rejected, noting the substantial increase in values this would cause). This would capture a greater proportion of the total utility of the recreation visits. As well as travel time, time spent at the site could also be valued, and this would capture an even greater (and probably significantly greater) proportion of the total utility of the recreation visits. However, these approaches would no longer produce an observed exchange-value (although with various assumptions, such as linking the value of time to wage rates, could estimate one).

The reason for developing the travel-cost method was because exchange values measure the welfare from outdoor recreation, particularly informal recreation in the natural environment, so poorly. Relying on travel expenditures will result in decision-makers being given data that represents an unknown (but potentially small) fraction of the value that recreation provides. This creates a risk of policy failure, as with incomplete information, decision-makers may not allocate adequate priority to spending or other measures that support outdoor recreation (e.g. maintaining public parks or rights of way).

12 ANNEX F: DISCOUNTING

Discounting can be justified through social time-preference (people value benefits now more than benefits later) and/or returns to investment (projects should bring greater social return than alternative uses for funds) (see HMT 2018).

Standard economic methods define the discount rate as a function of pure time preference and consumption growth, via the Ramsey formula, $\rho_t = \delta + \eta \cdot g_t$. This defines the discount rate at time t (ρ_t) as the sum of the utility rate of discount (δ) and the rate of growth in consumption between the present and t (g_t), weighted by the elasticity of marginal utility of consumption (η).

The choice of discount rate has great influence over results (Weitzman 2007) but is hard to justify objectively (Arrow et al. 2013) A recent USEPA expert panel of 12 economists (Arrow et al. 2012) unanimously agreed that "the Ramsey formula provides a useful framework for thinking about intergenerational discounting." However, they did not reach agreement on "how the parameters of the Ramsey formula might be determined empirically", let alone on actual values. They explain this with reference to a long-running debate between a "descriptive" approach (based on behaviour observed in markets) and a "prescriptive" approach (focusing on ethical considerations to set parameters).

So despite its importance, there is no universally accepted way of calculating a discount rate, resulting in a multiplicity of estimates. Discount rates of a few percent, standard for short-term policy appraisal, result in huge discounting of long-term impacts – applying these rates for climate policy would justify a "wait and see" approach, leading some to argue that discounting is inappropriate for long-term, significant environmental changes (Stern et al. 2006; Saez & Requena 2007; Stern & Taylor 2007; Faccioli et al. 2016). Some authors advocate instead declining or hyperbolic discount rates (Kirby 1997) to combat this problem. Others use a low constant rate - the Stern Report, for instance, has been criticized (Nordhaus 2007) for using a very low discount rate (0.1%), a factor of ten or more less than conventional studies (e.g. 4% average in DICE model, Nordhaus 2008). Heal and Millner (2014) argue that there are no objectively correct discount rates, just different ethical positions that need to be weighted: analysing policy for the future 'becomes an exercise in social choice' that requires aggregating 'the diverse preferences of individuals into a representative discount rate'.

These debates notwithstanding, most national governments and international institutions have a standard rate to ensure consistent discounting across all public sector appraisals (European Commission 2015; HMT 2018). The UK uses a semi-hyperbolic approach, with a rate of 3.5% for the first 30 years then declining stepwise beyond that, and any UK public sector analysis should stick to that guidance. Beyond that, CBA should consider the impact of the discount rate on the analysis, applying sensitivity analysis using different discount rates, and explicitly discussing impacts in different time periods (HMT 2018).

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