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Cost-Benefit Analysis of Climate Change Adaptation Projects

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Foreword

Vista Analyse has prepared a methodology document for Cost-Benefit Analysis (CBA) of climate change adaptation projects as an input to the bilateral project CLIMCITIES; CLIMate change adaptation in small and medium size CITIES.

Vista Analyse is cooperating with the Institute of Environmental Protection - National Research Institute (IOŚ-PIB), a governmental Institute in Warsaw, Poland, on the project. The project is financed under the Cooperation Fund of the Bilateral Financial Mechanism of the European Economic Area for the years 2009-2014 and the Polish state budget.

The main objective of the CLIMCITIES project is to develop adaptability to climate change in small and medium-sized Polish cities by providing local knowledge on adaptation to climate change. As part of the project, five Polish cities have developed adaptation strategies in cooperation with IOŚ-PIB and scientific centres. This methodology document is an input to the strategies. It provides guidance for how to perform a Cost-Benefit Analysis in the context of climate change adaptation, as well as how the methodology could be implemented in the case of one type of adaptation measure; a rain garden.

Haakon Vennemo

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Executive summary

We explain the steps involved in a Cost-Benefit Analysis (CBA), and show how CBA may be applied to the analysis of a climate change adaptation project. CBA of adaptation projects is becoming necessary as climate change draws closer and the need for adaptation increases, while funds are scarce.

Adaptation to climate change is local

Adaptation to climate change will be necessary this century. Some areas will become drier, mostly if they are dry already. Other areas will become wetter, mostly if they are "wet" already, i.e. precipitation is high. Sea levels will rise, storm patterns will differ from what we are used to, and temperatures will increase. Societies will need to adapt to this.

Adaptation to climate change is mostly local. It will affect each and every local community and more often than not it is local communities that are best positioned to develop adaptation measures.

During 2017, the Institute of Environmental Protection in Warsaw and Vista Analyse have trained executives from local communities in Poland in developing adaptation measures to climate change. Some cities have developed strategies for adaptation. This methodology document has been developed as an input to the strategies.

CBA is helpful for making priorities and assessments

Local communities have limited funds and it is important to spend funds wisely. We present a method that is helpful for making priorities and assess which adaptation projects give "value for money". This is the CBA method.

We explain the CBA method and suggest how it may be used

We explain the methodology to an interested reader with little knowledge of the topic, and illustrate how it may be applied to a climate change adaptation project, specifically a rain garden. A rain garden is an important example of a blue-green solution (a surface level solution) for handling excess rainwater and threats of flooding. Rain gardens are becoming popular in many countries, but they can be made in different ways with different cost-benefit trade-offs, and they do not suit every location equally well. Hence the need for a CBA to assess whether money spent on rain gardens is wisely spent. We do not have data to perform the actual analysis, but we suggest what data is needed and what role it plays in the analysis. Besides preparing for priorities and assessments, CBA is a way of focusing data collection efforts.

Nine stages in a benefit-cost analysis

There are slight variations in how the stages of a benefit-cost analysis are laid out, but we find it useful to distinguish nine stages, see Table S.1.

Table S.1 Stages of a Cost-Benefit Analysis

Stage	Short description
1. Define problem and goals	Describe the problem that needs to be addressed. This involves identifying the character of the problem (it's extent, who it affects etc.) and the context in which the problem exists. Based on the problem, define one or more goals for the project and criteria that must be met to achieve the goal(s).
2. Establish baseline scenario	Establish a baseline scenario, which represents a continuation of the current situation without the project.
3. Specify alternatives	Specify one or more project alternatives that addresses the problem in 1.
4. Map effects	For each alternative, map all potential costs and benefits.
5. Monetise effects	As far as possible, value all market and non-market effects and calculate net present value of each alternative.
6. Describe non-monetised effects	Describe effects that cannot be valued qualitatively.
7. Describe distributional effects	Describe distributional effects, for example by developing a stakeholder matrix.
8. Sensitivity analysis	Perform a sensitivity analysis to illustrate the sensitivity of results to changes in variables in the analysis. This could either be done by performing a partial sensitivity analysis, a scenario analysis, or a Monte Carlo sensitivity analysis. Perhaps the most important factor for determining the outcomes of climate adaptation projects is climate change. Sensitivity to climate change scenarios should therefore ideally be tested in this step.
9. Overall assessment	Finally, an overall assessment is made, considering the results of each alternative, including impacts that have been valued and those that have been described qualitatively, as well as the uncertainties associated with each alternative.

In the case of a rain garden the alternative may be an unrestricted manifestation of climate change, e.g., flooding, or it may be a conventional measure to reduce or eliminate flooding (such as increased sewerage capacity). We assume in this methodology document that the alternative is climate change. If instead the alternative were increased sewerage capacity, sewerage capacity could also be compared to climate change, which would indirectly compare the two measures against each other. Several measures may be integrated into the analysis in this way.

1. What is a Cost-Benefit Analysis?

Many public and private projects have a wide range of impacts and can affect several different groups in society. The weighing of these consequences is complicated and raises the need for methodology that can simplify the comparisons. A Cost-Benefit Analysis (CBA) is an answer to this need, and an analytical tool for prioritising and assessing various actions that can be taken to achieve a goal.

In a CBA, comparisons are simplified by the fact that many of the consequences of a project are expressed on a common scale; in monetary terms. A CBA aims to provide a complete assessment of the potential impacts of a project on the welfare on society. The analysis includes both market impacts, such as investment and operating costs, but also impacts for which there are no market prices, such as changes to water quality, ecosystem function, and human health.

While the analysis attempts to value all costs and benefits of a project in monetary terms, there may be instances where this cannot be done. Any impacts that cannot be valued in monetary terms should be described qualitatively in the analysis, and quantified in terms of physical impacts as far as possible (e.g. area of landscape affected, number of instances of health problems). In a CBA, all relevant effects should be priced, quantified and / or described verbally.

For some types of projects, it may be the case that it is difficult or undesirable to place specific economic values on important outcomes (e.g. disasters involving large-scale loss of life). An approach can then be used that identifies the least-cost solution that achieves a given goal, for example keeps probable losses to an acceptable level. This is called a cost-effectiveness analysis and is a variation of a CBA. Cost-effectiveness analysis is discussed further in section 3.5.3.

A CBA involves comparing a baseline scenario, which represents a continuation of the situation *without* the implementation of a project, with one or more project alternatives. The "best" alternative is the one that maximizes the expected value of the project to society.

The usefulness of a CBA rests on the assumption that the values used in the analysis provide a reasonable expression of the society's appreciation of the different types of consequences. The sum of individuals' willingness to pay is often used as the expression of society's valuation of the project.

CBAs can vary from comprehensive and complex studies to brief and simple analyses. The required scope and detail of the CBA will depend on the specific project under consideration. CBA is most commonly carried out to assess a project before it is implemented. The CBA can however also be performed to evaluate the performance of a project after it has been implemented.

While CBA is a valuable tool for assessing the net effects of a project, it is not intended as the only basis for decision-making. Decisions should be based on an overall assessment of the conclusions of the CBA against additional information, for instance concerning the distributional impacts of a project, and political considerations.

2. When to perform a CBA?

A CBA can be performed in a variety of situations. It may be for a project, policy change, regulatory change, programme, reform, or plan. It may be applied to small or large projects, new projects, rehabilitations, or upgrades. In the remainder of the text we refer to these as ‘projects’.

The starting point for any project is a problem or a need to change the current situation. In the context of climate change adaptation, the problem would stem from climate change, either from changes that are already occurring or expected future changes. For example, a city may be experiencing floods due to more frequent and intense rainstorms and seek to implement measures to reduce the risk and severity of floods.

The entity responsible for addressing the problem may have an idea of various measures that could achieve the desired outcome, but lack sufficient information on the consequences of the measures to make a well-founded decision. This is when it is useful to perform a CBA.

Some countries have formal guidelines for when to perform a CBA, for example determined by the size of the investment, or the significance of the expected effects of a project. For instance, in Poland, a CBA should be undertaken for major investment projects (over 50 million euros) included in operational programmes (OPs) of the European Regional Development Fund (ERDF) and the Cohesion Fund within the Europe 2020 strategy.[1] However, it is also beneficial to perform CBAs for smaller projects.

[1] See European Commission (2014) for specific guidelines for these kinds of investment projects.

3. How to perform a CBA?

As previously mentioned, the starting point for a CBA is a problem that needs a solution. It is important to understand the problem clearly. The CBA considers different alternative courses of action that may solve the problem.

Before beginning a CBA, it should be ensured that the necessary resources in terms of staff and possibly consultancy are available. If the objective of the analysis does not match the resources available for the study, it would be better to reconsider the study. Perhaps the objective needs to be constrained to studying just a few alternatives; or to undertake a screening of the most important impacts; or perhaps it is possible to obtain informative results without valuation. It is recommended to be explicit about any constraints in the analysis, especially if elements relevant for the analysis have been omitted.

An initial literature review of studies within the subject area is a way of collecting information that might provide inspiration and avoid duplication of work. Involvement of stakeholders in the process is also a way of collecting and making use of available information. In some cases, the information and data necessary for the analysis are only available from private companies or local authorities. Establishing a steering committee is a particular form of involvement that enables stakeholders to obtain insight in the methodology applied and assumptions made. This may help the result of the CBA to be accepted more easily.

Identifying the target audience, e.g. policy-makers, public administration, industry representatives and NGOs, can help define the problem to be analysed. Policymakers, be it local, provincial or national, may have different needs for information and decision support, depending on the scale of the project and the complexity of the problem.

It may also be desirable to describe the roles and responsibilities of the public authorities involved and affected by the project. This would indicate which authorities should be involved or at least consulted during the process. In addition, it might indicate where additional information could be gathered from.

The course of a CBA can be divided into nine main stages, as illustrated in table 3.1. How detailed the individual stages are, may vary from analysis to analysis. The stages are described in further detail sections 3.1 to 3.9. It is important to clearly describe all assumptions made throughout each stage of the analysis to ensure the analysis is transparent and verifiable.

For the context of undertaking economic appraisals of investment projects under the Cohesion Policy 2014-2016, relevant guidelines include:

- European Commission (2014). Guide to Cost-Benefit Analysis of Investment Projects – Economic appraisal tool for Cohesion Policy 2014-2020.
- Minister Rozwoju i Finansów (2017). Guidelines for issues related to project preparation investment projects, including income generating projects and hybrids for 2014-2020.

Table 3.1 Stages of a Cost-Benefit Analysis

Stage	Short description
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2. Establish baseline scenario	Establish a baseline scenario, which represents a continuation of the current situation without the project.
3. Specify alternatives	Specify one or more project alternatives that addresses the problem in 1.
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9. Overall assessment	Finally, an overall assessment is made, considering the results of each alternative, including impacts that have been valued and those that have been described qualitatively, as well as the uncertainties associated with each alternative.

3.1 Define problem and goals

The first stage of a CBA is to *define the problem*. This can be done by answering the following questions:

- What is the problem?
- What groups/people are affected by the problem?
- What is the extent of the problem?

- How serious is the problem?
- What factors may impact the problem over time?
- Why does the problem need to be solved now?

In this phase, it can be useful to talk to people who have expertise in the relevant sector/industry or particular knowledge of the problem. It is also important to identify reasons for why the problem exists.

It is also useful to describe the socio-economic/demographic, political and institutional context in which the problem exists. Examples of the type of elements that could help define the problem are given in table 3.2.

Table 3.2 Examples of elements for presentation of context in baseline scenario

Element	Examples
Socio-economic/demographic	Data on the population living in the involved area Description of the existing economic activities and services
Political, institutional, and regulatory factors	Reference to EU directives and sector policy documents Reference to the priority axis and the intervention areas of an Operational Programme (OP) *(only applicable to projects funded under an OP)* National/regional strategies on adaptation to climate change National civil protection / risk management strategies or plans Reference to flood risk management plans
Environmental framework	Quality and environmental status of the affected area Protected areas Areas subject to high hydro-geological risks or other environmental risks
Technical	Location and extension of the involved area Morphological, geographical and geological features Weather and climate conditions Existence of sites of natural or cultural interest Pollution and contamination in soil, groundwater, sediment and surface water bodies

Source: Adaptation of Table 4.9 in European Commission (2014), page. 171.

Based on the problem, one or more goal(s), and criteria that must be met to achieve the goal(s), should be defined for the project. The purpose of this first stage is to provide a solid foundation for the analysis.

Examples of goals that may be relevant in a context of climate adaptation are (European Commission, 2014, p. 171-172):

- Protecting human health
- Protecting buildings and other assets
- ‘Climate proofing’ the built environment and existing infrastructure
- Decreasing pressure on natural resources
- Protecting coastal zones, forests, and natural parks from deterioration
- Increasing the ecosystem’s resilience

3.2 Establish the baseline scenario

The next stage is to establish a scenario which describes the current situation and the expected future developments if no action is taken to solve the problem. This is called the ‘baseline scenario’ and represents a ‘do-nothing’ alternative; it is a continuation of the situation *without* the implementation of a project. The definition of the problem, as described in section 3.1, provides a basis for the baseline scenario. Expected future developments in society, such as economic growth, population growth, policy changes etc. should also be taken into account in the baseline scenario. It is crucial for the analysis that the specification of the baseline scenario is as realistic as possible. A specification of the baseline scenario that is overly pessimistic or optimistic can lead to an over- or underestimation of the net effects of the project.

Sometimes the current state is used as a baseline scenario. While the current state in some cases represents the future reasonably well, this is not given. Usually the baseline scenario will in fact evolve from the current state. It is sometimes said that an evolving, dynamic baseline depends on more assumptions than a continuation of the current state, but to assume zero change in important drivers of a baseline scenario is just another assumption. It is not any more speculative to assume that the baseline scenario dynamic than it is to assume that it is completely static.

When it comes to establishing a baseline scenario, CBAs of adaptation projects differ from CBAs of most other projects. The most important benefit of investing in adaptation to climate change is the expected avoided damage from future climate change. The expected avoided damage is calculated as the difference between the expected damage caused by climate change with and without adaptation, i.e. the difference between the baseline damage and the (residual) damage under adaptation. However, since future climate change is uncertain, the benefits of investing in adaptation are also uncertain. The sensitivity analysis of a CBA can be used to illustrate the sensitivity of results to different climate change scenarios, see section 3.8.2.

Note that a climate change scenario usually is based on assumptions about population growth, economic growth and mitigation policies, and therefore includes important assumptions about a baseline trajectory, which should be made clear in the description of the baseline scenario.

The assessment of adaptation projects usually requires high resolution climate projections for the climate phenomenon the adaptation project is expected to address. For instance, if options for mitigating flooding are being assessed through a CBA, the climate change projection should include information about the probability of flooding due to excessive rainfall or sea level rise. It should also be possible to map expected damages resulting from flooding to the climate change projection. This is further discussed in section 3.4.

3.3 Specify alternatives

This stage involves identifying relevant projects that may solve the problem in terms of size, timing, project design and cost. The definition of the problem and project goals, as well as the baseline scenario, provide the basis for the identification of relevant alternatives. One alternative may result in net benefits compared to the baseline scenario, however there may also be other alternatives that generate higher net benefits. It is therefore important that there is a thorough process for consideration and selection of alternatives.

The alternatives should be specified based on realistic and well-founded assumptions. The description of each alternative should start with a general description of how it can achieve the project goal(s). The description must also include any dependencies and / or impacts from other approved and planned projects.

Sometimes, a screening of options and narrowing down to only a few alternatives (or just one alternative) is done before the CBA. For projects where this has not been done before the CBA, a description of the breadth of available alternatives, a narrowing down of alternatives, and a brief explanation of why some have been excluded should also be given.

The description of the alternatives should be based on the baseline scenario, and any assumptions about external factors (e.g. regarding climate change or policy developments) should be the same for the baseline scenario and the alternatives, unless the alternatives are expected to influence any of these factors.

For each alternative, describe:

- The actions to be taken
- Where the project will be implemented
- The target group(s) of the project and other stakeholders (anyone significantly affected by the costs or benefits of the project)
- The entity responsible for implementing the project
- Timing for implementation and decision-making processes, including possibilities for flexibility in the implementation (e.g. a staged implementation)
- How the project will be financed
- Potential barriers (e.g. laws or regulations)
- Other relevant activities to facilitate the implementation of the measure.

In addition to assessing different alternatives, different solutions for the timing of implementation and the consequences of deferring investment decisions should be considered. The timing of the implementation will affect the net effects of the project, and finding the best possible timing can be important in order to optimise the positive effects of the project.

3.4 Map effects

The next stage of the analysis is to identify the effects of the alternatives. Both market and non-market effects must be included. For costs and benefits, the expected value must be given, as well as a description of the uncertainty of the estimates. As mentioned above, the most important benefit of adaptation projects is the avoided damage of events caused by climate change. Undertaking a CBA of adaptation projects therefore requires estimates of expected damage, as well as information about the extent to which the project alternative(s) are expected to prevent the damage. The estimates of damage can for instance be based on data from previous events, such as flooding or heat waves, which again can be used to calculate expected annual damages (see for instance Olsen et al., 2015 for an example related to urban flood risk). The calculation of expected damages is complex, and in most cases the analyst will retrieve information about expected damages from experts.

In addition to creating an economy that is more resilient to the effects of climate change, adaptation strategies/measures often have ancillary effects that can either be positive (co-benefits) or negative (co-costs). For example, the implementation of blue-green measures to adapt to heavier and more frequent rain storms in the future, can also have additional benefits such as cleaning the air, supporting wildlife, and creating attractive recreational areas (Chambwera et al. 2014). All relevant and significant ancillary effects should be considered and included into the CBA.

Some projects may cause ripple effects. That is, the project may cause one effect, which again leads to other effects and so on. In CBAs only the first effect should be included, to ensure effects are not double counted (Norwegian Government Agency for Financial Management 2014).

3.5 Monetise effects

A CBA is carried out to assess various solutions to a problem and their contribution to welfare. In order to do so, the analysis aims to monetise the costs and benefits of different project alternatives. In a financial analysis, costs and benefits are valued using market prices only. In a CBA, however, costs and benefits are measured by *shadow prices*. The key principles for the use of shadow prices is that benefits should be valued by people's collective *willingness to pay* to achieve the benefits, while costs should equal the value of the resources used in the project in their best alternative use (the *opportunity cost* of the resources).

Put more simply: Benefits are valued based on what people collectively are assumed to be willing to pay for these benefits, and costs are valued based on what people collectively are willing to pay to avoid these costs. In this context, 'people' is everyone affected by a project, or in other words; everyone that would place a value on the effects of the project.

Shadow prices are often equal to the prices observed in the market, but under certain circumstances, they may differ. Examples of factors that result in differences between shadow prices and market prices include environmental effects, taxes, and imperfect competition.

A CBA involves the valuation of *all* effects of a project. However, not all effects can easily be valued, especially those that arise from changes to goods and services not traded in a market. This is often the case for the benefits of a project. Valuation of market and non-market effects is covered in sections 3.5.1 and 3.5.2, respectively. Section 3.5.3 describes cost-effectiveness analysis, which is a version of CBA suited for situations where it is challenging to estimate benefits, and section 3.5.4 describes the concept of net present value calculation.

3.5.1 Market effects

The key market effects of an adaptation project are likely to include the costs of implementing, operating, and maintaining the project. The resources necessary to implement, operate and maintain the project may have a market price that equals the shadow price, but there may also be some distortions in the market for which the shadow price should be adjusted.

For example, imagine that a city is considering to re-enforce a dike to increase its stability and provide more safety against flooding. The wages of the labour force used to re-enforce the dike should be included in the CBA as project costs. The wages included should however be the shadow wages, which may differ from the actual wage paid by the company. If the State gives subsidies to employment in this area, the wage paid by the company may be lower than the social opportunity cost of the labour.

Whether the shadow price differs from the market price must be assessed on a case-by-case basis. There are several approaches to calculate the shadow price, and each of them could be more or less suitable for certain typologies of goods and services. The European Commission has published a guide to cost-benefit analysis of investment projects (see European Commission 2014), and presents some general rules for the conversion of market prices to shadow prices.

The guide distinguishes between whether goods are inputs or outputs of the project. Outputs are primarily valued using the willingness-to-pay approach, which is described in section 3.5.2. See also Annex VI of European Commission (2014) for a detailed description of the approach. As far as inputs are concerned, they can be regarded as tradable or not in international markets. The general rule for internationally tradable goods, such as most manufactured commodities, is to use their border price.

For non-tradable goods, a different approach is followed, depending on whether they are minor items or major items. For minor items, a special parameter called standard conversion factor (SCF) can be used. For major items, the shadow price can often be calculated based on the long-run marginal cost. For labour, a specific shadow price (the shadow wage), which accounts for local distortions in the labour market, should be calculated. More detailed descriptions of these approaches and when they should be applied are given in Annex III in European Commission (2014).

It should be noted that accounting for the difference between shadow prices and market prices usually matters less for the outcome than accounting for non-market effects. Therefore, if there is little time and unless the analyst has advanced competence, market prices could be used to indicate shadow prices, unless there are obvious reasons for doing otherwise.

3.5.2 Non-market effects

No cost-benefit analysis is complete without a consideration of non-market effects. Non-market goods and services are goods and services for which a market value is not available. In principle, the value of a non-market good or service can be captured by people’s collective willingness to pay for the good or service. Examples of (positive) non-market effects are prevention of injuries or accidents, improvement of landscape, noise reduction, increased resilience to current and future climate change, etc. The valuation of non-market effects is often fraught with methodological and practical difficulties, but it is usually better to include an uncertain estimate than to leave it out of the CBA altogether.

In the context of climate change adaptation, the benefits of a project are non-market benefits, and should be valued based on people’s collective willingness to pay to achieve these benefits. The key benefit from adaptation projects is the *avoided damage*, i.e. damage that otherwise would have occurred if the project had not been implemented (e.g. damage to properties and infrastructure, negative health impacts, loss of biodiversity etc.). This is of course challenging to estimate because it is not possible to predict exactly when an actual disaster will occur and with what intensity. The estimates will have to be based on probabilities of extreme weather events occurring (e.g. heat waves, storm surges, rainstorms, drought etc.).

Some examples of benefits from avoided damage, as well as other ancillary benefits from adaptation projects, are discussed below. These examples are based on pages

174-176 in European Commission (2014). Note that the below-mentioned benefits do not represent an exhaustive list. There may be other benefits that arise from the implementation of climate change adaptation measures and the full list of benefits should be assessed on a case-by-case basis.

A short description of the key approaches to measure willingness to pay in monetary terms for non-market effects is given in Appendix A.

Improved health conditions

Projects aimed at preventing the risk of natural disasters can lead to improved health conditions. For example, a measure implemented to reduce the risk of flooding could reduce the risk of diseases spreading from polluted water, or in the case of severe floods prevent the loss of life. Additionally, green infrastructure – such as green roofs or rain gardens - could contribute to cleaner air and associated improved health benefits. Approaches that can be used to value the changes in health outcomes include stated preference approaches (surveys) or revealed preference methods (hedonic wage method). If it is not possible in practice to measure the willingness to pay for improved health outcomes using the methods mentioned above, the human capital approach[2] or the cost of illness approach[3] may be applied.

Increased recreational value

This benefit could arise from the recovery or preservation of sites with recreational value (e.g. beaches, natural parks and protected areas) where recreational activities such as trekking, picnicking, and bathing can be carried out. Some adaptation projects may also create new recreational areas in urban centres, for example by opening up streams in cities for flood prevention. Increased recreational value may be estimated using revealed preference methods, such as the travel cost method[4] or hedonic pricing method[5], or stated preference methods. Alternatively, the value transfer (or 'benefit transfer') approach can be used.

Ecosystem and biodiversity preservation

This benefit relates to the value people place on the existence of ecosystems and biodiversity in good conditions. Methods that can be used to value ecosystem and biodiversity preservation include contingent valuation and value transfer.

Reduction of damages to properties

Damages to properties is a common consequence of natural disasters and extreme weather events. The benefit of preventing damages to capital (infrastructures, buildings and machineries) and natural (forests, biodiversity) stocks could be measured based on expected avoided damage. The information and data needed to estimate the expected

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[2] The basic idea of the human capital approach is that an individual is 'worth' to the society what he/she would have produced in the remainder of their lifetime. See page 96 of European Commission (2014) for a more detailed description.

[3] The cost of illness approach combines direct and indirect costs into an overall societal estimate. Direct costs include the medical costs necessary for treating a particular disease. Indirect costs measure the value of lost production because of reduced working time due to illness. See page 130 of European Commission (2014) for a more detailed description.

[4] This is naturally most relevant for recreational sites people travel to, such as beaches and natural parks.

[5] This method is most relevant for recreational sites in urban areas, where the value of the recreational site could be reflected in property values.

avoided damage should come from properly developed flood risk and hazard maps, in combination with flood modelling.

Alternatively, one may estimate avoided damages based on market insurance premiums, as a proxy to the value of avoided property damages. For those assets where market insurance does not exist, averaged calculations for avoided costs for public administrations for civil protection activities, compensation paid to citizens, relocations of buildings etc. should be added to the analysis.

3.5.3 Cost-effectiveness analysis

For some types of projects, it can be relatively straightforward to estimate the costs of the project, while it is almost impossible or very challenging to value the benefits. There may also be instances where the valuation of effects raises difficult ethical questions (for example in the valuation of health benefits). In such situations, **cost-effectiveness analysis** is an alternative to CBA. The aim of the analysis is to find the least-cost solution to achieve a given goal. That is, the analysis compares the relative costs of different alternatives, while the benefits are the same for all alternatives.

An example of a situation where a cost-effectiveness analysis could be suited is where a project must be implemented to satisfy legal requirements. The legal requirements would then be given, and one could compare the costs of various solutions that would satisfy the requirements.

It should be noted that if one or more of the alternatives result in benefits *additional* to the given goal, these benefits must be included in the analysis. Take for example an analysis where the goal is to increase the resilience to flooding in an area by a certain amount. Different solutions to this problem may include expanding the existing sewage system, channelling water to nearby ponds or retention basins, or implementing rain gardens or green roofs. In addition to retention of water, the implementation of green infrastructure could lead to other benefits such as noise reduction, CO_2-capturing etc. In such instances, the benefits could either be included as negative costs (i.e. reduce the total costs of the option) or as a qualitative description.

3.5.4 Calculation of net present value

Once the costs and benefits of the different alternatives have been estimated, the **net present value** of each alternative can be calculated. The calculation of present value is a method to calculate the value in monetary terms of costs and benefits that occur at different points in time. The *net* present value is the present value of project benefits less the present value of project costs. In order to calculate the net present value, one needs annual estimates of expected costs and benefits, a social discount rate, and a project period. The estimation of costs and benefits has already been covered in this chapter. The social discount rate and project period are discussed below.

Social discount rate

In the calculation of net present value, future effects are discounted by a positive social discount rate, such that future effects are assigned a lower value than effects occurring today, all else being equal. Because the costs and benefits of adaptation to climate change occur at different points in time, the social discount rate is a key factor in CBAs of adaptation measures. The size of the discount rate can significantly impact the calculated value of long term projects. The higher the discount rate, all else being equal, the lower the contribution of future benefits and costs to the overall value of the project.

The European Commission (2014) recommends that a social discount rate of 5 per cent is used for major projects in Cohesion countries and 3 per cent is used for the other member states. As Poland is a Cohesion country a social discount rate of 5 per cent should be applied.

Project period

The estimated costs and benefits of a project should cover a period appropriate to the project's economically useful life and its likely long-term effects (European Commission, 2014). The reference periods proposed by the European Commission for different sectors are presented in table 3.3. These values should be considered as including the implementation period.

Table 3.3 European Commission's reference periods by sector

Sector	Reference period (years)
Railways	30
Roads	25-30
Ports and airports	25
Urban transport	25-30
Water supply/sanitation	30
Waste management	25-30
Energy	15-25
Broadband	15-20
Research and Innovation	15-25
Business infrastructure	10-15
Other sectors	10-15

Source: Table 2.1 in European Commission (2014), page 42.

If the NPV of an alternative is positive, the alternative will increase social welfare. If more than one alternative has a positive NPV, the one with the highest NPV will most likely yield the highest welfare gains. However, costs and benefits that have been described qualitatively must also be considered in the overall assessment. This is described in more detail in section 3.9.

3.6 Describe non-monetary effects

In most projects that result in environmental effects there will be some effects that are impossible, or impractical to value. Whenever money quantification is not possible, effects should at least be identified in physical terms for a qualitative assessment. Questions that can be asked to analyse the significance and extent of the effects include:

- What is the size of the area affected?
- How many people are affected?
- How significant are the effects on people? (low, medium, high significance?)
- How long will the effect last, and how often does it occur?

3.7 Describe distributional effects

A CBA should include an analysis of the distribution of the project costs and benefits across different groups of stakeholders.

The first step of the distributional analysis is to identify stakeholders that will be affected in a noticeable way by the implementation of the project. Examples of groups of stakeholders are residents in the relevant area, government, users and suppliers. Then, to summarise all the effects that are encountered by the project, a matrix can be developed linking each effect with the stakeholders affected by the impact. This is called a stakeholder matrix. Table 3.4 illustrates a possible set-up of a stakeholder matrix.

Table 3.4 Stakeholder matrix

Stakeholders	Stakeholder group 1	Stakeholder group 2	Stakeholder group 3	…
Effects (monetary & non-monetary)				
Effect 1				
Effect 2				
Effect 3				
…				

Source: Adapted from European Commission (2014), page 65.

3.8 Sensitivity analysis

When a CBA is conducted there is often uncertainty about what the actual quantities and prices will be. The purpose of a sensitivity analysis is to study how sensitive the result is to changes in key assumptions. Sensitivity analysis enables the identification of the 'critical' variables of the project. Such variables are those whose variations, be they positive or negative, have the largest impact on the project's financial and/or economic performance (European Commission 2014).

Three forms of sensitivity analysis are presented here:

- Partial sensitivity analysis: only one variable is changed at the time
- Scenario analysis: assessment of the consequences of simultaneous uncertainty about several variables
- Monte Carlo analysis: in addition to assessing simultaneous uncertainty in variables, this analysis takes into account correlations between these variables.

Since future climate change is uncertain, the benefits of investing in adaptation are also uncertain. Different future climate change scenarios, the possible range of outcomes that can occur, and the probabilities of the various outcomes should therefore be considered in the sensitivity analysis.

An often-used approach in CBAs of climate change adaptation, is to look at avoided damages under two or more climate scenarios to capture a wide range of climate change projections, and thus a wide range of possible avoided damage (see for instance Markandya et al. 2014). This will highlight the large uncertainty in projected climate change, and projected impacts of climate change. The scenario analysis, described in section 3.8.2, is well suited to analyse the sensitivity of project outcomes to different climate change scenarios.

The scenario analysis is an extension of the partial sensitivity analysis. The guidelines by the European Commission (2014) require that both a partial sensitivity analysis and a scenario analysis be performed for major investment projects (over 50 million euro) under the Cohesion strategy.

3.8.1 Partial sensitivity analysis

A partial sensitivity analysis studies the change in the outcome (here net present value) from changing one input variable at a time. Typical key variables for the sensitivity analysis are listed below.

- discount rate
- time horizon of the project
- quantity of emissions/discharges to be treated or the environmental resource considered in the analysis
- investment cost
- prices of electricity, fuel or other inputs
- monetised, key environmental impacts

The analysis is carried out by varying one variable at a time and determining the effect of that change on the NPV. The outcome of the sensitivity analysis should be presented together with the result of the CBA, so that it becomes visible for the decision-maker where the potential drawbacks of the project are. Also, the decision-maker should be made aware of any assumptions that are uncertain and have a high impact on the result. According to the European Commission (2014), variables for which a variation of ±1 % of the value adopted in the base case gives rise to a variation of more than 1 % in the value of the NPV should be considered ‘critical’.

The sensitivity analysis may be supplemented by a ‘worst case’ and ‘best case’ that show the outcome if several variables take on their worst or best possible values. If the result varies significantly with a change in a key variable, it is important to define this variable as precisely as possible.

Another component of the sensitivity analysis is the calculation of the **switching values**. This is the value that the analysed variable would have to take in order for the NPV of the project to become zero, or more generally, for the outcome of the project to fall below the minimum level of acceptability (European Commission 2014).

3.8.2 Scenario analysis

A scenario analysis is an extension of the partial sensitivity analysis, whereby a number of scenarios representing alternative future directions are created. Combinations of ‘optimistic’ and ‘pessimistic’ values of the critical variables identified in the partial sensitivity analysis could be useful to build different realistic scenarios. As described above, the scenario analysis can be used to analyse the sensitivity of the results of the CBA to different climate change scenarios.

3.8.3 Monte Carlo sensitivity analysis

The first step in a Monte Carlo analysis is to specify a probability distribution for each of the key variables. Then, the calculation of net benefits is repeated a large number of times randomly in a computer programme. The result of the analysis is a set of probability distributions showing how uncertainties in key variables may impact on key outcomes. More resources are required to undertake a Monte Carlo analysis than partial sensitivity analysis and scenario analysis.

For further reading on Monte Carlo analysis, see Boardman et al. (2006) and pages 71-73 in European Commission (2014).

3.9 Overall assessment

The final step of the CBA is to undertake an overall assessment of the results from each of the previous stages of the analysis. Factors to be considered include:

- The net present value of each alternative
- Non-monetised effects
- Uncertainty

The goal of this stage is to inform the decision-maker of the analysis in a transparent and straightforward manner and to present well-founded recommendations regarding adaptation measures.

4. Guidance for CBA of a rain garden

In chapter 3, we set out nine steps for performing a CBA. In this chapter, we will provide guidance for how you would go about to complete a CBA for the implementation of a rain garden. This is not an actual application of a CBA, but a demonstration of the types of issues to consider, data needed and how costs and benefits for the implementation of a rain garden could be estimated.

While we have used a rain garden as an example, several of the issues to consider and ways to calculate costs and benefits are relevant for other climate change adaptation measures as well.

4.1 Problem and goals

Cities are especially prone to flooding because they are characterised by a large portion of built-up area. Apartment blocks, roads, walkways, parking lots and other structures with impervious surfaces do not allow water to infiltrate into the ground, but send the water across the surface instead. This stormwater runoff (also called urban runoff or surface water runoff) increases the risk of flooding. It also carries pollutants with it and contaminates streams and lakes if left untreated before entering the water (Haughton and Hunter 1994 in Bolund og Hunhammar 1999).

Research has shown that around 55 per cent of precipitation in cities ends up as stormwater runoff due to the lack of vegetative cover and other permeable surfaces.[6] In contrast, there is only about 10 per cent runoff in areas with natural ground cover. The rest of the precipitation is absorbed into the ground or evaporates via the vegetation (FISRWG 1998).

Measures to reduce the risk of flooding in cities can generally be categorised into conventional measures, which channel water in pipes below ground, and blue-green measures[7], which are natural solutions based on water and/or vegetation and designed to absorb the rainwater locally. Blue-green measures can reduce the pressure on the drainage system in cities by infiltrating or retaining water during the peak of rainstorms. Rain gardens (also referred to as bioretention) are one of several blue-green measures. Other measures include green roofs, open streams, ponds and wetlands.

The suitability of the different measures will depend on the local conditions of the area in question. Firstly, the measures vary in their capacity to infiltrate/retain runoff and so it is necessary to analyse the extra capacity needed in the area to reduce the risk of future floods. Secondly, the costs of implementing different measures vary with conditions such as the type of ground cover and terrain, the value of the land, and the characteristics of the built environment in the area.

For this example, we are going to assume that there has been a selection process prior to this analysis, from which a rain garden is assessed to be the most suitable measure for an area. A rain garden is a planted depression whereby water is stored on the surface and later infiltrated into the ground or led into the drainage system. A rain garden is not a permanent pool, but is flooded temporarily during rain.

[6] Based on the assumption that there is 75 – 100 per cent impermeable ground cover.

[7] Also referred to as 'Sustainable Urban Drainage Systems (SUDS)' or 'Green Infrastructure'.

Rain gardens have the potential to control stormwater quantity and quality, as well as restore groundwater supplies. In addition, rain gardens provide green environments which can support biodiversity. Plants and vegetation can also help improve air quality, reduce noise, and capture CO_2. Rain gardens are typically small installations (for example the size of a garden bed) and could be analysed as a solution for a small area, or as part of a combination of solutions for a larger area.

A description of the floods that have occurred in the area in the past and the types of problems these floods have caused will help identify the extent and seriousness of the problem the rain garden is intended to solve. Other useful information includes characteristics of the sewerage system (separate or combined), any water bodies the surface water runoff would flow into, the degree of impervious surfaces, population, number of houses, activities in the area (e.g. industrial, commercial), and the state of natural resources and ecosystems in the area. The ideal tool to assess the likelihood of flooding would be a hydraulic model describing inflow, accumulation, and outflow in an area.

It is also useful to describe the socio-economic/demographic, political and institutional context in which the problem exists. This could include whether there are any plans or strategies (at local, regional or national level) for;

- Land use changes in the area
- Expansions/upgrades/alterations to the current sewerage system
- Stormwater management/climate change adaptation

The description of the problem should also include a description of who it affects. In the context of floods from stormwater runoff, this could include owners of the properties damaged during floods, insurance companies (payment of water damage compensation), the fire brigade (if their services are called upon during a flood), people affected by traffic delays or disruptions, and the city administration (repair of any damage to infrastructure and other clean-up efforts after the flood).

The project goal and associated criteria should be based on the defined problem. In the context of floods, the goal could for example be to *protect buildings, existing infrastructure, and other assets from water damage*. To achieve this goal, it would be necessary to reduce the velocity and volume of surface water runoff.

If contamination from surface water runoff is also a problem in the relevant area, an additional goal could be to *reduce contamination of water running into nearby water bodies*. To achieve this goal, it would be necessary to remove pollutants from the runoff before it enters streams or other recipients.

4.2 Baseline scenario

The next step is to establish a scenario that describes the current situation and the expected future developments if no action is taken to solve the problem. This is called the ‘baseline scenario’ and represents a ‘do-nothing’ alternative; it is a continuation of the situation *without* the implementation of a project.

4.2.1 Damage from floods

For the baseline scenario, we need to establish the likely annual flood damages in the future. This can be measured based on a combination of the **flood hazard,** i.e. the likelihood of a flood occurring and its characteristics, and the **vulnerability** of the area (Olsen et al. 2015).

Flood hazard

There are several factors that determine the likelihood of a flood occurring and the extent of the flood. In this example, we are concerned with pluvial floods (also called stormwater floods), which arise from stormwater accumulating from heavy rainfall. The key contributor to pluvial flooding is precipitation. Stormwater runoff generally collects when there is intense rain over a short period of time (often lasting from a few minutes to a few hours (DSB 2016)). From now on, we will use the term 'flood' synonymous with 'pluvial flood'.

The capacity of the sewerage system (both the speed at which it can transport water and the volume it can handle) also impacts the likelihood of a flood occurring. With the sewerage system overwhelmed, water can flow out into streets and nearby structures or force waste water back into houses through drain pipes.

Other factors that impact the amount of runoff include the terrain and ground cover. A high concentration of impervious surfaces leads to a higher level of runoff compared to natural ground cover because it allows less evapotranspiration and infiltration into the ground. The time of the year and antecedent conditions such as amount of rain in the days preceding the rainstorm could also impact the amount of runoff.

The flood hazard can be mapped using hydraulic models based on historic data. Input data for such models would include information on the factors that determine the likelihood of floods occurring (i.e. information about rainfall, sewer system hydraulics, terrain/elevation etc.).

Due to climate change, the intensity and frequency of rainstorms is expected to increase in the future, which in turn will increase the risk of flooding. It is therefore necessary that stormwater solutions implemented today are built to a capacity that can infiltrate the amount of stormwater runoff expected in the future.

A commonly applied method to adjust the amount of surface water runoff for climate change, is to multiply the precipitation intensity with a factor for expected relative increase, called a climate factor (COWI 2014). The climate factor can vary with the return period of precipitation.[8] For example, the probability of a precipitation event with a return period of 2 years may be expected to increase by 20 per cent, while it may be expected to increase by 30 per cent for a 10-year event (Zhou et al. 2013).

Since climate change evolves gradually and large uncertainties are inherent, the CBA should include a baseline scenario both with and without the expected climate change. This information is useful since it illustrates whether climate change adaptation measures will be worthwhile even in the absence of climate change (Zhou et al. 2013).

Vulnerability

Vulnerabilities describe the number of humans, buildings, items etc, present at the location involved and the potential adverse effects caused by their exposure to the hazard (Zhou et al. 2013).

[8] The probability of a flood occurring is typically described by the return period, which is a statistic measure of the average recurrence interval of an extreme climatic event (Haynes and others 2008 in Zhou et al. 2013). For example, a flood with a return period of 100 years is expected to occur once every 100 years. In other words, each year there is a 1 per cent probability of this type of flood event occurring. In the same way, a return period of 50 years means the flood is expected to occur once every 50 years, or have a 2 per cent probability of occurring each year, and so on.

The adverse effects can be categorised into direct and indirect effects. A list of potential adverse effects is given in Text box 4.1. The list is not exhaustive.

Text box 4.1 Potential adverse effects from floods

Direct adverse effects:

- Damage to buildings
- Damage to inventory, machinery etc. inside buildings
- Damage to infrastructure such as roads and railroads, water and sewerage system, power cables, and telecommunication cables.
- Erosion

Indirect adverse effects:

- Lost production and turnover for businesses
- Costs related to traffic restructuring and delays
- Loss, inconvenience, and damage from power cuts
- Contamination of water bodies
- Cost of time spent on administration and clean-up efforts in the aftermath of floods
- Negative health effects

Source: Vista Analyse and COWI (2015)
Note: The list is not exhaustive

The costing of flooding can be based stage-damage curves, which show the damage as a function of the extent and depth of floods. However, due to the complexity of urban contexts, costing in cities is often based on unit costs of flooding of specific assets (Zhou et al. 2012, Apel et al. 2006 and Ballestos-Canovas et al. 2013 in Olsen et al. 2015).

The unit costs should ideally include both direct and indirect adverse effects. Unit costs for material damages, such as damage to buildings, can for example be derived from insurance pay-outs after historic flood events. It is often more challenging to derive estimates/retrieve information about indirect effects (e.g. contamination of water bodies). as these are non-market effects. A description of methods that can be used to value these effects is given in section 3.5.2 and Appendix A.

Once unit costs for different asset groups / types of adverse effects have been established, the vulnerability can be measured using a GIS-based risk model which identifies flooded properties and the threshold values at which various damage classes will be flooded (Olsen et al. 2015).

An alternative approach is to apply average market insurance premiums for water-related damages in an area. This information could be retrieved from private insurance companies or public data bases. However, this is not an ideal approach due to the heterogeneity of cities; the size of the damage will vary considerably depending on the types of assets damaged in the flood.

If the adaptation measure is expected to prevent damage to one type of asset, the vulnerability analysis could focus on this asset group. For example, if rain gardens implemented in a residential area largely are expected to prevent flooded basements, one could apply the average value of insurance claims for flooded basements for the estimation of damage costs.

An example from Oslo of how insurance data could be used to estimate the potential for avoided damage from floods from blue-green solutions in an area called Ensjø is given in Text box 4.2. It should be noted that this is a simplified example which does not consider the effects of climate change, does not provide a complete picture of potential damage costs (indirect effects are not considered), and does not contain sufficient information about the effects of the proposed blue-green measures on flood risk compared to the conventional solutions.

Text box 4.2 Estimated avoided damage based on insurance premiums – example from Oslo

Ensjø area in Oslo

Ensjø area in Oslo has been subject to a major transformation in recent years. The area has been redeveloped from an industrial area with factories and car industry to a residential and commercial area. As part of the transformation, large investments have been made into creating new infrastructure, open public spaces and blue-green infrastructure. The blue-green infrastructure includes a surface-based system for stormwater management, whereby rainwater from surfaces (roofs, streets, parking lots) is collected in open channels and retained in pools before being led into a re-opened stream. The system for surface-based stormwater management is built to withstand a flood event with a 10-year return period.

To estimate the avoided damage from floods from the surface-based system, we have collected data from Finance Norway, which is the industry organisation for the financial industry in Norway, showing the number of insurance claims related to water damage and the value of these claims in Oslo municipality for the seven-year period from July 2007 to June 2014. The claims are from both private households and businesses. Note that the data does not include publicly owned buildings in Oslo and does therefore not provide complete information about the extent of the damage. However, the data should be relatively representative of the damages incurred by private households and businesses.

We have used numbers for water damages that arise from "intrusion from outside, above ground or through ground" due to "precipitation, meltwater, groundwater".[9]

Table Insurance claims (number and amount) related to precipitation in Oslo 2007-2014

Oslo Municipality, Insurance damages from surface water runoff	***Number of damages***	***Amount***
2007-2014 (7 years)	*4627*	*212,6 million NOK*
Average per year	*661*	*30,4 million NOK*

Source: Finance Norway in Vista Analyse (2014), table 4.1.

The numbers in the above table show that damages from July 2007 to June 2014 amounted to 213 million NOK, a yearly average of 30 million NOK. This is considered a conservative number since many damages are not captured by the data. We assume

[9] We have also assumed that the companies reporting insurance claims to Finance Norway have a market share of 86 per cent in Oslo and that there is an average excess requirement of 4,500 NOK for each claim.

Oslo municipality has the potential to reduce costs by 30 million NOK per year if it can prevent these damages.

Additionally, the frequency and intensity of rain storms is predicted to increase in the future because of climate change, which would increase the potential damages. However, the effect of climate change has not been considered in this example.

What proportion of this potential can be realised by the introduction of stormwater solutions in Ensjø? We have made a rough estimate of this effect by stipulating the share of damage costs in Ensjø based on the total damage costs for Oslo. 5000-7000 new apartments have been planned at Ensjø, which is 1.6 - 2.2 per cent of the total number of households in Oslo in 2012; 316,423 (SSB 2012). Based on this, we have assumed that the total number of households at Ensjø will be around 2 per cent of the total number of households in Oslo. We do not know what share of Ensjø's planned 100,000 m^2 of industrial area would be of the total industrial area in Oslo. For simplicity, we will assume that it will equal the share of households; 2 per cent.

Based on these assumptions we can estimate that around 2 per cent of the annual damages in Oslo would occur at Ensjø if the area has conventional solutions for stormwater management, with a standard equal to the average in Oslo.

If the local surface-based system will prevent these water-related damages, Ensjø could save annual costs of around 600,000 NOK per year (2 per cent of the annual costs for Oslo). Assuming a life span for the local surface-based system of 40 years, and a social discount rate of 5 per cent, the present value of the damage costs (discounted over 40 years) is approximately 10.3 million NOK. In a CBA, the present value of the benefits (here, avoided flood damage) should be compared with the present value of investment costs and any other costs incurred by the project.

Source: Example adapted from Vista Analyse (2014), pp. 33-39.

Expected annual damage

Combining the knowledge of the hazard with the vulnerability gives an estimate of the Expected Annual Damage (EAD) of floods in an area. See Olsen et al. (2015), Zhou et al. (2013) and Zhou et al. (2012) for detailed descriptions of how the EAD could be estimated using hydraulic and statistical modelling.

Ideally, the city would have pre-prepared flood risk predictions that can be used as input to the analysis. However, if the analyst does not have access to hydraulic models or flood risk maps of the area, a simplified approach would be to collect data on floods that have affected the area in the past and the conditions under which these floods occurred. This approach would only be relevant for relatively small areas, for which it is possible to link previous floods, the conditions that caused these floods and the damage caused by the flood. For example, let us assume a rain garden is considered for a residential garden that has experienced flooding of its basement several times in the past. In this case, one could collect historic data on the number of times the property's basement has been flooded, the conditions under which this happened (e.g. how many mm of rain over what duration of time), and the cost of the damage caused each time the basement was flooded. A simplified prediction of the likelihood of future floods could for example assume that the flood profile of the property will be the same in the future as it has been in the past, with the same associated damage cost. Further, one would assume that the impact of the rain garden is somewhere between zero and full removal of flooding of the basement. Accounting for climate change, however, is more complicated as one would have to relate predicted future changes in precipitation / weather conditions with the likelihood of floods occurring. This could for example be done by identifying a threshold level at which the basement would flood, and assess the change in likelihood of this threshold being reached in the future.

In general, the cost and effort necessary to undertake the analysis should be proportional to the extent of the measure(s) being considered.

4.3 The alternative scenario; rain garden

As already mentioned, we will assume that there has been a selection process prior to this analysis, from which a rain garden is assessed to be the most suitable measure for an area. Other alternative scenarios which would have been natural to assess include the use of conventional solutions (expansion of the drainage system) and other blue-green measures (e.g. green roofs).

To establish the alternative scenario, it is necessary to assess the costs and benefits of implementing a rain garden relative to the baseline scenario. This is discussed further in sections 4.4 and 4.5.

4.4 Costs

The costs of rain gardens can be categorised into investment costs, operation and maintenance costs, and the opportunity cost of land use. So far there is little experience with the implementation of rain gardens in Poland, so information about costs of rain gardens is limited. For specific installations of rain gardens being considered, the responsible firm should be able to provide an estimate of the costs required for the investment and operation/maintenance of their proposed rain garden.

Investment costs

The cost of implementing a rain garden depends on several factors, including its size, soil conditions, location, design, time of implementation and the types of plants and materials used.

According to the Minnesota Stormwater Manual, the surface area of a rain garden should be 5 – 10 per cent of the area from which it infiltrates stormwater runoff (MPCA 2008). In addition to the size of the runoff-area, the infiltration capacity of the filtering layer, the intensity and duration of precipitation, and local requirements to the maximum allowed amount of runoff into the sewerage system or streams, determine the appropriate size of a garden bed (Paus and Braskerud 2013).

Rain gardens that require drainage are generally more expensive than rain gardens where the soil at the location can be used as filter medium. This will depend on the local soil's ability to infiltrate water. Clay soil is generally unsuited for infiltration and rain gardens implemented in areas with clay soils will always need drainage (Paus and Braskerud 2013).

Operation and maintenance costs

Costs related to the operation and maintenance of rain gardens depend on a range of different factors, for example whether it is necessary to replace the soil underneath and the type of vegetation used.

Upkeep is important after a rain garden has been created to ensure that vegetation is established. Once the vegetation is established, the need for maintenance is similar to that of parks, with watering during dry periods, mechanical weed control and fertilisation as needed. Slurry on the filter surface may also need to be removed (Vista Analyse 2015).

It follows that, if the rain garden is implemented in a park, it would be reasonable to assume that the rain garden would not require additional operation and maintenance cost above what is needed to maintain the park.

Opportunity cost of land use

The implementation of a rain garden will require some area of land. This has a cost because the area could otherwise be used for something else. A relevant question is then; what is the value of this area of land in its best alternative use? To answer this question in practice, one can generally look at what the area would have been used for in the absence of the rain garden. If the rain garden would be implemented on a vacant block that otherwise could have been used to build properties, a reasonable measure of the opportunity cost of the land use could be the average land value (per m^2) in the area. However, if the rain garden is implemented in a park, where the current use of land is very similar to that of the rain garden (vegetative cover) one could assume that there is no opportunity cost incurred from the implementation of the rain garden.

4.5 Benefits

4.5.1 Avoided damage from floods

An important benefit of investing in a rain garden is the avoided damage from future floods. The expected avoided damage is calculated as the difference between the expected damage with and without adaptation, i.e. the difference between the baseline damage and the (residual) damage under adaptation.

The alternative scenario (implementation of a rain garden) would presumably have lower costs associated with damage from floods, compared to the baseline scenario, depending on the capacity of the rain garden to absorb and delay the flow of water and what this translates into in terms of flood risk reduction. Additionally, the potential damage from floods would also depend on the rain garden's ability to avoid contamination of water bodies. The difference in damage cost between the alternative scenario and the baseline scenario may amount to the full amount, or a portion of, the damage cost. The below sections describe factors impacting a rain garden's ability to control the quantity and quality of stormwater runoff.

Water quantity control

A rain garden's ability to control the quantity of water depends on its capacity to infiltrate water as well as its ability to delay the flow of water entering the drainage system. A rain garden with underdrain - leading water to the drainage system - infiltrates less water than a rain garden with no underdrain (MPCA 2008). The latter allows water to infiltrate to the ground and is also better suited to restore groundwater supplies. Whether drainage is necessary depends on the properties of the local soil. For example, drainage is needed in areas with clay soil.

The capacity of a rain garden to infiltrate water is a complex process influenced by the initial water content of the bioretention media, the capillary suction, and the pressure head from the ponded water (Paus et al. 2016). Paus et al. (2016) find that the infiltration capacity can be reasonably predicted based on the following parameters;

- Surface area

- The value for saturated hydraulic conductivity of the of the bioretention media
- The maximum level of water on the surface.

Higher levels of the above factors would result in a higher fraction of runoff infiltrated. Also, site-specific properties such as catchment size and slope, surface types, and time of concentration have large impacts on the infiltration capacity (Paus et al. 2016).

Water quality control

Stormwater runoff carries various pollutants with it such as oil, fertiliser, pesticides, sediment, and chemicals (Riverlink n.d.). If left untreated, stormwater runoff could contaminate streams, rivers and lakes and potentially affect recreational activities such as swimming and fishing, injure aquatic plants and animals, and contaminate drinking water.

A rain garden can improve the water quality by filtering pollutants from stormwater runoff. Particles in stormwater are withheld via sedimentation on the surface of the rain garden and filtration through a filter medium. The effect from sedimentation can be increased by ensuring slow inflows of water into the rain garden. The filter medium's ability to filter pollutants depends largely on its grain distribution properties. The properties of the filter medium also determine what type of pollutants that can be withheld (Paus 2016).

According to Paus (2016), a rain garden could reduce:

- Particles by around 90 per cent
- Oil by around 90 per cent
- Dissolved heavy metals (Cd, Cu, Pb, Zn) by around 80 – 90 per cent
- PAHs (Polycyclic Aromatic Hydrocarbons) by around 70 – 90 per cent
- Phosphate by around 63 per cent

The benefits of the reduction of pollutants depend on where these pollutants would have ended up in the absence of the rain garden and the impact this could have on humans and aquatic life.

4.5.2 Co-benefits

The plants and vegetation of rain gardens can provide ancillary benefits (co-benefits) in addition to the primary purposes of stormwater quantity and quality control. These co-benefits include;

- Noise reduction
- Improved air quality
- CO_2 capture and storage
- Local climate control
- Biodiversity
- Pollination
- Visual amenity
- Restoration of groundwater supply

The degree to which these co-benefits are realised and their significance will depend on several factors, including the size of green area provided by the rain gardens. Each of the potential co-benefits are described in further detail below. Methods to value these types of benefits (non-market benefits) are described in Appendix A.

Noise reduction

Noise as a result of human activity can be a problem in urban areas and be experienced as ‘noise pollution’. Green infrastructure such as lawns, trees, and hedges can reduce the noise by absorbing and reflecting sound waves. The noise is reduced directly (absorption) and indirectly (reflection – the noise is spread over a larger area and is experienced as less intense) (Fang and Ling 2003).

Bolund and Hunhammar (1999) refer to studies with examples of the significance of urban vegetation for the level of noise, where for example a lawn instead of concrete ground cover can reduce the level of noise from the surroundings by 3dB(A)[10]. Noise reduction is important because noise above certain levels have documented, negative health effects on sleep, ability to concentrate etc. Noise can result in both physical and psychological ailments. In cities, it can often be difficult to build sound baffles to a large extent, which is often done along roads outside cities. Green infrastructure, including rain gardens, can function as “softer” solutions for the problem of noise pollution in city centres.

Improved air quality

Traffic, industrial activity, transportation, heating of houses and workplaces, etc. all contribute to problems with low air quality in cities. Urban vegetation contributes to improve air quality by filtering particles and polluting gases such as carbon monoxide (CO), nitrogen dioxide (NO_2), and sulfur dioxide (SO_2) (Nowak 1994 and Escobedo and others 2008 in Gomez-Baggethun and Barton; Bolund and Hunhammar 1999). The ability to filter the air increases with the leaf area, which means that trees have a larger cleansing effect than bushes, which in turn have a larger effect than grass (Givoni 1991).

Good air quality is important to reduce respiratory disease and other negative health effects. Poor air quality can lead to excess mortality and morbidity, more days of sick leave, treatment expenses, and lower production and welfare.

CO_2 capture and storage

Photosynthesis is necessary for plants and trees to stay alive and grow. Photosynthesis is a chemical process that converts, among other things, the greenhouse gas CO_2 into biomass and oxygen (O_2). Urban vegetation - all that is green and alive - will therefore help to bind CO_2.

Local climate control

Vegetation generally absorbs heat from the air by means of evapotranspiration.[11] In addition, cities are typically warmer than surrounding, rural areas due to their energy consumption and building mass (the heat-island effect). For cities located in warm climates, green areas are therefore important to counteract this heat effect.

Biodiversity

Urban environments have many ecosystem components that act as habitats for different species. The variety in natural habitats / ecosystem components is also an important

[10] Decibels, a measure of noise/sound.

[11] Extraction of water in the soil by evaporation from the surface and transpiration from plants.

part of diversity.[12] Despite the constraints imposed by urbanisation, there is also a certain animal and plant life in cities. Relatively speaking, biodiversity is very low, but urban areas often have a surprisingly high number of species of certain taxonomic groups.[13]

In isolation, diversity of species is usually highest in medium urbanised areas, and decreasing with increasing urban structure (Gomez-Baggethun and Barton 2013). Biodiversity will therefore rarely be the main motivation for conservation and management measures in urban areas. However, there are certain instances where natural areas in or near cities may be important.

This presence of species of plants and animals is something many people appreciate. Watching squirrels, piglets, butterflies, frogs and salamanders, birds and beautiful plants can be an enrichment. Also, some people will value knowing that somewhere nearby there is animal life, even though they may never see the animals themselves.

Both the existence value (non-use value) and the actual value (use value) of physically observing an animal or plant is thus an important benefit related to green areas, trees, open streams, rivers and water.

However, the composition and design of urban natural elements is important. Even if something is green in colour does not mean it replaces / maintains species diversity in any way. A lawn with short-cut grass can be green, but is biologically a "lifeless desert". This may mean that the existence value is small. It should be noted that only a fraction of species is able to survive in urbanized areas, if it is facilitated.

Pollination and spreading of seeds

As already mentioned, urban areas often house a relatively large number of species of certain taxonomic groups. Two good examples of these are birds and bees. The roles of both of these animal groups in an ecosystem include tasks such as spreading seeds and pollinating. These are basically very important and to some extent irreplaceable processes, and one of the main reasons why nature is able to produce food. In urban contexts, however, pollination is less important, but for flowers and trees in parks and gardens, as well as residents' gardens, it is an important ecosystem service.

Amenity value

Green infrastructure can also add to the aesthetics of urban landscapes. However, if the green infrastructure includes small installations that go unnoticed to the public eye (e.g. rain gardens in private gardens), they are unlikely to impact the urban landscape in ways that provide recreational benefits (Zou et al. 2013). To have an impact on amenity value, the green infrastructure must generally be implemented large scale.

Restoration of groundwater supply

Cities deplete groundwater by tapping it as water supply. Lower water tables can create problems for groundwater-fed streams, lakes and wetlands, which either dry up or are instead supplied by dirtier surface water (University of Wisconsin-Madison 2002). Rain gardens can replenish, or recharge, groundwater supply and thereby help counter these effects.

[12] The genetic variation, as the third component of biological diversity, may be less central in urban contexts.

[13] A group in the biological system that consists of one or more biological species, which are usually thought to be related.

4.6 Parameters for calculation of net present value

4.6.1 Social discount rate

As described in section 3.5.4, a social discount rate of 5 per cent should be applied.

4.6.2 Project period

The estimated costs and benefits of a project should cover a period appropriate to the project's economically useful life and its likely long-term effects (European Commission, 2014). The life span of a rain garden is determined by the first of the following three events that occur (Paus 2016):

1. The filter medium is clogged and infiltration through the rain garden ceases
2. No remaining filtering capacity in the filter medium
3. The concentration of pollution builds up to too high levels

The first event has previously been thought to a limiting factor for the life span of rain gardens. However, recent research shows that rain gardens can have a good infiltration capacity after many years of operation (see Paus et al. 2014b). This is thought to be due to vegetation, which helps to maintain infiltration through the development of root systems, as well as earth worms, insects etc., which help make the filter medium more porous over time.

The second event occurs when there is no remaining filtering capacity of the rain garden, and unfiltered pollutants can flow into the recipient. Studies have shown that the it can take several years before this happens, for example 40 years for zinc (see Paus et al. 2014 and Paus et al. 2014c). A review of six existing rain gardens with varying operating time (2 to 8 years) also indicated a very good residual capacity for heavy metals (> 82%) (see Paus et al. 2014b).

The third event occurs when the rain garden has withheld pollution to the point where it constitutes a hazard according to health-based acceptance criteria for contaminated ground. For normal concentrations of pollutants in stormwater this may be expected to take a very long time as the concentration of pollution in water is low compared to these acceptance criteria. Where rain gardens are implemented near residential areas, kindergardens etc., the expected useful life should however be considered with this in mind (Paus 2016).

Based on the above information the project period for an analysis of rain gardens would need to be assessed based on the design, location of rain gardens, as well as observed life spans. However, in the absence of such information, it appears reasonable to assume a life span of 40 years. This life span was also applied in Vista Analyse and COWI (2015).

4.7 Concluding remarks

In this chapter, we have provided some guidance on issues to be considered, the kind of methods that can be used etc. in CBAs of blue-green measures, with a focus on rain gardens. Since this is not a numerical example, it has not made sense to comment on all steps of a CBA, as described in chapter 3. For example, we have not commented on the sensitivity analysis, distributional analysis, or overall assessment of the project, but these will of course need to be included in actual applications of CBAs.

References

Boardmann, A., Greenberg, D., Vining, A., Weimer, D. (2006). *Cost Benefit Analysis*. Concepts and Practice. Third edition, Prentice Hall, New Jersey.

Bolund, P. og S. Hunhammar (1999). Ecosystem services in urban areas, *Ecological Economics*, 29, 293–301.

Gomez-Baggethun, E. and Barton, D. (2013). Classifying and valuing ecosystem services for urban planning. *Ecological Economics*, *86,* pp. 235–245.

Chambwera, M., G. Heal, C. Dubeux, S. Hallegatte, L. Leclerc, A. Markandya, B.A. McCarl, R. Mechler, and J.E. Neumann (2014). Economics of adaptation. In: *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 945-977.

COWI (2014). Metoder for beregning av klimafaktorer for fremtidig nedbørintensitet. ("Methods for calculating climate factors for future precipitation intensity"). In Norwegian.

Direktoratet for samfunnssikkerhet og beredsskap (DSB) *("The Nowegian Directorate for Civil Protection")* (2016). Risikoanalyse av regnflom i by ("Risk assessment of pluvial flooding in cities."). In Norwegian.

European Commission (2014). Guide to Cost-Benefit Analysis of Investment Projects – Economic appraisal tool for Cohesion Policy 2014-2020. December 2014. Available from: http://ec.europa.eu/regional_policy/sources/docgener/studies/pdf/cba_guide.pdf [Accessed 19 June 2017].

Fang, C.F. og Ling, D.L. (2003). Investigation of the noise reduction provided by tree belts, *Landscape and Urban Planning*, 63, pp. 187–195.

Federal Interagency Stream Restoration Working Group (FISRWG) (1998). Stream Corridor Restoration: Principles, Processes, and Practices. Revised August 2001. GPO Item No. 0120-A; SuDocs No. A 57.6/2:EN3/PT.653.ISBN-0-934213-59-3.

University of Wisconsin-Madison (2002). 'Rain gardens' help recharge ground water. Available from: http://news.wisc.edu/rain-gardens-help-recharge-ground-water/ [Accessed 8 October 2017].

Givoni, B. (1991). Impact of planted areas on urban environmental quality: a review, *Atmospheric Environment*, 25B (3), 289–299.

Lindhjem, H., T. Hu, Z. Ma, J. M. Skjelvik, G. Song, H. Vennemo, J. Wu and S. Zhang (2007). Environmental Economic Impact Assessment in China: Problems and Prospects. *Environmental Impact Assessment Review*, 27(1), pp. 1-27.

Markandya, A., Galarraga, I. and de Murieta, E.S. (2014). *Routledge handbook of the economics of climate change adaptation*. Routledge, Oxon and New York.

Minnesota Pollution Control Agency (MPCA) (2008). Minnesota Stormwater Manual. St.Paul, Minnesota, USA. Available from: https://stormwater.pca.state.mn.us/index.php?title=Main_Page [Accessed 02.10.2017].

Navrud, S. (2001). Economic valuation of inland recreational fisheries. Empirical studies and their policy use in Norway. *Fisheries Management and Ecology*, 8 (4-5), pp. 369-382.

Navrud, S. (2004). Value transfer and environmental policy. Chapter 5 (pp. 189-217) in Tietenberg, T. and H. Folmer (eds.) 2004: The International Yearbook of Environmental and Resource Economics 2004/2005. A survey of current issues. Edward Elgar Publishing, Cheltenham, UK and Northampton, MA, USA.

Navrud, S. and Ready, R. (2007). Environmental value transfer: Issues and methods. The economics of non-market goods and resources series, Book 9, Springer, Dordrecht, Netherlands, 290 p.

Norwegian Government Agency for Financial Management (2014). *Veileder i samfunnsøkonomiske analyser ("Guidelines for Cost-Benefit Analysis").* In Norwegian. Avaliable from: https://dfo.no/Documents/FOA/publikasjoner/veiledere/Veileder_i_samfunns%C3%B8konomiske_analyser_1409.pdf [Accessed 22 June 2017].

Olsen, A.S., Zhou, Q., Linde, J.J. and Arnbjerg-Nielsen, K. (2015). Comparing Methods of Calculating Expected Annual Damage in Urban Pluvial Flood Risk Assessments. *Water 2015*, 7, pp. 255-270.

Paus, K. H. and Braskerud, B. C. (2013). Forslag til dimensjonering og utforming av regnbed for norske forhold. *("Suggestions for dimensioning and design of rain gardens for Norwegian conditions") Vann*, 01, 2013. Available from: http://dagvattenguiden.se/wp-content/uploads/2013/04/Paus-og-Braskerud_Forslag-til-dim-og-form-av-regnbed_Vann1-2013.pdf [Accessed 1 October 2017].

Paus, K. H., Morgan, J., Gulliver, J. S. and Hozalski, R. M. (2014). Effects of Bioretention Media Compost Volume Fraction on Toxic Metals Removal, Hydraulic Conductivity, and Phosphorous Release. *Journal of Environmental Engineering*, 140.

Paus, K. H., Morgan, J., Gulliver, J. S., Leiknes, T. and Hozalski, R. M. (2014b). Assessment of the Hydraulic and Toxic Metal Removal Capacities of Bioretention Cells After 2 to 8 Years of Service. *Water, Air, and Soil Pollution*, 225.

Paus, K. H., Morgan, J., Gulliver, J. S., Leiknes, T. and Hozalski, R. M. (2014c). Effects of Temperature and NaCl on Toxic Metal Retention in Bioretention Media. *Journal of Environmental Engineering*, 140.

Paus, K. H., Muthanna, T. M. and Braskerud, B. C. (2016). The hydrological performance of bioretention cells in regions with cold climates: seasonal variation and implications for design. *Hydrology Research, 47.2*, pp. 291-304.

Paus, K. H. (2016). Regnbed som renseløsning for forurenset vann ("Rain gardens as cleaning solution for polluted water"). In Norwegian. January 2016, version 1.0. Available from: http://dagvattenguiden.se/wp-content/uploads/2016/06/Overvann-Regnbed-som-renselosning.pdf [Accessed 02.10.2017].

Riverlink (n.d.). Stormwater Problems & Impacts: Why All The Fuss? Available from: http://riverlink.org/wp-content/uploads/2014/01/stormwaterseriesfinal1.pdf [Accessed 8 October 2017].

Vista Analyse (2014). Verdien av urbane økosystemtjenester: Fire eksempler fra Oslo ("The value of urban ecosystem services: Four examples from Oslo"). In Norwegian. Report number 2014/46.

Vista Analyse and COWI (2015). Kostnader og nytte ved overvannstiltak ("Costs and benefits of surface water measures"). In Norwegian. Report number 2015/02.

Zhou, Q., Mikkelsen, P. S., Halsnæs, K. and Arnbjerg-Nielsen, K. (2012). Framework for economic pluvial flood risk assessment considering climate change effects and adaptation benefits. *Journal of hydrology*, 424-425, pp. 539-549.

Zhou, Q., Panduro, T. E., Thorsen, B. J. & Anbjerg-Nielsen, K. (2013). Adaption to Extreme Rainfall with Open Urban Drainage System: An Integrated Hydrological Cost-Benefit Analysis. Environmental Management (2013) 51, pp. 586–601, DOI 10.1007/s00267-012-0010-8

Appendix A: Methods for valuation of non-market effects

The economic value of a change in a non-market good or service is measured based on people's collective willingness to pay to achieve (or avoid) this change. There are two main categories of approaches for the valuation of willingness to pay for non-market effects; revealed and stated preference methods. Revealed preference methods rely on observations of what people do, while stated preference methods ask people directly about how they value different non-market goods and services.

The revealed and stated preference methods are primary valuation studies which require significant amounts of time, resources, and expertise to be conducted. Due to these constraints, it is sometimes necessary to transfer adjusted value estimates from other sites to the project setting. This is known as value transfer (or 'benefit transfer'). It is however important to exercise caution when making such transfers. See Navrud and Ready (2007) for a comprehensive discussion of this method.

A further description of the methods for revealed preference, stated preference, and value transfer is given below.

Revealed preference methods

The revealed preference method uses observations of people's actions to infer their valuation of various goods and services. Examples of such methods include the travel cost method and the hedonic pricing method.

Travel cost method

The travel cost method uses the cost incurred by individuals travelling to reach a site, and the cost of staying at the site as a proxy for the environmental value of that site. The travel cost method is a lower bound in the actual willingness to pay – most people will of course value the recreational site distinctly higher than the cost of getting there. Over time, they might find cheaper and more efficient ways of making the travel without this implying that they value the site less. People who are fond of recreation may purchase a home close to the site, without this implying that they value the site less than others. There are also other challenges with this method, for example, that people like to have more purposes with a journey and that the time spent on the journey may not always be considered a cost.

Hedonic pricing method

The hedonic pricing method estimates the value of a non-market good by examining the relationship between the non-market good and the demand for some complementary good that has a price in the market.[14] The most commonly used method internationally is the hedonic pricing property method, which is based on the fact that the price of a property is determined in part by the specific characteristics of the property's structure, location and environmental characteristics. Environmental goods and services such as landscape amenity, noise and air quality are included among the characteristics. A property that has better environmental characteristics will presumably command a higher market price than a similar property with worse characteristics.

[14] A complementary good is a good that you buy less of if the "price" of the primary good increases (which is to say that its quality decreases). Travel expenses to a recreational site is a complementary good to the site itself, hence the travel cost method is actually a special instance of the hedonic pricing method.

Stated preference methods

Stated preference methods involve asking people if they are willing to pay to avoid changes in a non-market good or service and given that they say yes, how much they are willing to pay, typically per year per household. One can either interview people or reveal the willingness to pay through referendums.

The main method that uses personal interviews is called contingent valuation.

Contingent valuation

This method constructs a hypothetical, or ‘simulated’, market via a questionnaire methodology where respondents answer questions concerning what they are willing to pay for a specified change.

In the interviews or the questionnaire, the respondents are asked hypothetical questions about their willingness to pay to avoid negative changes in a non-market good or service or (more often) to achieve positive changes. The respondents are asked direct questions to reveal what they are willing to pay for a given good (WTP = willingness to pay) or will require in compensation to give up (WTA = willingness to accept), under certain given and specified assumptions.

It is important to describe the changes in non-market goods or services so that the respondents get a good understanding of the environmental changes in question. The wording of the question can often significantly impact the willingness to pay people will specify. It is therefore important to test for such effects, and if possible, make the necessary adjustments.

Value Transfer method

When there are one or more valuation studies available for a good or service, one must assess whether the estimated values could be transferred from the location of the original study to the location to which one wishes to transfer the value. This kind of transfer is often called benefit transfer- However, the method encompasses both benefits and damage, and should instead be called value transfer (Navrud 2004, Navrud and Ready 2007).

The benefit of the value transfer method is that transferring values from other studies often is cheaper than conducting a primary study. Primary studies also often require a significant amount of time, and value transfer is therefore a faster method in comparison.

The weakness of the value transfer method is that the uncertainty of the estimates increases. There could be several significant differences between the primary studies and the study to which one wishes to transfer the value estimates. For example, the good or service could have different characteristics, the change in amount/quality could be different, the availability of substitutes could be different, and the context for the valuation could be different. In addition, there could be differences in income, education, preferences, and attitudes among the affected households; which could lead to a different valuation of the same environmental change (Navrud 2001).

These uncertainties are in addition to the uncertainties already inherent in the original estimates. The increase in uncertainty in the estimates by the value transfer must be evaluated against the benefit of value transfer in terms of reduced time and costs, as well as an assessment of an acceptable level of uncertainty in the relevant situation (Navrud 2004).

Nevertheless, in a practical benefit-cost analysis of a project (such as one or more rain gardens) there are several non-market impacts to track in an analysis conducted on limited time, and value transfer of at least some of the impacts is unavoidable.

There are three main methods for value transfer (Navrud 2004; Navrud and Ready 2007):

1. Unit transfer
2. Transfer of Willingness-to-Pay function
3. Meta-analysis

Unit transfer

Unit transfer is the transfer of estimates of average willingness to pay for a certain environmental good or service for the location of the original study to the location where the new analysis is being conducted. This is the simplest form of value transfer and the one that arguably is used the most often in practical CBA. The transfer can be done with or without corrections of differences between the two locations. Corrections can be made based on inflation, level of income, or expert opinions of differences between the original and the new location.

One should strive to find a value estimate from a study that is as similar as possible to the new location in terms of the change in the environmental good or service being considered, socio-economic characteristics of the population etc. The transfer could also be based on estimates from several original valuation studies.

Transfer of the willingness-to-pay function

The willingness-to-pay function estimates the willingness to pay for changes in an environmental good or service as a function of various explanatory variables (for example income, education, use of the environmental good or service etc.). Estimation of this function at the new location is done by using the same coefficients in the function that was used for the original location, but use the mean value from the new location for the explanatory variables. This requires that the environmental change and the explanatory variables are comparable, and that the preferences of the respondents are the same, for the new and the original location. One should strive to find an original location that is as similar as possible to the new location. There also needs to be data available for the explanatory variables (included in the willingness-to-pay function) for the new location.

If a unit transfer is subject to appropriate corrections for income difference etc., the result may be viewed a simple case of a willingness-to-pay function.

Meta-Analysis

Meta-analysis is a statistical regression analysis of several previous valuation studies for a certain environmental good, to assess how the willingness-to-pay for the environmental good varies with different characteristics of the good, the relevant population, and aspects of the valuation method used. As every study is used as an observation, it is problematic to perform meta-analyses with few observations in the regression analysis. More than one estimate could be used from the same study if for example one has used different valuation questions in the original study, however one should then keep in mind that estimates from the same study would be correlated.

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