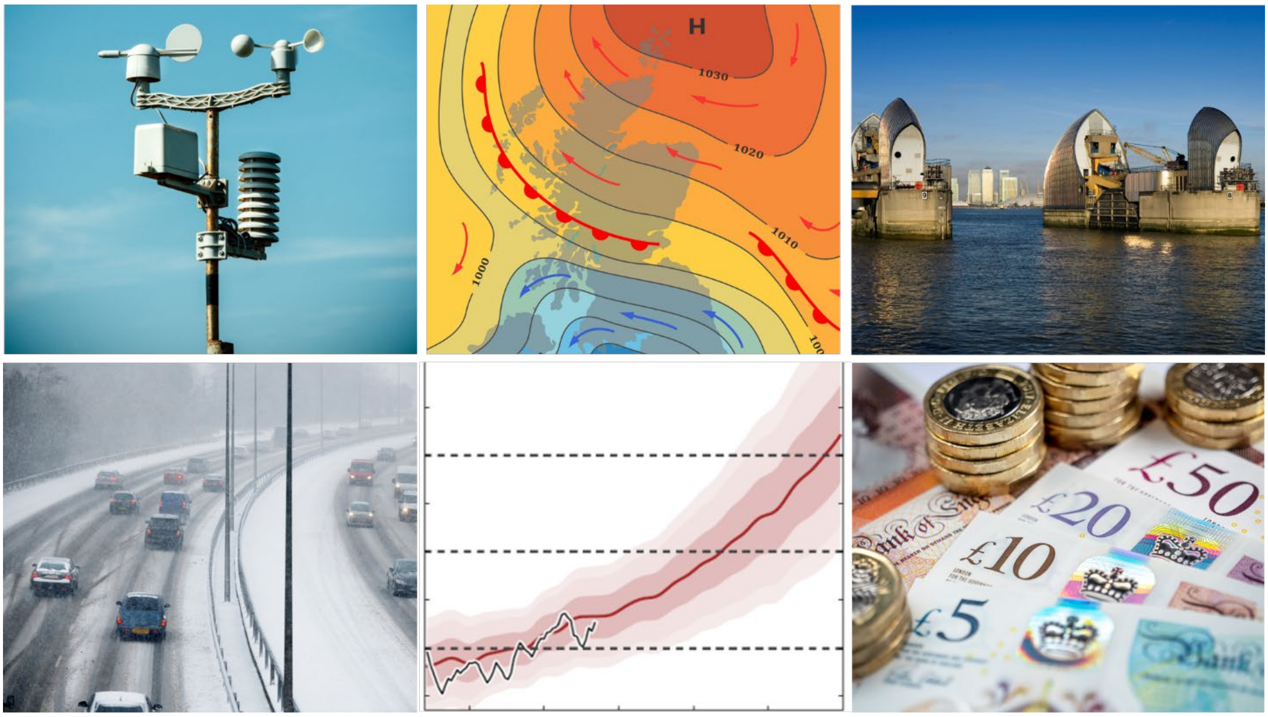
Guidance on Valuing and Monitoring the Economic Benefits of Climate Services



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Output from the project

'Climate Resilience – CR20-2 Standards for climate services and monitoring and valuing climate services'

Introduction

This report presents summary guidance for valuing and monitoring climate services, as part of the wider project *Climate Resilience – CR20-2 Standards for climate services and monitoring and valuing climate services*[1]. The aim of this valuation work (deliverables 2 and 4) was to:

- Propose a methodology and set of guidance for valuing climate services, as well as a suggested method and guidance for analysing value for money (as part of monitoring).
- Apply the methods and guidance in a set of case studies and provide lessons from testing the methodology.

This document provides a summary of the methodology for valuing and monitoring climate services, with examples on the application of these methods taken from the study case studies. A longer project report, and four case study applications, are included in the full report.

Defining climate services

There are numerous definitions of climate services, and these include different temporal periods and a varied range of information types[2]. For this report, we focus on climate services that support end-users with decisions, as these applications can potentially generate economic or social value. This is a narrower definition of climate services than the overall CR20-2 study, which is considering standards.

We also define climate services in terms of the information timescale they focus on. The climate services literature, and the overall CR20-2 study, generally consider climate services that address climate variability and climate change together. Such definitions exclude weather information (short-term, hourly, daily, or weekly forecasts).

For this valuation guidance, however, we separate climate services into two distinct periods and associated decision types.

- Information and services for months to years ahead (seasonal forecasting, inter-annual variability). These are associated primarily with services that address climate variability.
- Information including climate projections for future decades or centuries ahead. These are associated with climate change decisions (and sometimes called adaptation services).

This separation is important because the two time periods involve different methodological issues for quantification and valuation. Indeed, a key focus of this work, and the guidance here, is to examine whether traditional methods for valuing weather and climate information services (e.g., for weather forecasts, seasonal forecasts and early warning, see WMO, 2015) can be transferred to the climate change and adaptation context.

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[1] This work is being undertaken by a consortium of JBA Consulting (lead), in association with ClimateSense, Paul Watkiss Associates (PWA), Professor Rob Wilby, and Becky Venton, on behalf of the Met Office.

[2] The definition used by the Global Framework for Climate Services is that these 'provide climate information to help individuals and organizations make climate smart decisions'…with 'customized products such as projections, trends, economic analysis and services for different user communities', with the aim that 'climate services equip decision makers in climate-sensitive sectors with better information to help society adapt to climate variability and change'. https://gfcs.wmo.int/what-are-climate-services

The study has also considered the economic benefits of improved observations and historic information, in their role in improving climate services. The overall focus of this guidance, in terms of the different timescales of information and decisions of relevance from weather and climate services, is shown in the figure below.

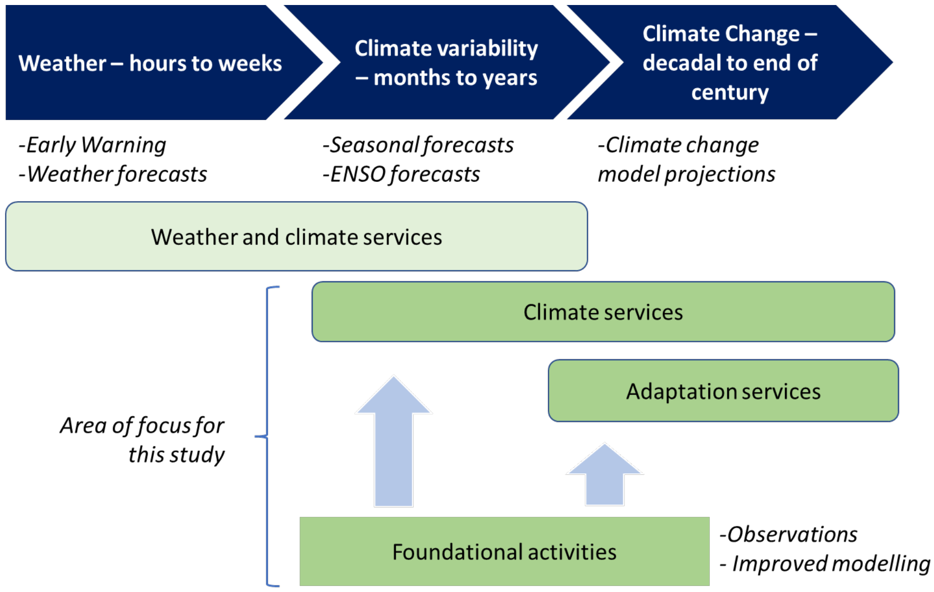

Figure 1. Time scales of information and decisions, including the study focus areas.

What are the economic benefits of climate services

Investing in climate services leads to better information, such as new or improved seasonal forecasts. In turn, this information provides economic benefits to users, as it can lead to positive outcomes from the actions and decisions that users subsequently take. This is known as the value of information.

For example, seasonal forecasts provide information that allows farmers to prepare for weather trends over the coming months, i.e., for above or below rainfall. This can then provide information to address these projected changes, such as planting early maturing varieties or increasing water storage. These actions are, in turn, likely to increase agricultural production from higher yields or reduce losses from extreme events, generating benefits for end-users.

These benefits include the financial or private returns from improved decisions, e.g., yield improvements and profitability for farmers. However, they also include societal or public benefits, such as reduced health risks or environmental benefits. Together these market and non-market effects provide the total economic benefits to society from climate services. In the meteorological literature, these are sometimes referred to as socio-economic benefits (SEB).

It is possible to quantify these economic benefits. To do this, an analysis can be made of the activities and outcomes that arise from the use of new or enhanced climate services, as compared to a baseline or counterfactual without the use of the information. The difference between the 'with service' and the baseline (without) represents the benefits that can be attributable to the climate service.

By using economic analysis, these benefits can be valued (monetised) and then compared to the costs of setting up and running the service, to look at the overall net benefits delivered.

There are a number of important benefits from undertaking these economic studies:

- Economic valuation studies provide a direct tangible estimate of the achievements of a climate service. They are extremely useful in quantifying and communicating the overall impact of activities, as well as justifying current and future investment.
- Economic studies can help to develop an improved understanding and better articulation of climate service efficiency and effectiveness and provide quantitative information to help demonstrate and report on Value for Money (VfM).
- The integration of economic thinking during the design of a climate service study can help to enhance benefits and maximise impact. Similarly, such studies can be used to improve existing services, helping to identify where and how to increase impact.

This document provides guidance on undertaking the economic analysis of climate services. It provides a summary of the steps needed to assess the monetary benefits of climate services and to undertake a cost-benefit analysis (CBA), using examples from the case studies undertaken in the study. The guidance also provides advice on how to use these economic results to provide information for assessing VfM.

The guidance builds on the existing methods in the literature on valuation of weather and climate information services (WMO, 2015[3]), and updates recent guidance for W&CI services from the WISER 2 project (WISER, 2021[4]), however, it also extends these studies by assessing the transferability and providing guidance and lessons on applying these methods to adaptation services.

Box 1. Key terms

Economic analysis. Economic analysis is carried out from the perspective of society and includes the economic valuation of non-market effects, such as environmental, cultural, social and health benefits. Sometimes these are called **Socio-Economic Benefits** in the meteorological literature.

Cost Benefit Analysis (CBA). CBA is an economic decision-support tool that measures all relevant costs and benefits to society of a project, programme or policy in monetary terms (including non-market effects such as environment or health). The results of a CBA are usually presented as a net present value (NPV) or benefit-to-cost ratio (BCR).

Benefit to Cost Ratio (BCR) . A metric used to express the results of a CBA, derived by estimating the total present value of benefits divided by total present value of costs.

Net Present Value (NPV). A term for the sum of a stream of future values that have been discounted to bring them to a present value.

Value for Money (VfM). An approach used by UK Government to assess the optimal use of government spending. VfM is estimated using three criteria: economy, efficiency, effectiveness, alongside a fourth component on equity.

[3] WMO (2015). Valuing Weather and Climate: Economic Assessment of Meteorological and Hydrological Services. World Meteorological Organization, Geneva.
[4] WISER. (2021). Socio-Economic Benefit Guidance for the WISER Programme. Published February, 2022.

The steps for economic analysis of climate services

This guidance sets out eight steps for valuing climate services.

1. **Identify the type of economic benefits**
2. **Develop a value chain**
3. **Review and decide on the methods**
4. **Develop a baseline for the current situation**
5. **Assess the change with the climate service in place**
6. **Assess the costs of the project**
7. **Compare costs to benefits (and undertake CBA)**
8. **Explore how benefits could be enhanced**

The steps for economic valuation of climate services. Updated from WISER, 2022.

These steps are described in the following sections, with examples from the case studies undertaken in the project.

Step 1: Identify potential economic benefits

The first task is to **list the possible benefits** of the new or enhanced climate service. This is linked to the outcomes that the service is trying to achieve, i.e., the result of the improved information from the service and its use in decisions.

For instance, this could be the benefits of improved seasonal forecasts in enhancing crop yields and incomes for farmers. Or it could be the reduction in damage to assets from improved climate projections and their use in climate risk assessment and project design. These benefits are also relevant for monitoring and evaluation (see later section).

A good place to start for this step is to list ll the possible end-users or beneficiaries from the service, and then list the benefits of the climate service to each of these groups. This should capture all benefits, including

- Market benefits, e.g., enhanced agricultural yields or avoided losses that might arise from seasonal forecasts, or reduced damage to infrastructure from improved climate projections and use in design.
- Non-market benefits, e.g., reduced loss of life from new early warning systems to tackle observed changes, or environmental benefits from improved use of resources (e.g., in water management).
- Indirect or spill-over benefits for other organisations or beneficiaries who might gain from the new or improved information, e.g., indirect benefits to the food industry from agricultural benefits, or reduced disruption to transport and supply chains from improved infrastructure design.

An example of a benefit list is presented below from the seasonal forecast case study. A list of beneficiaries is presented, and for each of these, the specific types of benefits are identified. It is stressed that the benefits are listed separately, even for the same users, because individual benefit streams may require a different analysis.

Table 1. Example of climate service benefits for transport for winter seasonal forecasts.

End-user	Expected benefits
Transport operators	
Heathrow airport and airlines	Reduced flight delays
	Better planning for de-icing operations
Train operators	Reduced service delays
	Reduced rail accidents and incidents
Highways agency and local authorities	Reduced accidents (costs of response)
	Better planning for use of salt
Passengers	Reduced travel time losses
	Reduction in risk of accidents, reduced damage
	Reduction in risk of accidents, avoided fatalities and injuries
Freight transport operators	Reduced disruption and travel time delays
Wider economy	
Upstream suppliers & other businesses	Local and other economic effects such as planning stock inventories

Once this list is completed, it is important to identify which benefits to focus on in your economic analysis. Depending on time, local context and resources available, the analysis may be very comprehensive, aiming to quantify many or even all the potential benefits. Or it may focus on one or two of the most important direct benefits only.

Step 2: Develop a value chain

The second step is to **develop a value chain** for the new or enhanced climate service. This is needed because the benefits of climate services are only generated if users make better decisions with the information they receive. This means that economic studies need to consider the steps from the generation of information, the communication and reach achieved, the uptake and use by end-users, and finally the benefit that this action achieves. These steps can be considered using a climate service value chain, shown below.

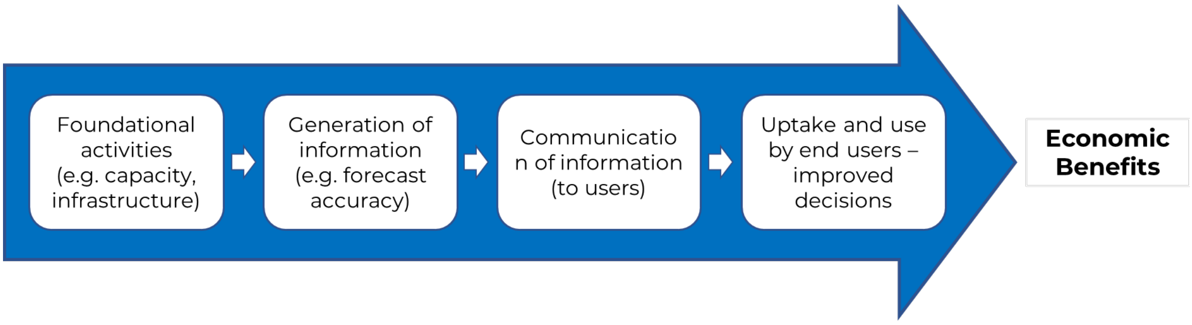

Figure 2. The value chain for climate services.

The chain starts with foundational activities that underpin the service, e.g., meteorological infrastructure and observations.

It includes the generation of information, e.g., the production of a seasonal forecast and its accuracy, the communication of this information to end-users and the number of end-users reached.

Finally, the value chain includes the understanding and use of the information and the effectiveness of the action undertaken by end-users in decisions.

Importantly, there is a drop off at each stage of the value chain. For example: forecasts will not be 100% accurate; only a proportion of relevant users will be reached; not all end-users will act on the information; and the final action may or may not reduce impacts. The value chain allows an analysis of these 'efficiency losses'.

A key part of an economic analysis is to map the climate service value chain. As well as helping in the estimation of benefits, such analysis can also be used during design to improve services, by highlighting all the steps needed.

The exact steps will vary with the type of climate service and on the planned activities. It can be useful to develop a decision tree to map the flow of information from generation through to end-use, to develop the value chain.

An example is shown right for the heat health alert case study. This identifies the cascade of steps from generation of information, reach achieved, level of use, and overall effectiveness. This information was compiled from survey data and from expert elicitation. This value chain was subsequently used to subsequently assess the efficiency losses at each step (see % values shown) and to quantify the benefits of the service, for subsequent valuation.

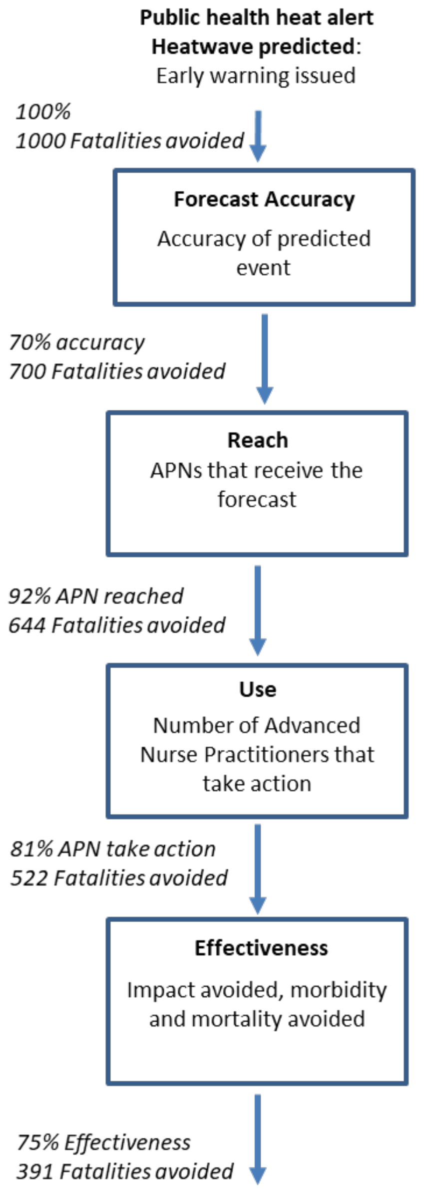

Figure 3. Value chain and efficiency drop off for public heat alerts.

The exact approach will depend on the type of climate service being considered. If the project improves an existing climate service, the focus should be on understanding and analysing the value chain of the current service, and the potential changes planned. If the project introduces a new climate service, then it is important to develop and map out all the steps in the new value chain. Understanding the value chain will help define the baseline (Step 4) and estimate the benefits of the project (Step 5) and has broad applicability irrespective of the method used.

These value chains are also useful for adaptation services. While they have not been used to date in the adaptation literature, they provide a useful addition, to help understand the steps in the use of climate information for adaptation decisions, and the efficiency losses in the pathway from information to decisions. This can include the consideration of how uncertainty might affect decisions.

Step 3: Review and decide on the methods

The next step is to **decide on the methods** for the economic analysis. A number of methods have been used for W&CI services, that are also applicable to climate services.

The choice of method depends on two issues:

- The type of climate service and the suitability of various methods to assess benefits.
- The capacity, level of expertise, and the time and resources available for the economic analysis.

Methods can broadly be distinguished into those that assess:

- The **potential** benefits of climate services, which typically use *ex ante* methods (before the service is introduced), and
- The **actual** benefits after implementation, which use *ex post* analysis (after the service is introduced).

A description of possible methods are included in the box. Current economic guidance is not prescriptive, and there is often not a 'best' or most applicable method. Nonetheless, certain types of service, and limits to resources, do lend themselves to particular approaches.

Box 2. Potential Methods for the Valuation of Climate Services

Ex ante models
Decision-theory based models that can be applied to estimate potential benefits, for example, using a crop model to assess the possible increases in yield from improved seasonal forecasts.

Integrated economic models
Models that can assess aggregate effects, including cross-economy linkages, or wider economic effects for example, input-output, trade, partial or computable general equilibrium models.

Cost-loss models
Models used to analyse extreme events and EWS. These include probability loss curves based on historical event information, and can be extended to look at non-monetary effects e.g. fatalities.

Ex ante surveys
This approach uses survey-based elicitation of individuals' preferences, to assess their willingness to pay (WTP) for potential new services.

Ex post surveys
These directly survey users to explore actual (or perceived) benefits from climate services.

Statistical and econometric analysis
These use statistical analysis (ex post) to assess impact/outcomes from the introduction of W&CI services, controlling for other variables to attribute benefits.

Impact assessments
These undertake direct measurement of service impact on a group or area, before or after, or relative to a control, e.g. using agriculture field plots.

Value (Benefit) transfer
This method takes estimates developed in one context and applies these in another context, rather than undertaking primary studies, adjusting values for context.

The potential applicability to climate services, and the resource and expertise needed to implement them, are presented in the Table below, for climate services that focus on climate variability (such as seasonal forecasts).

Table 2. Possible methods and resource and expertise needs for climate services (variability)

Description of Method	Resource & Expertise Needs
Surveys of willingness to pay (ex ante) for new or improved services.	Medium to high. Cost of survey and analysis. High level of expertise involved.
Revealed preferences studies, e.g., averting behaviour.	Medium to high. Cost of studies and analysis. High level of expertise involved
Survey/questionnaire of likely beneficiaries (ex post)	Medium. Cost of survey and processing results but can be included in the baseline and end-line survey. Low -medium expertise required.
Modelling of impacts from seasonal variations (ex ante) e.g., effects on agricultural yields /incomes.	Medium to high. Time spent on developing model and data analysis of results. High expertise required.
Economic modelling (ex ante) suitable for larger scale change, e.g., computable general equilibrium modelling.	Medium to high. Time spent on developing model and data analysis of results. High expertise required.
Impact assessments, e.g., test plots to allow measurement of benefits.	Medium to high. Development and analysis of test plots and data and analysis of results. Medium – high expertise required.
Econometric analysis (ex post), e.g., quantification of income benefits of improved weather forecasting on basis of regression analysis of data.	Medium to high. Time spent on developing econometric analysis and data analysis of results. High expertise required.
Benefits transfer, e.g., transfer from previous studies for similar improvements elsewhere, with adjustments for context.	Low cost. Review previous studies and interpretation to allow transfer to current context. Low expertise required.

However, not all of these methods are applicable to climate services associated with future climate change. A key lesson from the case studies is that for adaptation services, it is difficult to use ex post methods, especially for more proactive (future orientated) adaptation, due to the long time periods involved. This means there is usually more focus on ex ante methods, notably ex ante modelling.

To help choose a method, it can be useful to look at previous economic studies for similar climate services, and review the methods that were used and the level of detail involved. For example, if your project is for seasonal forecasts for agriculture, look at previous applications in this area. There are also more technical descriptions – and reviews of previous applications for different project types for climate variability - in Soares et al. (2018)[5] and in the Asia Regional Resilience to a Changing Climate (ARRCC) report on Valuing climate services (Suckall and Soares, 2020[6]) which includes consideration of advantages and disadvantages of different approaches.

[5] Soares M.B., M. Daly, S. Dessai (2018). Assessing the value of seasonal climate forecasts for decision-making methods. WIREs Climate Change, Vol 9, Issue 4. https://doi.org/10.1002/wcc.523

[6] Natalie Suckall and Marta Bruno Soares (2020). Valuing climate services: Socio-Economic Benefit studies of weather and climate services. Publication prepared as part of the Asia Regional Resilience to a Changing Climate (ARRCC.

Step 4: Develop a baseline for the current situation

The next task is to develop a **baseline.** The exact baseline work will vary with the method chosen, but irrespective of the approach, this task aims to produce a snapshot of the conditions before (or without) implementation of the new or extended climate service. For most approaches, it is usual to collect baseline information before the new or updated service is introduced, although it can be possible to estimate baseline information if this has not been possible.

In general terms, it is useful to start by mapping the climate service benefits and value chain (see Steps 1 and 2) and using this to help develop baseline information design. When a climate service already exists, the baseline should identify and assess the characteristics of each step of the value chain, i.e. in terms of accuracy, uptake and use of information, including the end-user decision and benefits that arise.

If a completely new climate service is being developed, it is important to develop a new value chain (see Step 2) in order to understand the overall steps from information generation through to end-users, and ensure relevant data is gathered or assessed on each step, before the service is introduced.

The value chain will provide insights on what the baseline needs to investigate, for example, if a survey-based method is used, then a survey questionnaire (and complementary analysis) might be used to assess current forecast accuracy, how many people are currently reached, the existing level of use by end-users, to develop the baseline. If an ex ante modelling approach is being used, there will be a need to create a counterfactual model run, ensuring this captures the relevant value chain steps and is therefore representative of a modelled baseline scenario.

The baseline also should capture the baseline economic case. If a climate service already exists, it should quantify the social, economic and environmental impacts of climate-induced events on users across sectors (e.g., households, private and public sector), before the service is enhanced. If a climate service does not exist, the focus will be on how the target (future) users of the new W&CSI are currently affected by climate-induced events.

The study case studies provide examples of baseline analysis. These baselines can often be difficult to assess, especially if the economic valuation is of an existing service (which has not undertaken a baseline analysis). Nonetheless, the case studies show it is possible to derive a baseline through the use of review, analysis and interviews, to build up a realistic counterfactual.

The case studies have also highlighted the difference in baseline analysis when assessing adaptation services, especially for future oriented information and decisions. In this case there is a choice between using static futures, e.g., picking one or two future scenarios and central model outputs, or considering uncertainty, e.g., to capture the full range or envelope of possible future baselines. This influences the subsequent analysis of benefits, and whether a more theoretical analysis of benefits is estimated (from a static approach) or decision making under uncertainty is applied.

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https://www.metoffice.gov.uk/binaries/content/assets/metofficegovuk/pdf/business/international/arrcc_mop_wp4_seb_evaluation_guidance-final.pdf

Step 5: Assess the change with the service in place

This step seeks to assess the benefits with the climate service in place, from the new information and the subsequent decisions that are taken. This scenario can be then compared to the baseline, to estimate the additional benefits attributable to the climate services. This comparison can involve different techniques depending on the exact method and the approach being taken (e.g., 'before vs. after' or 'with vs. without').

This step aims to identify, quantify and monetise the benefits directly resulting from climate services activities. To assess benefits - relative to the baseline or counterfactual – the analysis can look at:

- The changes that have arisen / are projected to arise due to the climate service along all steps of the value chain, relative to the baseline. Many projects enhance several steps, e.g., improved reach and more targeted user information.
- Assessing the changes quantitatively, for example, in terms of increased % accuracy of forecast, or numbers of additional people reached.
- Assessing the improvement in decisions and the associated economic benefits, for example, the reduced loss or damage, increased yields and income as a result of the project.

These benefits should be mapped to specific categories. The benefits of the intervention should be clearly identified, quantified and if possible monetised.

Some methods (e.g., ex ante willingness to pay or econometric studies) work directly in economic terms. Other methods (e.g., surveys or models) may need to quantify benefits first in physical terms, and then apply unit values to value these benefits. Benefits are identified and measured in the units in which the impact is directly expressed, for example, through yield increase or lives saved. These are then valued using market prices. If markets are distorted or market prices are not available, shadow prices can be used, which provide estimated values. Examples are given below.

Table 3. Examples of benefits and associated physical and monetary values

Type of benefits	Description	Unit value (e.g., £/)
Increased agriculture yields	Tonnes/year Profit/ha/year	e.g., £/tonne (see wine case study)
Avoided or reduced asset losses and damage	Type and quantity of assets saved	e.g., £ reconstruction/repair cost savings (see climate allowances case study)
Reduced number of fatalities and injuries	Number of fatalities avoided	e.g., £ value of statistical life (see heat alert case study)

It is highlighted that for non-market benefits, such as environmental, health and educational outcomes, economic techniques can be used for monetary valuation. This includes revealed and stated preference methods (see further resources). The valuation of non-market benefits is often challenging, although it is often possible to provide indicative estimates through the use of value transfer (see Step 3). An example of this is included in the health heat-alert case study, which values the potential change in fatalities using approaches used in Government economic appraisal.

There is more detailed guidance on valuation methods in the WMO Valuing Weather and Climate: Economic Assessment of Meteorological and Hydrological Services (see earlier) and in the UK economic appraisal guidance in the Green Book[7]. These include guidance on valuing non-market benefits, and there is also guidance on environmental valuation available from the OECD[8].

There is also a need to consider:

- Causality. The role of a climate service in affecting outcomes along the value chain needs to be clearly justified through the use of a sound methodological approach.
- Attribution. The presence of other programmes or factors which might have affected the outcomes must be considered, to attribute the change to the project only.

For example, the health heat-alert scheme case study investigates attribution issues related to current early warning and future climate change model projections.

Finally, the case studies have identified important issues around the quantification of benefits for adaptation services, as compared to climate services focused on variability, i.e., when using climate model projections. In this case, there are important differences in 'real-world' benefits according to the decision method used, and specifically, whether a static approach is used (i.e., examining one or two central scenarios) versus decision making under uncertainty (when the range or envelope of scenario and model uncertainty is considered).

Economic benefits from adaptation services are lower when uncertainty and ex post outcomes are taken into account, as with decision making under uncertainty, as compared to a simple 'if-then' analysis which assumes that the projections will be accurate. However, the use of decision making under uncertainty will generate higher real-world benefits.

Step 6: Assess the costs of the project

Once benefits results are available, these can be compared with information on costs to answer the question of 'how the costs of the new or enhanced service compare to its benefits?'

What costs should be considered? The costs of a project or programme are not just the value of the funding, i.e., the project cost. They include a range of other costs associated with the set-up and delivery of the service across the value chain (see Box 2).

How to assess costs? This task involves capturing all the various cost elements and building up the cost streams (over time) for the project or programme. This should include the investment in new or additional meteorological stations and the costs of operating the service. It should also take account of the additional costs for communication and uptake of information.

Finally, and often overlooked, it should include any costs associated with end-user decisions or activities. This includes the costs of end-user time or action. For example, in the health heat-alert case study, this included the costs of advanced nurses who take action when the alert is triggered. This should also include costs for false negatives, i.e., when costs are triggered from incorrect

[7] HMT (2022). The Green Book. https://www.gov.uk/government/publications/the-green-book-appraisal-and-evaluation-in-central-governent/the-green-book-2020

[8] OECD (2018). Cost benefit analysis and the environment. https://www.oecd.org/environment/cost-benefit-analysis-and-the-environment-9789264085169-en.htm

forecasts, noting in this case, there are no additional benefits (compared to the baseline) but costs are still incurred.

These same costs also apply to adaptation services. For example, the costs of climate proofing infrastructure are an important component of the case study on allowances. In this case, information from climate projections and allowances are used in the design of infrastructure, leading to economic benefits in reducing the risks of climate change. But these design changes will also have a cost. It is important to include these when assessing the overall costs of the climate service, as it is only from the expenditures on climate proofing that benefits will be realized.

Box 3 Cost categories

It is important to capture all the relevant categories when assessing climate services. This includes:

Project costs. Including project funding borne. This might include both capital and operating and maintenance -capital costs:

Capital costs
The investment costs, such as the capital investment in new meteorological station infrastructure. As well as the capital costs, there may be set-up costs associated with training or technical assistance support.

Operating and maintenance costs
This includes all activities associated with running the service. This includes recurring/operating costs such as staff costs, modelling and forecasting, and maintenance).

Third-party costs. Including any co-financing provided by other donors and/or government and national institutions (e.g., meteorological authorities), and costs borne by intermediaries responsible for communication (e.g. radio stations).

Value chain costs
Costs will be incurred at various stages along the value chain, and these should be included. For example, the costs of communication and outreach.

End user costs
There are costs associated with the decisions or actions taken by end-users. These may involve direct costs, e.g., costs of material to fix a roof before a storm, or the costs of changing to different crop varieties. These actions also include resource and opportunity costs. For example, the time taken to fix a roof as well as the materials, or the time to attend workshops. It is more challenging to capture these end-user costs, but if they are excluded, costs will be underestimated relative to benefits.

Step 7: Assess benefits and undertake a CBA

The next step **compares the costs and benefits** of the project or programme, by undertaking a cost-benefit analysis (CBA).

CBA is a standard economic appraisal technique that assesses a programme or project by estimating the economic benefits it produces over time, and comparing these to the costs over time, both from a societal perspective. It is commonly used in UK public policy appraisal (Green Book, 2022). As highlighted earlier, this cost-benefit analysis is undertaken from the societal perspective, considering all costs and benefits that affect the welfare and wellbeing of the population (including environmental, health, societal costs and benefits).

The CBA uses the information gathered in the previous steps and compares the incremental costs and benefits resulting from the climate service over time. However, the costs and benefits that arise in different time periods (in different future years) have to be assessed in equivalent terms, in so-called present value terms. This adjusts the values using discount rates (see Box 4).

Once the present value of costs and benefits has been assessed, these can be used to estimate an overall net present value (NPV). This is the difference between the present value of benefits and the present value of costs over the evaluation period. Alternatively, the benefit to cost ratio (BCR) can be estimated, which is the total present value of benefits divided by the total present value of costs.

If a climate service project has a positive net present value, or a BCR of >1, this demonstrates that benefits outweigh the cost. The higher the NPV or the greater the BCR, the more positive that the project is.

It is also important when developing the CBA to develop an accurate profile of costs and benefits over time, which align with a realistic set-up and delivery of the project.

Box 4. Costs and benefits in future time periods

Costs and benefits in economic appraisal are estimated in 'real' base year prices, which means the effects of inflation are removed.

Costs and benefits that arise in different future years are adjusted to provide equivalent, directly comparable values using **discount rates**, and expressed in present values terms.

This is the standard approach in economic appraisal methods and takes account of the fact that individuals and society prefer to receive goods and services now rather than later. The choice of the discount rate will depend on the context and country. In the UK a discount rate of 3.5% is used (HMT Green Book) was used, as a typical rate used in economic appraisal.

For example, costs are likely to be borne in the early years as the project is set-up, but benefits will normally not start for a year or two later, i.e., there will be a delay between costs and benefits.

At the same time, benefits will usually extend beyond the period of the project funding, i.e., in future years. However, the level of benefits in these years may be reduced if the project activities are not fully sustained.

The annual benefit profile should therefore reflect these aspects, for example, to phase up at the start, to deliver fully during project funding, and then (depending on sustainability actions) to phase down in later years.

There is more detailed guidance on cost-benefit analysis in the WMO Valuing Weather and Climate: Economic Assessment of Meteorological and Hydrological Services and in the UK economic appraisal guidance in the Green Book. There are also examples of cost-benefit analysis spreadsheets, that provide templates for undertaking analysis.

The cost-benefit analysis of adaptation services does involve additional issues to climate services (for example, such as seasonal forecasts) as it involves different information (climate projections) and different timescales and decision types. This is particularly the case with proactive, planned adaptation. In these cases, the economic benefits generated by the service arise in the future, they are subject to high uncertainty, and they can involve differences in the timing of costs and benefits over time which are strongly affected by discounting, especially when there are up front costs and long-term benefits. These issues are explored in more detail in the climate allowances case study.

Step 8: Sensitivity analysis and enhancing benefits

The final step is to test the robustness of the economic analysis, and to look for further improvements. Therefore, an economic study should consider biases and uncertainties, potential omissions, and undertake sensitivity analyses for key variables, testing how these affect the results. This analysis can also be used to explore how benefits could be increased.

There are three key aspects to this step:

1) To describe all the methodological limitations and biases of the method used. This provides a transparent description of the potential caveats, and the limitations, potential omissions and quality of the information used. These should be presented clearly, including with an analysis of how these might affect results (e.g., leading to potential over- or underestimates).

2) To test how the results would differ if some of the key assumptions or outcomes are changed, using sensitivity testing. This can include a number of tests to see how robust the results are:

- It is good practice to run a sensitivity analysis on the CBA by changing some of the underlying assumptions. Sensitivity testing can be around outcomes (e.g., lower benefits than reported in a survey) or methodological (use of a declining discount rate).
- It can also be used to look at the profile of costs and benefits over time and how this might affect the CBA. For example, it is possible to model decreasing benefits over time, after the initial period of project financing has ended, or to investigate the impact of different discount rates on the CBA results. These tests can show how robust a project is, e.g., if the NPVs remain high and BCRs positive even under different assumptions, this gives greater confidence in the positive aspects of the project.
- All sensitivity tests should be clearly explained, and the results transparently presented, for example, documenting how the sensitivity tests change the BCR or NPV, and if they alter the overall conclusions.
- Switching values can also be investigated. These are assumption values which lead to a switch in the NPV from positive to negative or reduce a BCR to below 1. For example, this can identify the lowest level of benefits that can be produced from a seasonal forecast that still gives a positive economic return and assess whether the project is likely to generate higher benefits than this minimum level.

3) To use the findings of the economic analysis to explore how benefits could be enhanced. The information from an economic analysis can be used to identify how to further improve a project, especially when combined with sensitivity testing.

For example, the sensitivity analysis might reveal which steps of the value chain have the most influence on the overall size of benefits, or the pinch points in the value chain where a small additional improvement might lead to large benefits.

This information can be used to target any follow-on resources, or subsequent project phases, and help deliver higher overall benefits and impact.

The case studies provide examples of sensitivity analysis, looking at key assumptions, or key methodological elements, that might affect the robustness of the results.

Monitoring and Evaluation

A related issue for climate services is around the framework for monitoring and evaluation (M&E), and this links to the concepts of a Theory of Change and Logical Frameworks.

The process of programme or project development for climate services can use logic models (also known as logical frameworks or logframes) to encourage a structured approach. This involves a standardised set of steps (the causal pathway or results chains) of a logical framework, and the flow from input and activities, through to the subsequent outputs and outcomes, and finally, to the overall impact. This is shown below with an example for climate services.

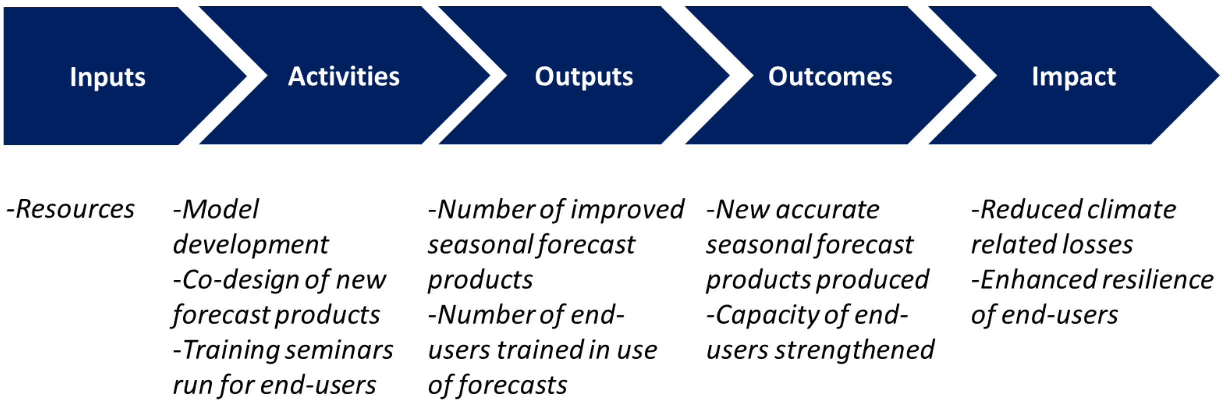

Figure 4. A logical framework and examples for climate services.

Any climate service project can be framed in terms of a logical framework. These logframes also form the foundation for monitoring and evaluation. A climate service can identify output and outcome-based indicators that can be used to monitor and evaluate the performance of the climate service, for example capturing the number of forecast products or the number of end-users trained in their use. The economic benefits from climate services can be included as an outcome or impact metric for such a logframe.

Value for Money

Value for Money (VfM) is not about securing lowest prices or costs, it is about delivering best overall value. This guidance uses the framework for value for money used by the National Audit Office[9], which is based around the 3Es: economy, efficiency, effectiveness. Note that sometimes a further category (Equity) is also included. These 3Es can be linked to a logical or results framework (as in

[9] https://www.nao.org.uk/successful-commissioning/general-principles/value-for-money/assessing-value-for-money/

previous section), to help drive VfM in managing inputs, and maximising the level, quality and impact of outputs and outcomes for climate services. The 3Es are summarised as follows:

Economy (inputs, i.e., spending less). This refers to ensuring the lowest cost use of goods and services within a project. It focuses on making sure that input unit costs are benchmarked against market norms and thus that value is maximised through strong procurement processes.

Efficiency (inputs to outputs, i.e., spending well). This refers to ensuring that the quality and quantity of inputs are appropriate to achieve the envisaged outputs and that inputs are managed in an efficient way during project delivery. The input to output ratio is the key consideration.

Effectiveness (outputs to outcomes/impacts, i.e., spending wisely). This refers to what extent programme outputs are likely to result in the desired outcomes, whether a programme can demonstrate that the chosen outputs are the most effective way to achieve these outcomes, and how these outcomes can be measured.

Economic studies can help to develop an improved understanding and better articulation of a project's efficiency and especially its effectiveness, and so they can provide direct quantitative information to help demonstrate and report on Value for Money (VfM). A high BCR is an indicator of high VfM efficiency. The results of the economic analysis also feed into effectiveness, by allowing comparison of the economic benefits (and BCR) of investing in the particular climate service (or elements of the project), as compared to alternatives.

Table 5. VfM aspects for climate services.

3E	VfM	**Metrics**
Economy	Ensuring procurement delivers lowest cost of goods and services. Cost-benchmarking to assess the unit costs for a given input	Cost per input, e.g. Day rates (£/day) £ per meteorological station
Efficiency	Ensuring the training, communication and use to deliver outputs. Efficiency of the choice of investment	Cost per output, e.g., £/workshop, £/ per forecast product developed Benefit to cost ratio (BCR) of the investment
Effectiveness	Choosing the balance of investment between equipment, capacity, dissemination, user uptake, etc. to result to ensure desired outcomes. Identifying the most cost-effective investments	Cost per outcome, e.g. £/beneficiary reached, £/avoided £impact BCR of investing in W&CI services versus other areas