Interreg North Sea Region CATCH European Regional Development Fund
EUROPEAN UNION

A Stepwise Method for Midsize Cities to Identify, Assess and Value Ecosystem Services

Kris Lulofs, Gül Özerol and Athanasios Votsis

CSTM, University of Twente, The Netherlands

2 November 2022

Table of Contents

1. Introduction

This method offers guidance in identifying, assessing and valuing ecosystem services (ESS). The target users of the method includes urban planners and decision-makers in midsize cities. The method covers multiple options ranging from basic activities, which deliver qualitative information, to more advanced options, which require a quantitative analysis. The choice between these options is left to the users. With this flexible approach, the method serves as a tool for collective decision-making. If the ESS in cities are identified, assessed and valued, such activities will create new insights for decision-making.

Ecosystem services are the revenues from natural systems that enhance human well-being. Natural systems in cities are often referred to as "the urban natural capital". Urban planners can maximize the benefits by strategies that are known as "renaturing cities'', ''nature-based solutions'', ''urban greening'' and ''green infrastructure''. If urban planners add natural elements, the urban natural capital will grow. Such natural capital might help to deal with urban challenges, such as extreme temperatures and weather events, air pollution, excessive noise, and scarcity of space for leisure and social bonding activities.

Urban climate change adaptation (CCA) projects can have impact on the urban natural capital for the better or the worse. Applying this method only enables the identification, assessment, and valuation of ESS, without imposing a certain direction for action. The method takes no position in whether urban planners and decisionmakers should strive for a positive impact.

2. Summary of the Method

The core of the method consists of:

- **Figure 1** that visualizes the relationship between the natural capital, ESS categories, and human well-being; as well as the influence of CCA projects.
- **Figure 2** that introduces the four steps to identify, assess and value ESS.
- A **''cookbook''** per step with detailed guidance for each step.

Furthermore, in the ''**cookbook**'':

- **Table 1** summarizes the different ESS that are relevant for cities, specified for the four ESS categories as included in Figure 1.
- **Figure 3** guides the user on how to use the ''**cookbook''** while elaborating step 1.
- **Figure 5** guides the user on how to use the ''**cookbook''** while elaborating step 4.

Acknowledgements: We are indebted to the CATCH partners for the feedback they provided on draft versions. This method is rooted in the Millennium Ecosystem Assessment (MEA) programme of the United Nations[1]. In the MEA programme, the core knowledge gained in several decades of research and development was brought together and integrated into an inclusive typology of ESS. The MEA did not focus on urban natural systems and their ESS yield specifically. Therefore, we made an elaboration of ESS categories, focusing on urban areas (see Table 1). Furthermore, a substantial body of valuation methods found in OECD's environmental cost-benefit analysis guidelines[2] is added to MEA in Step 4 of this method. The latter to guide assessing and valuing the ESS delivered by CCA projects.

[1] https://www.millenniumassessment.org/en
[2] https://www.oecd.org/env/cost-benefit-analysis-and-the-environment-9789264085169-en.htm

3. Key Relationships

Figure 1 visualizes the relationships between the urban natural capital, the four ESS categories, and the well-being of the people; as well as how CCA projects are of influence. In this figure, **blue arrows** represent forward reasoning from a CCA project towards its impacts upon urban natural capital and ESS, and **green arrows** represent backward reasoning, from peoples' needs in an urban area towards related ESS and required urban natural capital leading to terms of references for (CCA) projects.

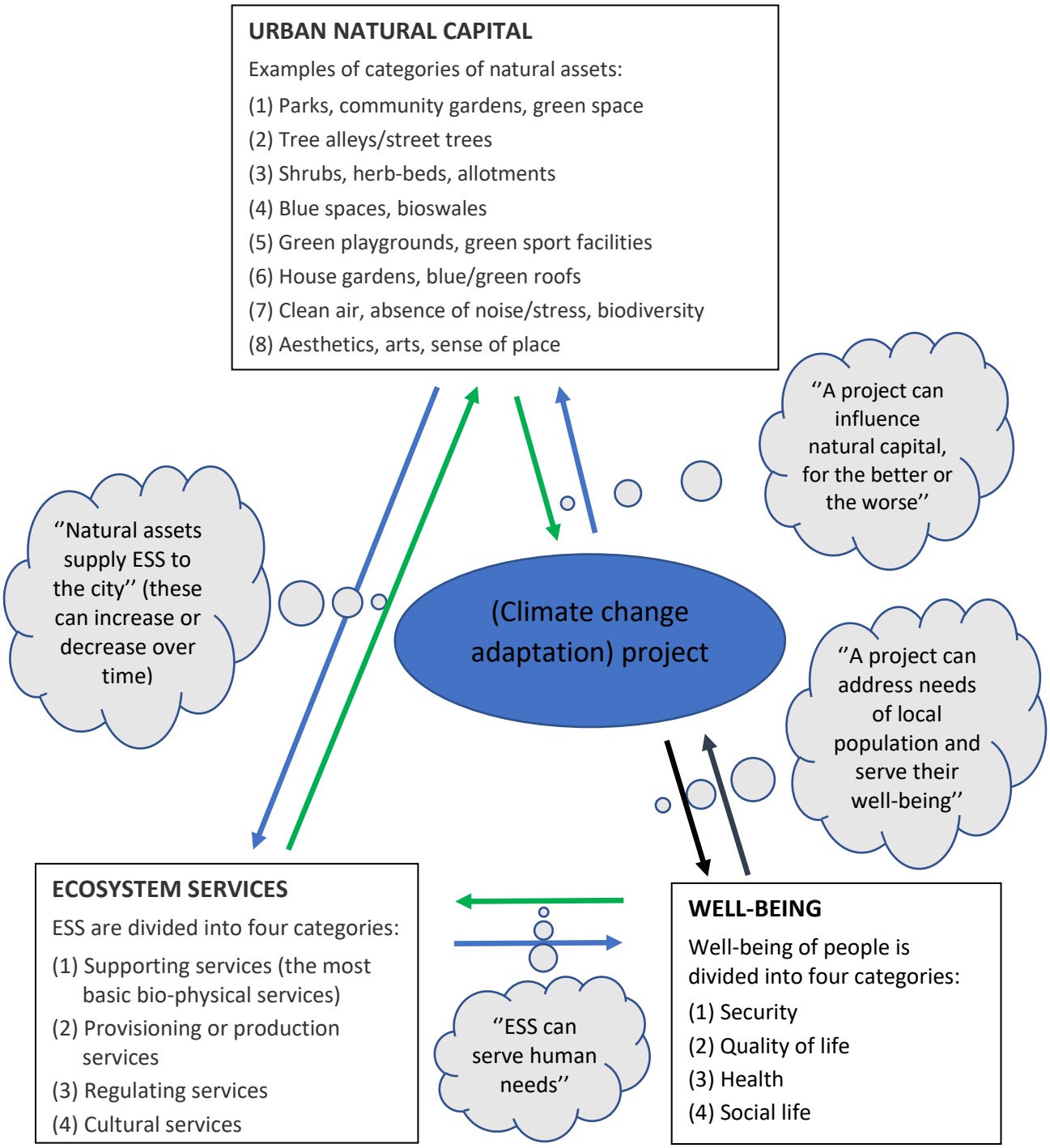

Figure 1. Relationships between CCA projects, urban natural capital, ecosystem services, and well-being (**Blue arrows** represent 'forward reasoning', and **green arrows** represent ''backward reasoning'')

4. The Stepwise CATCH ESS Method

The method that offers guidance in identifying, assessing and valuing ESS consists of four steps as shown in Figure 2. The process starts with Step 1, through which the scope and the relevant ESS are identified depending on the aims of the CCA project. In Step 2 indicators for each selected ESS are identified. In Step 3 the units for measurement or estimation are selected, which is followed by the actual estimation and measurement. Step 4 concerns the valuation of ESS in non-monetary and monetary terms. The right-side of Figure 2 emphasizes that the assessment is often done with an urban CCA project and/or the local needs of people in mind (cf. Figure 1). This is likely to influence decisions in each step, including whether all four steps are completed or not, and to what level of detail.

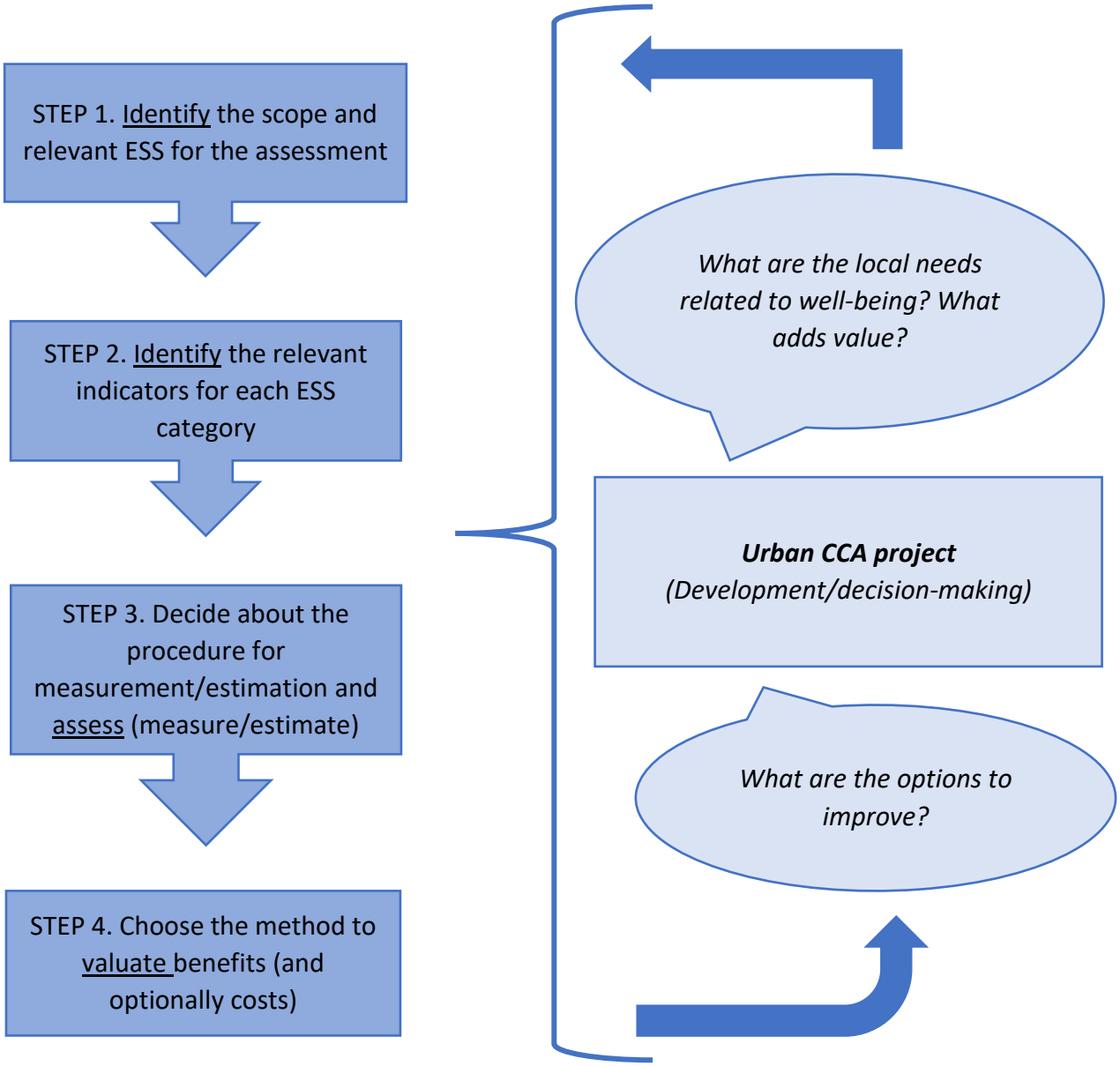

Figure 2. Overview of the Stepwise CATCH ESS Method

5. "Cookbook''

This cookbook offers support for the four steps included in Figure 2. It is assumed that there is an activity with an aim to identify, assess and valuate ESS that are linked to a CCA project.

- Divided in 15 questions, the cookbook makes it possible to adjust the decisions and activities according to your focus and needs. Tailoring the approach to the users' needs is important, since the quantification and valuation of ESS is not always required or needed. Sometimes it is sufficient to identify the kinds of ESS yields and to conclude that these revenues are positive. Other times, a thorough look at the costs and benefits is needed.
- It is tempting to guide towards extensive analysis and complete information and knowing the system and how it works to every detail. If the resources are restricted, there is a trade-off between a broad and a deep analysis, or between the extremes of knowing ''a bit about a lot'' and knowing ''a lot about little''. Starting broad and then zooming in is also an option.
- Across the questions there is a distinction between the current status in terms of urban natural capital and related ESS revenues and the changes brought about by the envisioned activity. Some activities focus on understanding the current status ('present baseline'), while others aim to identify and/or assess the envisioned changes ('alternative futures').

Step 1: Identify the relevant scope and ESS for the assessment

There are 8 guiding questions suggested for Step 1. The user should reflect on what is needed. The possible choices in Step 1 are as follows:

- In its simplest form, Step 1 can include **the questions 1-3** only to focus on the project area and a qualitative identification of the relevant ESS that the project brings.
- If the interest of the endeavour is also whether this yield makes sense in the context of the existing urban natural capital, Step 1 should also include **the questions 4 and 5**.
- If the interest of the endeavour is also whether project-related ESS make sense for the wellbeing and needs of the local people, Step 1 should also include **the questions 6-7**.
- For all options above, Step 1 ends with answering **question 8** to reflect on the results of Step 1 and to decide on whether to stop the endeavour or to engage in Step 2.

The above choices result in four options for Step 1. Figure 3 provides an overview of these options and the corresponding questions.

Figure 3. Matrix of Step 1 options

		Include the assessment of existing natural capital?	
		No	**Yes**
Include the assessment of people's wellbeing and needs?	**No**	**Questions 1-3 and 8;** just the project-related ESS identification	**Questions 1-5 and 8;** project-related ESS identification plus mapping existing urban natural capital
	Yes	**Questions 1-3, 6-7 and 8;** project-related ESS identification plus mapping peoples' needs	**Questions 1-8;** project-related ESS identification plus mapping existing urban natural capital plus mapping peoples' needs

As described, the simplest take on Step 1 is to focus on the **questions 1-3**.

1. **What are your project's physical boundaries?** Define its location, geographical extent and limits. For example, the boundaries of a neighbourhood or postcode, or smaller areas such as a park or street segment.

2. **Can you identify the ESS that the envisioned project will bring?** Check Table 1 and choose the relevant ESS under each of the following categories[3]:
   a. Regulating services: …
   b. Provisioning services: …
   c. Cultural services: …
   d. Supporting services: …

[3] These categories relate to the four categories of the MEA, for more information, please read the acknowledgement in section 2 or visit https://www.millenniumassessment.org/en.

Table 1: ESS for urban contexts, specified per MEA category

Urban ESS by MEA category	**Description of the urban specific ESS**	**Relevant?** Yes / No
Regulating services		
Storm water management	The timing and magnitude of collecting, storing and draining water can be influenced, managing runoff and flood risks *(core ambition of many CCA projects)*	
Sponge city (Droughts)	The timing and magnitude of collecting and storing water for drought can be influenced, by creating a ''sponge city'' *(core ambition of many CCA projects)*	
Heat island management	Microclimate and temperature extremes (heat islands) can be managed by using green and blue infrastructure *(core ambition of many CCA projects).*	
Carbon sequestration	Urban ecosystems can play a (limited) role in climate by sequestering carbon.	
Erosion control	Vegetation cover plays an important role in soil retention and the prevention of precipitation hinder.	
Air purification	Vegetation influence air quality by contributing and extracting chemicals, trees, shrubs, lawns, and others can contribute.	
Water treatment	Urban wetlands, puddles, ditches can help to filter out and decompose pollution from water and run off water.	
Noise reduction	Urban ecosystems, landscapes and green infrastructure can reduce noise levels and by that reduce stress factors.	
Pollination and seed dispersal	Urban ecosystems, landscapes and green infrastructure can influence distribution, abundance and effectiveness.	
Pests and diseases control	Ecosystems can influence pathogens, such as viruses, and disease factors, such as mosquitos, or can have impact on stress factors, such as noise reduction.	
Provisioning services		
Food production	Urban ecosystems are capable of carrying substantial resources for (urban) farming, fishery, livestock.	
Compost production	Introducing more biotic materials in urban metabolism enables options for compost.	
(Fresh)water availability	Cities and urban landscapes influence the continuous circulation of water in the Earth-atmosphere system by influencing storage, infiltration and supply.	
Energy production	Urban areas are capable of carrying substantial carrying capacity for renewable energy, and a little for biofuels.	
Production other materials	Many materials can be derived from ecosystems, such as wood, reed, plants, flowers, natural medicines, biocides, gum.	
Cultural services		
Leisure space	People like to have space for relaxing, social activities and sports.	
Physical and mental health	Reducing stress factors influences well-being and health of people, sense of place and social cohesion also works positive.	
Tourism/visitors	People choose where to spend their leisure time based on their appreciation of the natural or cultivated landscapes and cityscapes in a particular area.	
Sense of place / cultural heritage	People value recognized values of place, be it historic, cultural, natural, spiritual and religious.	
Community building / social cohesion	Urban landscapes influence the types of social relations that humans have, sharing space and shared activities, for instance (communal) gardening, sports, leisure.	
Inspiration / education	Ecosystems provide a rich source for inspiration and formal and informal education.	
Aesthetics /arts	Humans appreciate beaty reflected in parks, scenic landscapes, (green) architecture and housing locations.	
Supporting services		
Nutrient cycle	Nutrients recycling links living organisms with non-living organisms, taking up by living organisms and decomposition are the crucial processes.	
Oxygen production	Trees, plants, algae and bacteria contribute to the oxygen production.	
(Vital) soil formation	Soil is formed by micro-organisms and physical processes that decompose organic matter, essential for the health of systems.	
Habitat provided	Habitats provided to humans, animals and plants with resources such as shelter, food and water.	
Habitat for biodiversity	Varying natural habitats support a variety of species.	

Regarding question 2: For each of the four MEA categories, Table 1 provides the list of ESS that are relevant for the urban environment. Here, it is important to remember that ESS are delivered by natural systems, and thus by added green and blue elements. The additional ESS yield thus comes from the added natural (blue and green) elements (compare Figure 1). The method also allows to consider any benefits from non-natural constructed or hybrid infrastructure (if this suits the needs of urban planners and decisionmakers regarding the location and ambitions). There is in natural systems always interaction between biotic and non-biotic elements, thus also in the urban landscape.

3. **Is the job doable for the involved team?**
    a. Yes. Proceed after completion, depending on your step 1 preferences, to questions 4-5; questions 6-7 or to question 8. (If you find yourself puzzled by this, revisit the introductory text of Step 1 and Figure 3 to understand the Step 1 'a la carte' menu).
    b. No. Who has the expertise to collect this information? External or internal? Amend the elaboration of questions 1 and 2 by further rounds of iteration.

Regarding question 3: Derived from experience with ESS assessment in urban settings, the list included in Table 1 works. Working in a multidisciplinary team and involving people with experience are known success factors. In-house personnel with hands-on local experience can offer invaluable knowledge for managing the list: municipal gardeners, park managers, animal experts. Furthermore, the local residents and community can provide insights through multiple engagement methods, such as surveys, interviews, workshops, art and science events. Further developing and refining some indicators can be a daunting but also rewarding step in a specific context.

Introducing **questions 4 and 5:** Mapping natural capital (ecological assets) implies gathering and presenting information on bio-physical characteristics of the urban area and related ESS yields. In questions 1 and 2 the emphasis was on the ''envisioned future state'', by diving into identifying the ESS yield of a project. Now the emphasis is on the revenues from existing urban natural capital. Mapping the natural capital as it is calls for describing landscape units and their elements such as semi-natural and natural habitats, vegetation and biodiversity.

Questions 4 and 5 address the key issues for mapping the existing natural capital (the ''present state'').

4. **Can you represent the ecosystem assets of your project's area with a land use map or maps?**
    a. Yes (Who in your organization has the information and the know-how to produce relevant land use maps?)
    b. No. If no information or capacity is in place, where can you seek help?
        i. A first option is to use high-quality, freely available EU datasets of the land uses and land covers of Europe: CORINE[4] and Urban Atlas[5] ➡ contact?
        ii. A second option is to use public official land use data[6] from domestic sources, for instance national, regional, or municipal registries ➡ contact?
        iii. Lastly, such data are often produced and available by universities, consultancies, and public organizations (e.g., water authorities) ➡ contact?

Regarding question 4: In most situations, GIS-based maps are available at various levels and scales, such as maps of land use and land use change over time. There are also maps available with regard to specific bio-physical characteristics of land units, such as vegetation, of species distribution (both flora and fauna), maps of trees, maps of endangered species, maps of climate conditions, urban watershed, air-quality and air pollution, noise levels, soil pollution.

[4] EU-wide dataset, freely downloadable at https://land.copernicus.eu/pan-european/corine-land-cover.
[5] Detailed dataset for selected EU cities, freely downloadable at https://land.copernicus.eu/local/urban-atlas.
[6] Note that these data are (as a rule) the source of the EU CORINE and Urban Atlas datasets, but the benefit is often that the national source data come at higher geographical detail.

As an illustration of how a combination of maps and perspectives might look like, Table 2 gives the overview of maps used by the city of Utrecht doing ESS endeavours.

Table 2. ESS-related maps used by the city of Utrecht

Name	Source	Reference
Green Structure Plan 2030	Utrecht municipality	opendata@utrecht.nl http://www.utrecht.nl/images/DSO/DSOmilieu/groen/GSP.pdf
Trees & Green Management maps	Utrecht municipality	opendata@utrecht.nl http://utrecht.gemgids.nl/bomenkaart/
Trees structure maps	Alterra & Utrecht municipality	Processed at 2.5 m raster level from http://Bomenregister.nl
Neighbourhood green plans (10 districts)	CBS & Kadaster 2016	http://www.cbs.nl/nl-NL/menu/themas/dossiers/nederland-regionaal/links/toelichting-wijk-en-buurtkaart-2013-2015.htm
Air quality maps	RIVM PM10	http://nationaalgeoregister.nl/geonetwork/srv/dut/search?#|b472d8ac-2eb0-4a79-96fc-f0cbc1f717bb
Noise maps	Noise from Road & Train	http://www.utrechtmilieu.nl/geluidskaarten/
Heat stress maps	USGS	Present reflectance temperature [Degrees Celsius] (July 15, 2015), LANDSAT 8 band 10 & 11, converted to °C http://landsat.usgs.gov/best_spectral_bands_to_use.php
Land cover maps	Alterra	TOPNature: Scaleless-enriched 2.5 m raster version of TOP10NL for fast web mapping visualization and ecological applications
Buildings in the Netherlands	Kadaster	Basisregistraties Adressen en Gebouwen (BAG) https://data.overheid.nl/data/dataset/basisregistratie-adressen-en-gebouwen-bag-

Source: Maes J, Zulian G, et al. (2016) Mapping and Assessment of Ecosystems and their Services. Urban Ecosystems. Publications Office of the European Union, Luxembourg: p. 51.

5. **Based on the land use map of question 4, what is the natural capital inside the boundaries of your project?** Make a list of natural assets and express them in number, length, or area. Examples of green and blue space elements:
   a. Tree covered park (1 ha)
   b. Park with grass (½ ha)
   c. Open grassland (½ ha)
   d. Stream (½ km)
   e. Wetland (¼ ha)
   f. Natural pond (500 m^2)
   g. Shrubs (1 ha)
   h. Herb beds (… ha)
   i. Bioswales (… ha)
   j. Street trees (250 trees)
   k. Green roofs (…)
   l. House gardens (…)
   m. Community gardens (…)
   n. Green playgrounds (…)
   o. House gardens (…)
   p. Railroad banks allotments (…)
   q. Green sport facility (…)

Regarding question 5: The above list of examples is not exhaustive. Both the list and units can be adjusted to the location, and also depends on the data sources that have been used in question 1. For inspiration, you can refer to the EU's Urban Atlas guide: https://land.copernicus.eu/user-corner/technical-library/urban_atlas_2012_2018_mapping_guide.

Introducing **questions 6 and 7:** Mapping the build-up area and its impact on natural ESS, and the resulting needs of the people are the lenses that are now added. Key guiding questions for mapping this (the ''present state'' and resulting needs of the local people):

6. **Can you gather additional information about buildings, infrastructure, population, and economic and social activities in your project's area and their effect on the natural capital (check questions 3 and 4)?**
    a. Yes. Who in your organization has the information and the know-how to produce a land use map and assess impacts on natural capital and ESS, at least in a qualitative manner?
    b. No. If no information or capacity is in place, where can you seek help?
        iv. European data ➡ contact?
        v. National, regional, and/or local data ➡ contact?
        vi. Universities, consultancies, and agencies ➡ contact?
        vii. Other sources ➡ check the tips below.

Regarding <u>question 6</u>: This question involves mapping the built environment and its impact on and/or intertwining with natural capital. In many cases the impacts will be negative. A well-known and frequently used example refers to paved, hard surface. Combined with uncontrolled runoff from buildings, such can easily lead to water in the streets in case of heavy precipitation. Due to that the system is unnatural in its speed of drainage, causing both situations of too much water and too little water. Furthermore, for instance underground structures can influence groundwater and groundwater flows. Also, the main structure of buildings can influence cooling and heating, as well as the extent of air pollution. If designed cleverly, the built environment can also deliver fewer negative effects, as well as rethinking can lead to positive effects of constructed elements. Such positive effects are not limited to green and blue spatial elements; hybrid urban design often also helps. Mapping the footprint of the built environment leads to crucial information and understanding, and local needs (to improve) become evident. A step further than just mapping the built environment is to map the activities happening in it: mobility, commerce, education, along with the social capital, such as population and demographic groups. In this way, you will develop a deep understanding of how human activities and the local environment are linked to each other and what the trends are.

The ''cookbook'' started with mapping ESS (questions 1-3) and natural capital (questions 4 and 5). Mapping and relevant maps are equally insightful for elaborating question 6. As illustrated by ESS endeavors on the city of Rome on air pollution. The map of annual averages of PM_{10} (lethal airborne pollutant particles less than 10 microns in size) expressed in µg per m^3 (micro-grams per cubic meter) showed large variation across the city. That map expressed air pollution as element of urban ecological assets. Another map showed the PM_{10} absorption capacity of different types of vegetation per hectare. Comparison of both maps showed a pattern of high negative correlation: where pollution is higher, absorption capacity tends to be lower.

Source: Manes F., Silli V., Salvatori E. et al (2014) Urban ecosystem services: Tree diversity and stability of PM_{10} removal in the metropolitan area of Rome. Annali di Botanica 4:19-26.

7. **Having defined your current status in questions 1-6, can you now begin assessing whether the (CCA) project will contribute to peoples' needs, desires and impacts, in the perceptions of people, urban planners, and local politics?**
   a. Yes. Who in your organization has the information and skills to envision these impacts, at least roughly and qualitatively, and to indicate which indicators of measuring success are relevant to include in the assessment?
   b. No. If no information or capacity is in place, where can you seek help?
      On the visions, needs, and wants side
      i. Stakeholders and communities ➡ workshops, surveys, interviews, …
      ii. Policy agendas, strategic documents, regulations, …
      On the impacts side
      iii. European agencies[7] ➡ contact?
      iv. National, regional, and/or local agencies[8] ➡ contact?
      v. Universities, consultancies, and agencies ➡ contact?
      vi. Other sources ➡ check the tips below.

Regarding <u>questions 1-7</u>: It was envisaged above that primarily the internal staff can provide answers, working in a qualitative manner, while iterating steps until the outcome is satisfactory, given the needs. Starting with basic maps can be practical, while visiting the location several times might be useful as well. Teamwork, expert panels and participatory setting are a worthwhile additional ingredient. What also might help is to compare with and get inspiration from similar studies. Finally, there is always the option to involve outside expertise from consultants or public organizations at national, regional, or local administrative levels. Though in this first step iteration, while working toward decisions which of the steps elaborated above offer the most appropriate perspectives for the situation might also do the job to a satisfactory level.

8. **Now that you have a grip on relevant natural capital and relevant ESS, do you wish to assess the impact of your ecosystem assets and/or project on key performance indicators?**
   a. No. Stop here and prepare a description of your findings of questions 1-7.
   b. Yes. Proceed to question 9.

Regarding <u>question 8</u>: If challenges such as ESS endeavours are engaged in, it is tempting to work to a level of inclusiveness, completeness, preciseness and reliability that leaves no doubt ''at all''. Question 8 is meant to reflect on whether further steps are needed. Especially the inclusion of question 7 in the list above requires at least a ''quick and dirty'' qualitative assessment. And if further steps are needed, to reflect critically on the elaboration of the remaining steps included in this ''cookbook''.

[7] A good start is the European Environment Agency (https://www.eea.europa.eu/) and the European Chemicals Agency (https://echa.europa.eu/).
[8] For instance, the PBL Netherlands Environmental Assessment Agency (https://www.pbl.nl/en).

Step 2: Identify the relevant indicators for each ESS category

When the discussion zooms into notions such as “solutions”, “impacts”, “usefulness”, “benefits”, and so forth, measurement becomes important, as does the understanding of what intervention is being evaluated, against what, how, and with whom in mind.

An ESS indicator delivers information on the characteristics and trends of a particular ESS. This information makes it possible to measure or estimate the extent the service occurs, the trends in time and the rate of change due to, for instance, a CCA project.

Question 9 suggests selecting ESS indicators in an iterative process with three sub-questions as lenses.

9. **Which indicators are available, feasible and desirable for each of the included ESS?**
   a. Can indicators be based on available data?
   b. Are there indicators that are easy to count, measure or estimate?
   c. Are there better, though more demanding, indicators?

Regarding question 9: A review (search) of studies that show some resemblance can be valuable to track down indicators and compose a gross list to start reflecting on indicators. Alternatively, a brainstorm on with some experienced people also helps. Forward and backward iterations through the three sub-questions (cf. question 9) is advised while reflecting upon four indicators as suggested by van Oudenhoven et al. (2018), compare Figure 4 for further guidance. Starting by ‘’credibility’’ (scientific robustness) and finishing with the ‘’feasibility’’ lens is not always the most promising sequence of applying the four reflective criteria. The challenge is often in optimizing towards available resources and needs of decision makers.

For evaluating and selecting indicators, van Oudenhoven et al. (2018) introduced and elaborated the criteria of credibility, salience, legitimacy, and feasibility, as shown in Figure 4.

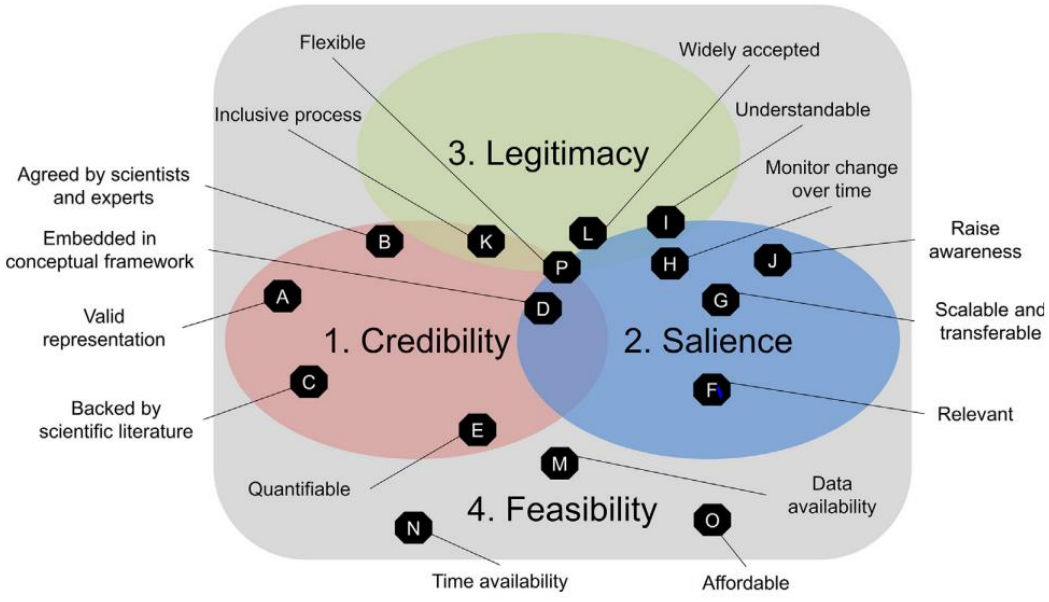

Figure 4. Criteria for evaluating and selecting indicators

Source: Alexander P.E. van Oudenhoven, Matthias Schröter, et al. (2018). Key criteria for developing ecosystem service indicators to inform decision making. Ecological Indicators, 95, 417-426.

More elaboration on the selection of indicators for each criterion can be found in the article by van Oudenhoven et al. (2018) that also includes a checklist for selecting indicators.

Focusing somewhat more on the benefits of a project, question 10 asks about how indicators can be used for measuring or estimating the benefits of a project.

10. **Can you reason upon how benefits are measured and/or estimated by using your indicators?** For inspiration, an example is given that relates a tree covered park to five potential benefits and includes some indicators that can be quantified:

    a. Tree covered park
        i. Regulating of microclimate and temperature extremes
            1. Reducing heatwave intensity by 0.5 degrees Celsius.
            2. Avoiding 50 hospitalizations.
        ii. Improving air quality
            3. Reducing PM_{10} by 0.2 ppm.
            4. Avoiding 6 asthma attacks.
        iii. Improving psychological well-being
            5. 50 residents state feeling calmer having this park in their area.
        iv. Regulating flooding
            6. Avoiding damages in 10 shops and houses.
        v. Providing recreation
            7. 40 residents / day visit the park to walk.
            8. 10 music events / week occur in the park.

Regarding question 10: If the decision is made to quantify selected indicators, the units of measurement become important. Quantification is not always required to meet the needs of decisionmakers. Sometimes qualitative assessment does the job, for instance when the decision has to be made between different alternatives and the kind of services delivered might vary between the alternatives. Or an outlook beyond reasonable doubt can be given, or with some disclaimers. To connect this to an example: For improving air quality, reducing PM10 by 0.2 ppm at first sight is easily measured. There are air quality measurement devices, though the challenge is to keep all other influencing factors stable. Immediately it becomes clear that measuring might not be that easy. Working in a qualitative manner might also be worthwhile. There are many sources that make inventory of measures and impacts. Regarding PM10 reduction, it is common knowledge that road traffic, and especially (older) diesel vehicles emit a lot of particles, and therefore getting rid of them would help. But what if the project design question is whether green infrastructure might help? Multiple sources are available, such as this one: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/938623/Review_of_interventions_to_improve_air_quality_March-2019-2018572.pdf

If a qualitative estimation is chosen, careful consideration of the procedure, work forms and reasoning is needed. Table 3 shows an example from the city of Trento doing the ESS assessment, combining quantitative measurements based on environmental monitoring (air pollution, noise pollution, etc.) and analysis of population and vulnerability indicators that are service-specific, including qualitative elements.

Table 3. Indicators per included ESS in a study for the city of Trento

Ecosystem service	Supply indicator	Demand indicator (conditions of the urban environment)	Demand indicator (population and vulnerability)
Microclimate regulation	Cooling effect (ΔT)	Urban Heath Island	Density and vulnerability to heat
Air filtration	PM10 captured	Air pollution concentration	Density
Noise mediation	Noise reduced	Noise sources	Density and vulnerability to noise
Water flow maintenance and flood protection	Water retained	Hydraulic and hydrogeological risk	-

Source: Maes J, Zulian G, et al. (2016) Mapping and Assessment of Ecosystems and their Services. Urban Ecosystems. Publications Office of the European Union, Luxembourg: p. 45.

Step 3: Decide about the procedure for measurement and/or estimation

This step provides reflection on two issues. First, it is important to understand that even when a nice indicator exists and the decision is taken to measure it quantitatively, such a measurement might not be so easy. Question 11 aims to help you discuss and secure the necessary expertise on measuring the chosen indicators. Second, depending on the policy needs or the stage of the urban planning process you are currently at, there are different ways to utilise the indicators and to build a policy argument based on the indicators. Question 12 aims to help you decide on how to proceed with the indicators in a way that is useful and relevant for your current policy needs.

11. **Do you need external expertise to gather the information?**
    a. No. Proceed to question 12.
    b. Yes. Who has the expertise to collect this information and for which item? External or internal? List, contact and amend question 11. Some examples:
        i. European agencies[9] ➡ contact?
        ii. National, regional, and/or local agencies[10] ➡ contact?
        iii. Universities, consultancies, and agencies ➡ contact?
        iv. Other sources ➡ check the tips below.

Regarding question 11: It is worthwhile to check data availability from local, national and international sources. Because high quality geoinformation availability is ample. This would help to avoid collecting data that are already collected by others for a different purpose in the past. Satellite and aerial images, land use/land cover maps, and the cadastral reveal a lot of information. For instance, NASA's free-to-use SEDAC service provides high resolution long-term average concentrations of key air pollutants for the entire world at 1 km^2 resolution[11], whereas a Google Scholar search reveals plenty of information of the effect of green roofs on air pollution[12].

12. **Would you like to calculate the monetary benefits and/or costs of your project and, further, to develop an argument about its economic implications?**
    a. No, not interested in monetisation or economic assessment. Stop here and prepare a description of your findings for the applicable questions 1-11. Also consider whether a multicriteria analysis would be of assistance (See Step 4 for further information).
    b. Yes, interested in the monetary benefits only. Go to step 4, read the introduction, check Figure 5 and question 13.
    c. Yes, interested in both the benefits and costs, but do not want to monetise the benefits. Go to step 4, read the introduction, check Figure 5 and question 14.
    d. Yes, interested in the net monetary benefits and costs. Go to step 4, read its introduction, check Figure 5 and question 15.

Regarding question 12: If benefits have to be evaluated in monetary terms, quantification is needed. Furthermore, quantitative indicators come with the need of measurement or estimation. If a project is still to be implemented, it can be hard to measure its impacts, but usually there is an understanding about what is proposed in terms of ecosystems, qualitatively and quantitatively. A pragmatic option would be to look at evaluation studies of similar interventions elsewhere in academic and grey literature. Another pragmatic model would be to look for available models to estimate the impacts. In case of the latter, you would need to adjust the input data, to be based on your project. And if models are available, there might be experts that can apply the reasoning on a specific case or cases. Though it is possible to conduct your tailor-made valuation study. and in practice a balance of all these methods is desirable. One of the most up-to-date introductions on this subject is OECD's guidelines on environmental cost-benefit analysis[13].

[9] A good start is the European Environment Agency (https://www.eea.europa.eu/) and the European Chemicals Agency (https://echa.europa.eu/).
[10] For instance, the PBL Netherlands Environmental Assessment Agency (https://www.pbl.nl/en).
[11] https://www.earthdata.nasa.gov/eosdis/daacs/sedac
[12] https://scholar.google.com/scholar?hl=en&as_sdt=0%2C5&q=effects+of+green+roofs+on+air+pollution&btnG=
[13] Freely accessible at https://doi.org/10.1787/9789264085169-en.

Step 4: Choose the method to valuate benefits

In question 12, you selected an approach to communicating the benefits of your project. These options are summarised in Figure 5. They build upon each other (from top-left clockwise), but you can stop at any point you prefer, depending on the information needs of your peers and your decision-making processes.

Figure 5. Matrix of options for economic assessments

		Monetise benefits?	
		No	**Yes**
Monetise costs?	**No**	**Questions 1-11; no economic assessment**: Communicate a list of benefits qualitatively or as indicators. The list can be scored and weighted (multicriteria analysis).	**Question 13; economic assessment via ESS valuation**: Translation of indicators to monetary values
	Yes	**Question 14; economic assessment via cost effectiveness analysis**: Improvements in an indicator in relation to the costs	**Question 15; economic assessment via cost-benefit analysis**: Net benefits minus the costs of a project, over a time horizon

"No economic assessment" does not always imply that no further elaboration is done. Since a list of benefits or indicators is available from steps 1-3, a multicriteria analysis (MCA) is possible. It can be done by ranking the benefits or indicators, and optionally weighing them. Reasoning towards the highest-ranked project alternative in this way is often a viable alternative or complement to economic analysis. This ranking-weighing exercise can be a collective one via internal or public workshops. More information on MCA can be found in these short introduction videos: https://www.youtube.com/watch?v=-JUaQcO4Dfo and https://www.youtube.com/watch?v=7OoKJHvsUbo.

For the three remaining options of Figure 5, indicated as "economic assessment", the economic value of ecosystems can be expressed in monetary terms using several techniques. On the one hand, market prices of what will be produced locally by ESS can be found for goods and materials that are traded, while it is also possible to assess to what extent people make an income from ESS. Also, if you avoid recurring damages via ESS, for instance less flood damage, fewer heat stress illnesses, or lower energy use, you can translate this into monetary savings. On the other hand, the majority of social and environmental benefits of ESS are not market goods (for instance good health or biodiversity), so surveys or observing people's behaviour are needed to estimate the economic implications of changes in their provision. Considering the above, five main methods can help monetise the value of ESS, in order of difficulty:

(a) the income that communities make from the products of your installed or preserved ESS;
(b) the physical or human damages that are to be avoided by installing or preserving ESS;
(c) adapting the results of existing valuation studies into the context of a new project (value transfer);
(d) derive ESS values from actual choices of people, e.g., home sales (revealed preferences);
(e) ask people about ESS values via surveys, questionnaires, and choice experiments (stated preferences).

Value (or benefit) transfer (option c) is often a good choice as there are plenty of existing studies that have assessed the economic benefits of ESS. These studies can be re-used by adapting the results to your location and its context such as income and population size and density. An accessible overview of economic valuation methods can be found at https://valuing-nature.net/sites/default/files/images/VNN-Demystifying%20Economic%20Valuation-Paper.pdf (Demystifying Economic Valuation) and at https://www.ecosystemvaluation.org/dollar_based.htm (Dollar-based Ecosystem Valuation Methods).

Lastly, costs can be of two types. First, the initial investment and ongoing costs needed to keep a project running. Second, the potential loss of ESS benefits that is brought about by a project (for instance, a housing development or infrastructure project). Both types of costs must be deducted from the envisioned benefits in order to understand either economic efficiency or effectiveness. Finally, the idea of costs and benefits almost always relates to comparing different alternatives, including the current status.

13. **You will perform an ESS valuation study. There are a few strategies to estimate the economic value of your ecosystem assets and you can build a list of monetised benefits via:**
    a. Avoided costs ➞ estimate the monetary value of the recurring damages you expect to avoid by installing or preserving ESS. For instance:
        i. Fewer damages due to fewer flooding events or lower inundation.
        ii. Savings from reduced energy use.
    b. Individual or community income from local production of ecosystem goods. For instance:
        i. Local farming and local gardening produce sales at household or community level.
    c. Stated preferences (asking people's views) ➞ refer to the resources listed below and prepare to organize or commission a survey.
        i. Do you have in-house expertise on CEA? ➞ proceed with stated preferences valuation.
        ii. No in-house expertise? ➞ You may wish to consult the resources mentioned below as well as contact organizations such as PBL[14], EEA[15], and OECD[16].
    d. Revealed preferences (observing people's behaviour) ➞ refer to the resources listed below and acquire a database of recent (1-5 years duration) house sales in your city that record the sale price, location, and characteristics of the sold property (size, age, amenities, etc.)[17].
        i. Do you have in-house expertise on CEA? ➞ proceed with revealed preferences valuation.
        ii. No in-house expertise? ➞ You may wish to consult the resources mentioned below as well as contact organizations such as PBL, EEA, and OECD.
    e. Value transfer (applying prior studies to your project) ➞ refer to the resources listed below and prepare to organize a literature review.
        i. Do you have in-house expertise on CEA? ➞ proceed with the benefit transfer of ESS value.
        ii. No in-house expertise? ➞ You may wish to consult the resources mentioned below as well as contact organizations such as PBL, EEA, and OECD.

Regarding question 13c: The **stated preferences** methods include contingent valuation, discrete choice experiments and subjective well-being. **Contingent valuation**[18] and **discrete choice experiments**[19] survey people about their choices and preferences regarding hypothetical changes in the provision of ESS and (often) the associated costs and trade-offs. After statistical analysis of the survey responses, the willingness to pay or willingness to accept certain improvements or degradations are calculated, providing an estimate of the economic value of various ESS. **Subjective well-being**[20] attempts to move closer to life quality concepts and tries to capture a wider set of well-being dimensions.

Regarding question 13d: In contrast to stated preferences methods, **revealed preferences** perform statistical analysis of observed behaviours, often concerning how much people pay for certain goods or services by considering real choice alternatives and their budget constraints. The main difference between stated and revealed preferences is that the former focused on hypothetical but highly tailor-made policy changes, while the later focused on actual but rather standardized behaviours. The following reference guide is available for three stated preferences methods, **hedonic price**, **travel cost**, and **averted behaviour**: https://www.oecd-ilibrary.org/sites/9789264085169-6-en/index.html?itemId=/content/component/9789264085169-6-en.

Regarding question 13e: The following is a reference guide for the **value transfer** or **benefit transfer** method, which aims to re-purpose existing (and often expensive) valuation studies by adapting their key inputs and parameters to the particular conditions in your project. For instance, by rescaling the units costs and/or benefits to the scale of a new project, by adjusting to the income and population of the new project, or by taking into account the specific land use mix and built-up density of the new project: https://www.oecd-ilibrary.org/sites/9789264085169-6-en/index.html?itemId=/content/component/9789264085169-6-en.

[14] PBL Netherlands Environmental Assessment Agency (https://www.pbl.nl/en).
[15] European Environment Agency (https://www.eea.europa.eu/).
[16] Organization for Cooperation and Economic Development (https://www.oecd.org/environment/).
[17] Such dataset is called "hedonic dataset" and is most often managed and provided at a cost by the national association of real estate brokers. For instance, in the Netherlands, this would be the Dutch Association of Real Estate Brokers (NVM). In some countries, public organisations have the right to use such data for free.
[18] www.oecd-ilibrary.org/sites/9789264085169-7-en/index.html?itemId=/content/component/9789264085169-7-en
[19] www.oecd-ilibrary.org/sites/9789264085169-8-en/index.html?itemId=/content/component/9789264085169-8-en
[20] www.oecd-ilibrary.org/sites/9789264085169-10-en/index.html?itemId=/content/component/9789264085169-10-en

14. **Your will perform a cost-effectiveness analysis (CEA).**
    a. Gather the costs of investing into and maintaining your ESS project. These can be initial investment and construction costs, operational and maintenance costs, personnel costs, or even lost revenues due to reallocation of land uses.
    b. Gather the quantified key performance indicators of question 10.
    c. Do you have in-house expertise on CEA? ➡ proceed with the CEA calculations.
    d. No in-house expertise? ➡ You may wish to consult the resources mentioned below as well as contact organizations such as PBL[21], EEA[22], OECD[23], or the Society for Benefit-Cost Analysis[24].
    e. CEA is meaningful only when comparing the indicators-to-costs ratios of at least two alternatives. Most often, the cost effectiveness of a proposed project is compared to that of another project, or that of doing nothing, which is the current status. If you consider expanding your natural assets in the project area through multiple alternatives, repeat questions 10-12 for each strategy and compare the CEA results of the different alternatives.

Regarding question 14: CEA is currently quite popular in health economics and public health policy, for instance, air quality improvements, Two introductory videos on the CEA method can be viewed at https://www.youtube.com/watch?v=Ydj4E88p7D4 and https://www.youtube.com/watch?v=rDmFxJnrhR8.

For guidelines, you can refer to the EU's guidance on CEA at https://europa.eu/capacity4dev/evaluation_guidelines/wiki/cost-effectiveness-analysis-0, as well as to Better Evaluation's introduction to CEA at https://www.betterevaluation.org/en/evaluation-options/CostEffectivenessAnalysis.

15. **You will perform a cost-benefit analysis (CBA).**
    a. Gather the costs of investing into and maintaining your ESS project. As with question 14, these may be initial investment and construction costs, operational or maintenance costs, personnel costs, or lost revenues due to reallocation of land uses.
    b. Gather the monetized benefits of question 13. Here it is important to understand that different project alternatives will have a different list of effects, and attached monetary benefits and costs, in comparison to the current status. The differences depend on how much each alternative changes the ESS compared to the current status.
    c. Do you have in-house expertise on CBA? ➡ proceed with the CBA calculations.
    d. No in-house expertise? ➡ You may wish to consult the resources mentioned below as well as contact organizations such as PBL, EEA, OECD, or the Society for Benefit-Cost Analysis.
    e. CBA is meaningful only when comparing at least one proposed project to the alternative of doing nothing, which is the current status. If you are considering expanding your ecosystem assets in the project area in more than one alternative ways, repeat questions 10-13 for each investment strategy and compare the CBA results of the different alternatives.

Regarding question 15: An accessible video introduction to social CBA, meaning a CBA that considers also the social and environmental effects, can be viewed at https://www.youtube.com/watch?v=7tdKkeNClPE. The complete list of short introductions to topics central to social-environmental CBA can be viewed at https://www.youtube.com/watch?v=7tdKkeNClPE&list=PLBfu1mD9hk67Vrm0SPK-fmQgmzWQ2zvNA.

In terms of text resources and handbooks, perhaps the state-of-the-art in social CBA is this recent handbook: https://cdn1.sph.harvard.edu/wp-content/uploads/sites/2447/2019/08/BCA-Guidelines-Summary-May-2019.pdf. OECD has also produced one of the best reference guides to understand and perform economic assessments in the environmental domain: https://doi.org/10.1787/9789264085169-en. Lastly, the Dutch Environmental Assessment Agency has also produced a great set of guidelines for CBA: https://www.pbl.nl/en/publications/general-guidance-for-cost-benefit-analysis.

[21] PBL Netherlands Environmental Assessment Agency (https://www.pbl.nl/en).
[22] European Environment Agency (https://www.eea.europa.eu/).
[23] Organization for Cooperation and Economic Development (https://www.oecd.org/environment/).
[24] Society for Benefit-Cost Analysis (https://www.benefitcostanalysis.org).