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D11.2 – Framework for evaluating changes in ecosystem services Part A: DESSIN Cookbook

FINAL VERSION (Summer 2017)



The research leading to these results has received funding from the European Union Seventh Framework Programme (FP7/2007-2013) under grant agreement no. 619039

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TITLE OF THE REPORT

D11.2: FRAMEWORK FOR EVALUATING CHANGES IN ECOSYSTEM SERVICES
 Part A: DESSIN Cookbook – Final Version

SUMMARY

The DESSIN ESS Evaluation Framework is a structured approach to measuring changes in ecosystem services (ESS). The main purpose of running an evaluation using this framework is to facilitate the application of the ESS Approach in the appraisal of the effects of innovative solutions on freshwater ecosystems and their services. The framework consists of the DESSIN Cookbook (this document), the Companion Document, a Supplementary Material File and a Case Reporting Template. The DESSIN Cookbook presents the practical steps that the user should follow to apply the DESSIN ESS Evaluation Framework. It is intended as a practical guidance for running the evaluations and thus does not include elaborate descriptions of the concepts used (these are found in the Companion Document). The cookbook guides the user through the 5 Parts of the evaluation framework, detailing and exemplifying the practical steps to follow in the application of the framework.

DELIVERABLE NUMBER

D11.2

WORK PACKAGE

WP11-13

LEAD BENEFICIARY

Ecologic Institute

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QUALITY ASSURANCE

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PLANNED DELIVERY DATE

31/12/2015

ACTUAL DELIVERY DATE

15/04/2016 (updated in Summer 2017)

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List of Acronyms and Abbreviations

CICES – Common International Classification for Ecosystem Services

DPSIR – Driver, Pressure, State, Impact, Response

DWTP – Drinking Water Treatment Plant

EEA – European Environment Agency

ESA – Ecosystem Services Approach

ESS – Ecosystem Services

FESS – Final Ecosystem Services

FEGS-CS – Final Ecosystem Goods and Services Classification System

IESS – Intermediate Ecosystem Services

MCDA – Multi-Criteria Decision Analysis

MEA – Millennium Ecosystem Assessment

NACE – Nomenclature statistique des activités économiques dans la Communauté européenne. In English, Statistical classification of economic activities in the European Community.

SA – Sustainability Assessment

USEPA – United States Environmental Protection Agency

WFD – Water Framework Directive

WTP – Willingness To Pay

WWTP – Waste Water Treatment Plant

Text formatting code:

Blue: DESSIN project elements and outputs

Green and italicized: DESSIN agreed terminology that can be consulted in the DESSIN Glossary

The DESSIN ESS Evaluation Framework is a structured approach to measuring changes in ecosystem services (ESS). The main purpose of running an evaluation using this framework is to facilitate the application of the ESS Approach in the appraisal of the effects of innovative solutions on freshwater ecosystems and their services. In the DESSIN context, innovative solutions can refer to both technical and management measures. The framework consists of the [DESSIN Cookbook](#) (this document), the [Companion Document](#), a [Supplementary Material File](#) and a [Case Reporting Template](#).

The [DESSIN Cookbook](#) presents the practical steps that the user should follow to apply the DESSIN ESS Evaluation Framework. This cookbook should be read as a step-by-step guide to fill in the [Case Reporting Template](#). The template gives the user an outline to structure and present the evaluation outcomes. Examples from the [DESSIN mature case studies](#) illustrating this procedure are included throughout the cookbook.

The [DESSIN Cookbook](#) is intended as a practical guidance for running the evaluations and thus does not include elaborate descriptions of the concepts used. The [Companion Document](#) provides this more detailed information on the theoretical background sustaining the framework. It contains a [Glossary](#) of agreed terminology that should be used for running the evaluations. Therefore, **the Companion Document should be read carefully before applying the practical steps described in this cookbook.**

The [Supplementary Material File](#) provides standardized lists (e.g. lists of *drivers*, *pressures*, *state* indicators, etc.) from which the user can select when conducting an evaluation. It is presented as a single MS Excel worksheet that aggregates the different catalogues that have been compiled under the DESSIN project.

The **DESSIN Cookbook** consists of an introductory chapter which gives an overview of the document followed by six subsequent chapters that guide the user through the 5 Parts of the evaluation framework (Parts I-V) and a reporting chapter, each detailing and exemplifying the practical steps to follow in the application of the framework. Each one of the chapters describing the 5 Parts of the framework is structured as follows: presentation of the chapter's objectives; listing of support material required to conduct that part of the evaluation; instructions to conduct the evaluation and report the results; consideration of uncertainty issues. Examples are provided throughout the different chapters to illustrate the instructions given.

Running an abridged evaluation

Parts II to IV of the DESSIN ESS Evaluation Framework represent the core of the evaluation. Users intending to conduct a rapid appraisal can focus on completing these parts of the framework. Users intending to achieve a more holistic evaluation should complete Parts I and V as well. Part I provides guidance on how to ensure a well-structured and complete preparation of the evaluation, e.g. delimiting the study area and identifying *stakeholders*. Part V offers a sustainability assessment module which opens the scope of the evaluation by integrating further dimensions into the analysis.

Background: The basis of the DESSIN ESS Evaluation Framework

The DESSIN ESS Evaluation Framework helps its user evaluate changes in ESS by linking biophysical, economic, and sustainability assessments sequentially. It was developed on the basis of the *Common International Classification of Ecosystem Services (CICES)* (Haines-Young and Potschin, 2011) and the *DPSIR* adaptive management cycle (EEA, 1999) (Figure 1). The former is a standardized system for the classification of ESS developed by the European Union to enhance the consistency and comparability of ESS assessments. The latter is a well-known concept to disentangle the biophysical and social aspects of a system under study. As part of its analytical component, the DESSIN framework also integrates elements of the *Final Ecosystem Goods and Services-Classification System (FEGS-CS)* (Landers and Nahlik, 2013) of the US Environmental Protection Agency (USEPA). For a more detailed description of these contributing frameworks please refer to the introductory chapter of the [Companion Document](#).

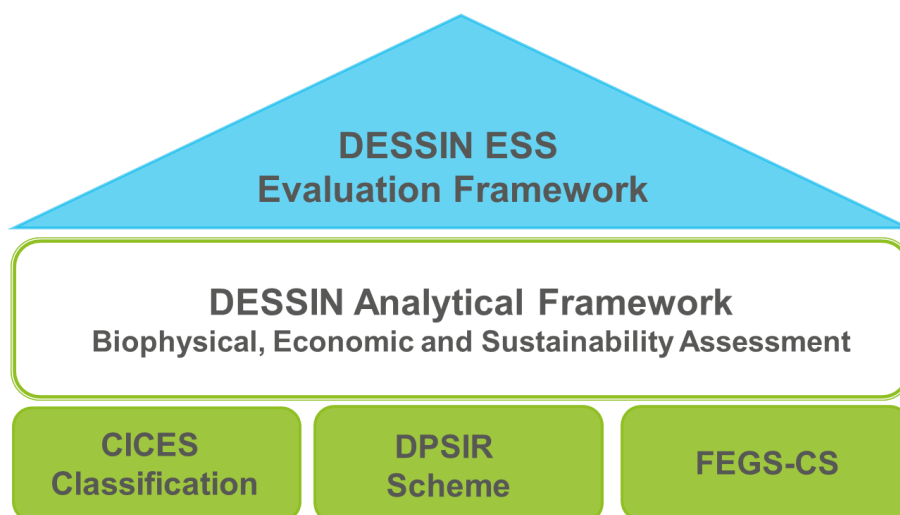


Figure 1. Components and foundations of the DESSIN ESS Evaluation Framework

In the *DPSIR* scheme as applied in DESSIN, the innovative solutions to be tested are considered *Responses* that may have influence on *Drivers* (anthropogenic activities with environmental effects), *Pressures* (the direct effects of such activities) and *States* (the conditions of the ecosystems under study). From the resulting changes in an ecosystem's *State*, the changes in *Impact I (ESS Provision)* are estimated. An economic assessment of the subsequent changes in *Impact II (ESS Use)* follows. Finally, this estimated change in the level of human well-being will inform policy and decision-making (further *Responses*). Figure 2 outlines the *DPSIR* scheme as applied in DESSIN.

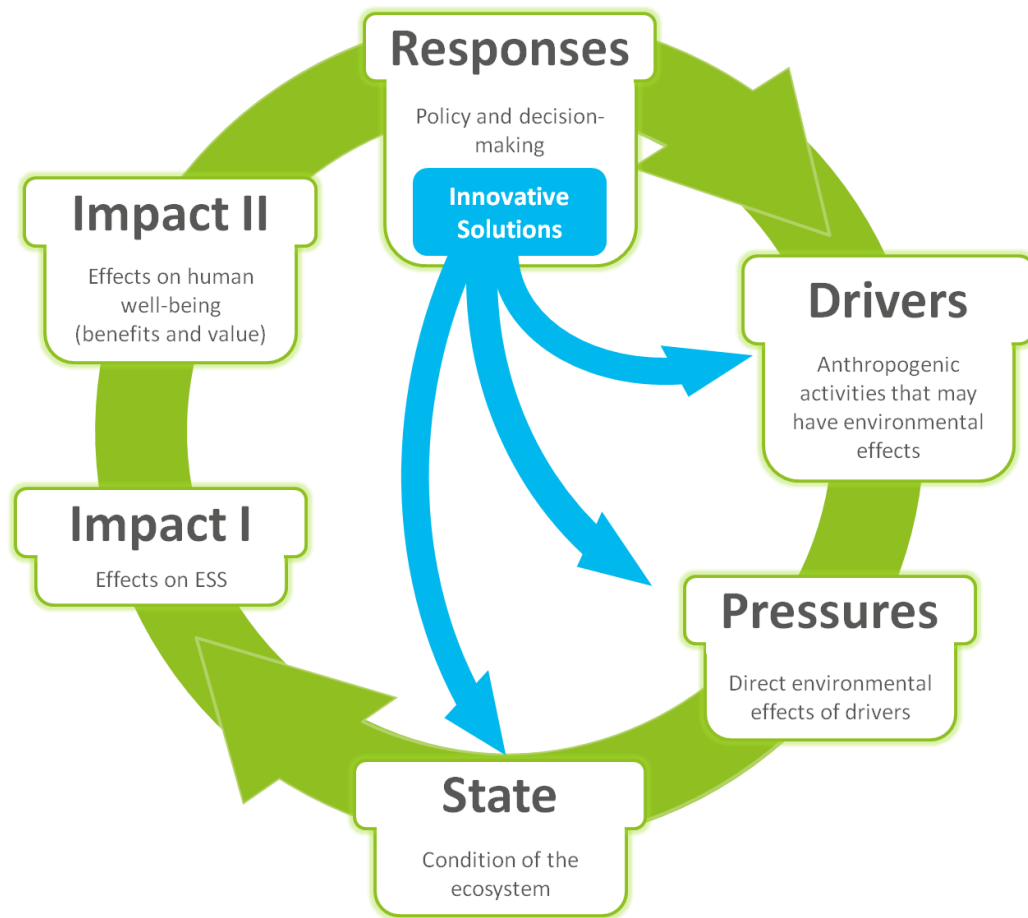


Figure 2. Conceptual approach of the DESSIN ESS Evaluation Framework (based on (Müller and Burkhard, 2012; van Oudenhoven et al. (2012); Haines-Young and Potschin (2011; 2013))

Using the DESSIN ESS Evaluation Framework facilitates the outlining and evaluation of changes in ESS that result from the implementation of innovative water management solutions. This enhances analyses of costs and benefits of such solutions by incorporating the economic value of the use of ESS.

To facilitate the assessment of innovative solutions using the ESS approach, the DESSIN ESS Evaluation Framework has been integrated into a Decision Support System, in the form of a software tool that can be downloaded from the project website (<https://dessin-project.eu/>). The tool provides decision-makers with a practical way to integrate the ESS approach into the evaluation and decision-making process.

Introduction: Purpose and Structure of the DESSIN Cookbook

In DESSIN, the evaluation of changes in ESS aims at quantifying the benefits for human well-being that result from the implementation of an innovative solution enhancing an ecosystem. The DESSIN approach screens the *claimed/expected capabilities of proposed measures* and, on this basis, advises how to forecast impacts on associated ESS. The *claimed/expected capabilities of the proposed measure* are the effects that the innovative solution being examined is claimed or expected to have on the general physicochemical, biological and hydromorphological characteristics of the water body under study (e.g. % reduction in the turbidity of the water).

The practical application of the DESSIN ESS Evaluation Framework considers the viewpoint of:

- a) a policy- or decision-maker confronted with a number of possible measures to choose from and to be applied in a freshwater environment or a freshwater-related urban environment (e.g. new technologies, management approaches, policy measures)
- b) an organization (e.g. technology developer, consultant) interested in whether consideration of ESS might provide support for uptake of new solutions

In this document a baseline scenario will be compared to one where the proposed measure is already implemented. However, the framework can also be used to compare among multiple proposed measures. This is simply done by running an evaluation for each of the individual options and comparing the results.

The DESSIN framework consists of 5 parts and its practical application can be broken down into 8 steps. This is depicted in Figure 3 and briefly summarized in the following paragraphs:

In Part I of the evaluation, the environmental system of interest (e.g. a surface or groundwater body, sub-catchment or catchment), i.e. the ecosystem, must be defined and described and the local *stakeholders* must be identified. Furthermore, administrative details and objectives of the assessment must be declared (see Part I of Figure 3 below).

In the following steps of the process a general overview of the *Drivers* found in the area of study must be gathered and the *Pressures* resulting from them must be identified (Part II). Once these first two elements of the *DPSIR* scheme have been characterized, the *claimed/expected capabilities of the proposed measures* (i.e. of the *Responses*) must be examined to determine if their effect would be on *Drivers*, *Pressures*, *State* or a combination of these. This can be used to develop a list of *case-relevant ESS*. Subsequently, and on the basis of the potential *beneficiaries* found in the area, *case-relevant ESS* are further categorized into *final ESS* and *intermediate ESS* (Part III).

After the important *Drivers*, *Pressures*, *claimed/expected capabilities*, *case-relevant ESS* and *beneficiaries* have been identified in Parts II and III, changes in ESS resulting from the proposed measures should be estimated. This is carried out in Part IV. Here, *parameters* and *indicators* used to estimate changes are selected and the changes are quantified. It must be noted that when the

framework is used to evaluate a proposed measure (as opposed to an already implemented measure), it is necessary to estimate the impacts of these innovative solutions as real world evidence is not yet available.

Finally, the sustainability assessment (SA) in Part V aims at comparing the wider social, environmental, and governmental aspects (e.g. economic impact and job creation, resources use and life cycle emissions, compliance with relevant regulations, stakeholder involvement) of the proposed measure as well as of alternative measures that could be implemented to achieve the same outcome. The SA will also facilitate the analysis of financial costs associated with the measures, providing insight on whether these are justifiable in relation to the benefits that result from the improvements on ecosystems and the delivery of ESS. This will help to identify the most cost-effective solution to the problems found in the study area.

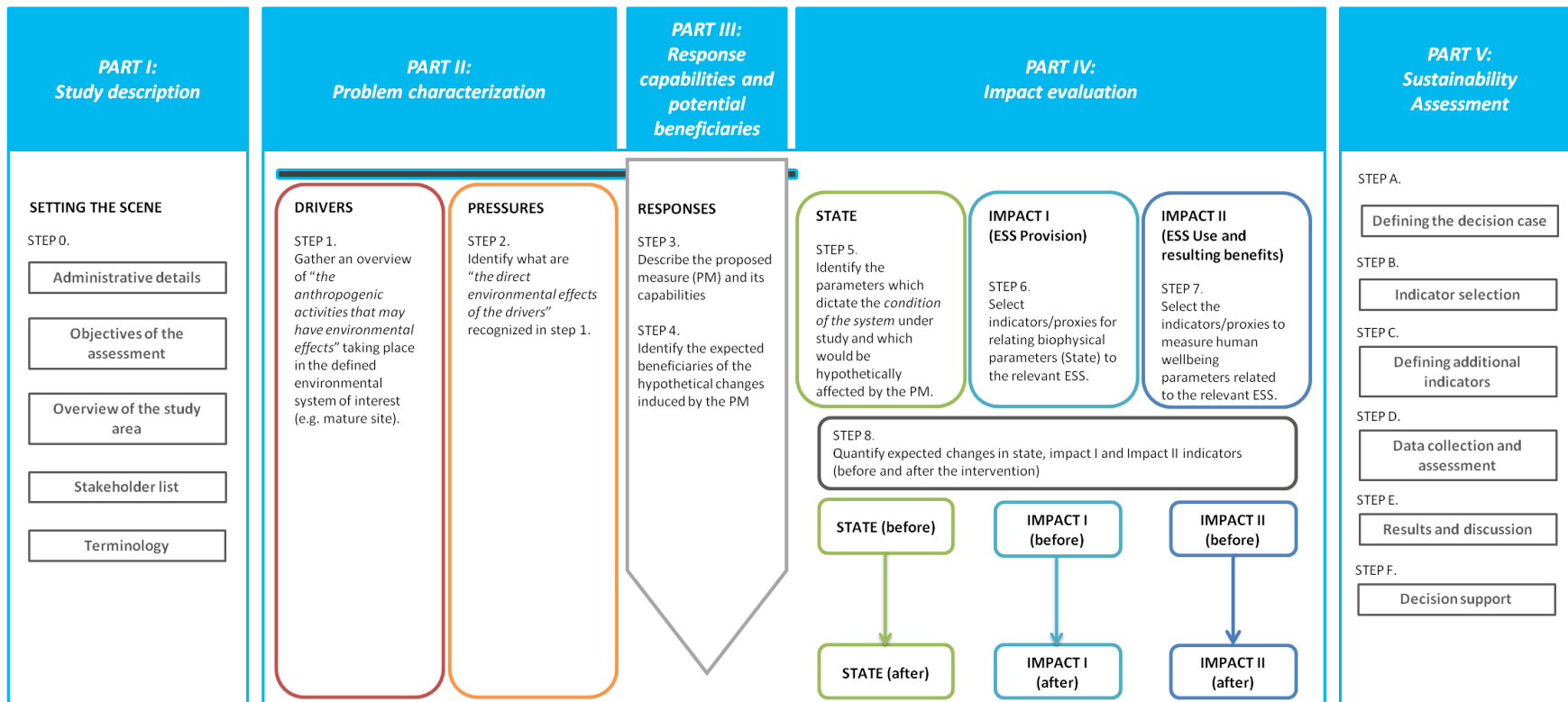


Figure 3. Practical steps for the application of the DESSIN ESS Evaluation Framework (and main chapters of this cookbook)

A note on handling spatial and temporal issues in the evaluation of changes in ESS

In the analysis of ESS, different spatial and temporal scales need to be considered. The benefits of ESS may be removed in space from the ecosystem providing them. The spatial distribution can act on local, regional as well as global scales. Furthermore, the ESS may change over time both seasonally and in a more long-term perspective. For some changes in pressures, there may be a time lag before changes in pressure and in ecosystem status manifest themselves in changed ESS. Users need to particularly pay attention to spatial and temporal scales when identifying (case-relevant) ESS and beneficiaries of ESS.

For consideration of these temporal and spatial issues, it is important to build on specific and often local knowledge about ecosystem interaction and function. Therefore, it is not possible to provide generic temporal and spatial guidelines for measuring changes in ESS. However, some advice and practical examples on how to deal with these issues are given below.

Box 1. Spatial scales

Some ESS are appropriately defined at small scales and others at larger units such as the river basin. In some cases, it is necessary to consider different scales simultaneously to be able to identify, describe and understand different ESS. For some biodiversity issues (e.g. for some floral protection), a smaller scale is appropriate. For others (e.g. protection of migrant birds), larger scales should be considered. For cultural and provisioning services, a scaling beyond the traditional understanding of the ecosystem boundary may be required.

Examples of ESS that may require consideration of larger spatial scales include: greenhouse gas/carbon sequestration in floodplains, wetlands, lakes and the marine environment; aesthetics of landscapes with semi-natural/artificial aquatic elements; fish stock recruitment; nutrient filtration and immobilization of pollutants; ESS provision from forestry; and cultural, recreation and tourist benefit services.

Spatial issues can arise when some ESS depend on interactions between ecosystems. Particularly relevant in regard to water bodies are interactions between upstream human activities and effects on ESS downstream. An illustrative example for this is a creek ecosystem which provides spawning and rearing localities for trout and salmon. These localities – and their good environmental state – are essential for fish production and fishery ESS provided by marine ecosystems that can be far away from the creek ecosystem.

Box 2. Temporal scales

Temporal scales

Particularly important in the DESSIN framework are the long-term effects on ESS provided by a specific area or ecosystem. For example, the provision of ESS relevant to fisheries, recreation and tourism may not show changes until a long time after measures for environmental improvement have been implemented. An illustrative example is the restoration of the River Skjern in western

Denmark (Pedersen et al., 2007), which led to changes in nutrient retention capacity, fish production, biodiversity protection and opportunities for recreation and tourism. The full effects of the restoration were first observed more than a decade after project implementation.

In relation to temporal resolution, understanding the dynamics of ecosystems and changes in dynamics are important factors. This becomes obvious when considering hydromorphological issues and related services. Flooding, for example, is by nature a temporal phenomenon. Delivery of natural flood storage capacity is an example of a service that must be provided with consideration for both time and space. However, flooding has both positive and negative impacts, and allowing controlled flooding can conserve biodiversity in wetlands (Amigues and Chevassus-au-Louis, 2011). In some rivers, preserving natural hydrological variation is a prerequisite for ensuring migration of species throughout the catchment area. It is not only the amount of water (discharge) that is important, but also the timing of the hydrograph may be important (i.e. the necessary storage capacity must be available at the right time).

In general, it is important to use an approach and method that are flexible and make it possible to expand and modify the evaluation both in a spatial and temporal context. There may not be one single appropriate scale for measuring a given ecosystem service and therefore a cross- and multi-scale approach may be required, as different scales may be relevant for understanding issues at play at different places. Even within the same area, different temporal and spatial resolutions can be required for identification of different ESS (Potschin and Haines-Young, 2011). Within DESSIN, rather than focusing on short-term effects, temporal scales should be aligned to the expected lifetime of the proposed technologies (or other innovations). This enables to take into account long-term changes and potential time-lags of changes in ESS. Furthermore, with this approach the expected (monetary) benefits for the full lifetime of the respective measure can be assessed.

Scales should match the origin of both supply and demand. Appropriate scales in regard to ESS provision can be biophysical units, such as ecosystem boundaries, biomes, catchments or floodplains. In contrast, typical locations of beneficiaries are urban areas or rural settlements. Hence, administrative units such as municipalities or administrative districts might be relevant scales (Burkhard et al., 2014; Zhang, Holzapfel & Yuan, 2012).

In the DESSIN framework, the delineation of the study area (Part I) is the starting point for consideration of spatial scales. The study area should cover central ESS and major beneficiaries. However, be aware that ESS beyond this spatial demarcation may be affected by the proposed DESSIN measure (see example of upstream and downstream in Box 1). Also, beneficiaries of ESS may as well be located outside the study area's boundaries. Furthermore, data availability can act as a limiting factor in regard to the number of beneficiaries that can actually be included in the evaluation, which in turn may affect the delineation of its spatial and temporal scales. Thus, it is suggested that in the initial phase of the evaluation the definition of the study area's boundaries remains flexible and an iterative approach to their definition is followed. As the process advances, case-relevant ESS are defined and beneficiaries are identified, these boundaries will become clearer.

1. PART I – Study description (setting the scene)

Objective of this chapter:

The aim of this section is to prepare the evaluation by delineating general basic characteristics of the study area like the geographical location and spatial extension, the intended audience and expected results of the assessment, among others.

Support material necessary for completion:

- [Case Reporting Template](#): DESSIN case study description template
- [Companion Document](#): DESSIN Glossary

SETTING THE SCENE

STEP 0.

Collect information to describe the 5 main elements of Part I: (1) the administrative details of the assessment, (2) the objectives of the assessment, (3) an overview of the study area, and (4) a list of local *stakeholders* (i.e. those present in the study area).

Instructions:

Refer to the DESSIN [Case Reporting Template](#) and fill in the following information about the assessment and the study area in the respective cells (see example in Table 1). For further details on the template used below please refer to Chapter 1 of the [Companion Document](#).

About the assessment itself:

- (1) Provide general information about the entities involved in carrying out the assessment, the providers of information for the assessment, the providers of funding for the assessment. Define also the intended audience of the results (Who will be the main recipient of the outcome report?).
- (2) Define and explain the specific purpose and the expected outcomes of carrying out the assessment (What do you want to achieve by evaluating changes in ESS in your area?).

About the study area:

- (3) Provide a detailed description of the study area considering its geographical location (e.g. Mediterranean region, Western Europe, Nordic region); its spatial extent; its environmental attributes (e.g. climate type, topography, water quality levels, water availability); the economic activities taking place within the area (e.g. land use, land use transitions, comparison of activities by share of GDP); its socio-economic profile (e.g. population density, average household income, age profile); and the socio-cultural aspects (e.g. value systems, role of landscape and land use in identity formation).
- (4) Elaborate an exhaustive list of local *stakeholders*.

Reporting:

The DESSIN case study description template found in the [Case Reporting Template](#) can be used for both collection and reporting of the general details of the assessment. Alternatively, a brief note compiling the different sections of the template can be developed by the user.

Table 1. DESSIN case study description template. Example taken from the Emscher mature case study.

Element of Part I	Instructions	Example: User entries
Administrative details	<p>1. Provide general information about:</p> <ul style="list-style-type: none"> the entities involved in carrying out the assessment the providers of information for the assessment the providers of funding for the assessment 	<ul style="list-style-type: none"> <i>Emschergenossenschaft (EG), University of Duisburg-Essen (UDE), IWW Rheinisch-Westfälisches Institut für Wasser (IWW)</i> <i>EG</i> <i>EU FP7 project</i>
Objectives of the assessment	<p>2.</p> <ul style="list-style-type: none"> Define the intended audience of the results (Who will be the main recipient of the outcome report?) Define and explain the specific purpose and the expected outcomes of carrying out the assessment (<i>What do you want to achieve by assessing changes in ESS in your area?</i>). 	<ul style="list-style-type: none"> <i>Intended audience: Researchers</i> <i>Objectives: The assessment is conducted with the aim of (i) testing the ESS Evaluation Framework proposed and (ii) identifying the benefits resulting from the Emscher conversion project for subsequently conducting a cost-benefit analysis.</i>
Overview of the study area	<p>3. Provide a detailed description of the study area considering:</p> <ul style="list-style-type: none"> geographical location (e.g. Mediterranean region, Western Europe, Nordic region) spatial extent environmental attributes (e.g. climate type, topography, water quality levels, water availability) economic activities taking place in the area (e.g. land use, land use transitions, comparison of activities by share of GDP) socio-economic profile (e.g. population density, average household income, age profile) socio-cultural aspects (e.g. value systems, role of landscape and land use in identity formation). 	<ul style="list-style-type: none"> <i>Northwest Europe</i> <i>The Emscher catchment basin covers 865 km²</i> <i>temperate seasonal climate, 150 m above sea level (source) to 25 m (mouth)</i> <i>The former land use was mainly urban settling, coal mining, steel production and steel processing. A shipping channel and a network of roads was built for that purpose. Today's land use is a very densely populated area with 17 cities that are apparently merged into one metropole conglomerate. There is hardly any agriculture; business has shifted towards service companies. The total built-up area is ~50%, agricultural land ~18%, natural area (incl. forested area) ~ 22%.</i> <i>2.2 Mio inhabitants live in the Emscher basin with a mean population density of 2,775 inhab./km²</i> <i>The people are used to avoiding the streams in the area since 1900, when creeks and rivers turned into a system of open wastewater channels. In a densely populated area, places for local recreation are highly demanded.</i>
Stakeholder list	<p>4. Elaborate an exhaustive list of the local stakeholders.</p>	<ul style="list-style-type: none"> <i>people living in the area;</i> <i>industry;</i>

		<ul style="list-style-type: none">• <i>mining companies;</i>• <i>industrial forestry;</i>• <i>NGOs;</i>• <i>water board (WWTP operator, CSO operator);</i>• <i>chambers of commerce;</i>• <i>industrial memorial tourism</i>
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2. PART II – Problem Characterization

Objective of this chapter:

Part II represents the first step in the core evaluation and is the entry point towards describing the entire *DPSIR* cycle. Here the relevant *Drivers* and *Pressures* will be identified in order to understand the full picture of the system under study. This enables the user to decide which *Pressures* to focus the rest of the evaluation on, and provides initial insight on what appropriate measures could be.

The aim of this part is to produce a qualitative overview of the *Drivers* present in the study area, relate these to resulting *Pressures*, and describe the latter. As a rule within the DESSIN assessments, *Pressures* should be described qualitatively. In specific cases where the proposed measures are expected/found to influence *Pressures*, then changes in those *Pressures* should be quantified. For more detailed information see Chapter 3 of the [Companion Document](#).

Support material necessary for completion:

- [Companion Document](#): DESSIN Glossary
- [Supplementary Material File](#): DESSIN Catalogue of Drivers and Pressures
- [Case Reporting Template](#)

DRIVERS

Definition: A human activity that may produce an environmental effect (i.e. a pressure) on the ecosystem (MARS, 2014).

STEP 1.

Gather an overview of “the human activities that may have environmental effects” taking place in the study area.

Instructions:

Refer to the “Catalogue of Drivers” found in the second sheet of the [Supplementary Material File](#). There you will find the “Characterization Table for Drivers” listing 11 types of *Drivers* and an “Other” option which can be used to include additional driver types.

Using the filter option, select those *Drivers* which are present in the study area (see Figure 4). Once you have filtered the relevant *Drivers*, provide a brief description of each of them including their main characteristics (e.g. an indication of their temporal and spatial scale) in the “Specification”

column

(see

1. Characterization Table for Drivers	
<i>The list of drivers is based on MARS, 2014.</i>	
DRIVER	SPECIFICATION (to be input by the user)
Industry	Industrial bad practices in the past: solvents and PAHs in groundwater and river. Industries increase in the metropolitan area: WWTP discharge.
Urban development	Inhabitants increase in the metropolitan area: WWTP discharge, intensive use of the river.

Figure 5). For example, for the *Driver* “Agriculture”, further details can be inserted to state whether this refers mainly to crop production, livestock farming or a mix of both. For the *Driver* “Tourism & recreation”, the types of recreational activities pursued, e.g. bathing, boating, etc. can be specified.

Reporting:

Use the information gathered in the “Characterization Table for Drivers” to formulate a brief descriptive text that provides a qualitative overview of the types of *Drivers* in the study area (see Box 3). This text will be used later to complete the evaluation report. Copy the selected *Drivers* into the annex of the [Case Reporting Template](#).

Uncertainty:

The uncertainty in this section is expectedly linked to the possibility to miss certain *Drivers*. Please state these limitations in your description.

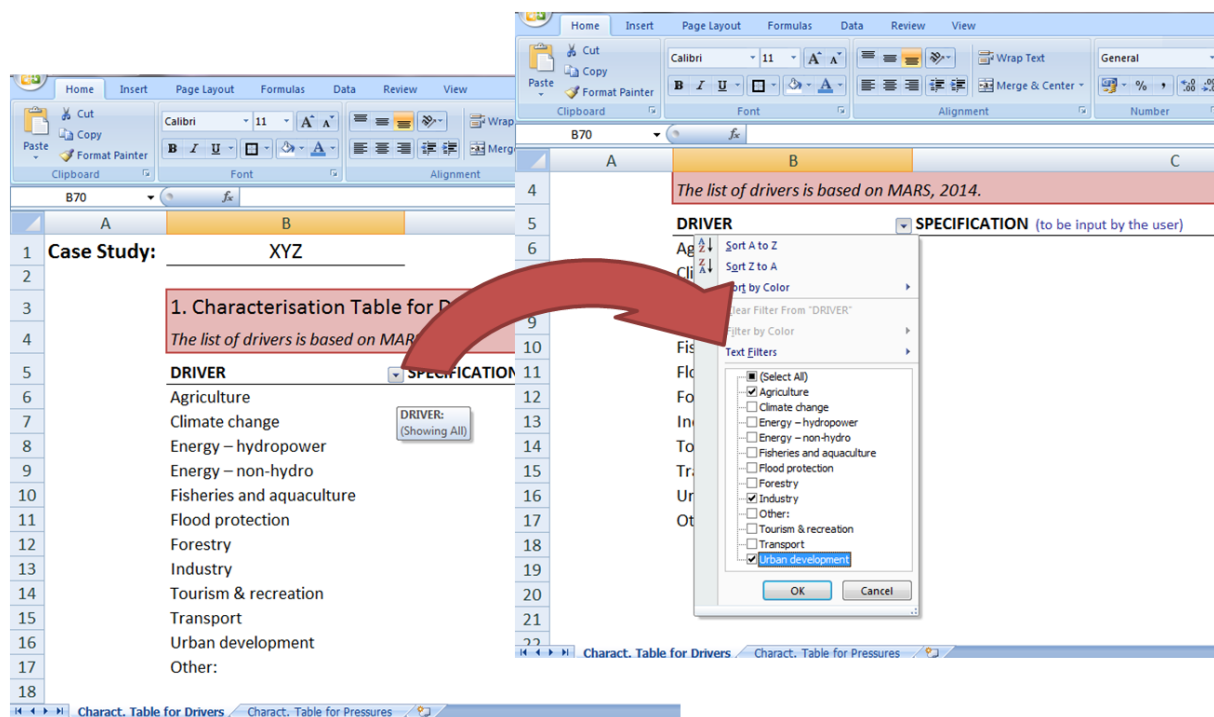


Figure 4. Filtering the drivers found within the study area using the DESSIN Catalogue of Drivers and Pressures

1. Characterization Table for Drivers <i>The list of drivers is based on MARS, 2014.</i>	
DRIVER	SPECIFICATION (to be input by the user)
Industry	Industrial bad practices in the past: solvents and PAHs in groundwater and river. Industries increase in the metropolitan area: WWTP discharge.
Urban development	Inhabitants increase in the metropolitan area: WWTP discharge, intensive use of the river.

Figure 5. Filling in the Characterization Table for Drivers. Example taken from the Llobregat mature case study (infiltration ponds)

Box 3. Synthesis of identified drivers in the study area. Example taken from the Llobregat mature case study (infiltration ponds)

In the Llobregat mature case study area, overexploitation of the aquifer has reduced the amount of water available. The aquifer's water level is below the sea level, and salt water intrusion has started. The salt concentration of the aquifer has increased in the area next to the industrial seaport. Main cause for this is the water use by industry.

Next to industry, urban development is an important driver for the intensive water use in the area. Along the low course of the river, the Baix Llobregat region is a fast growing area in terms of population. From 1975 to 2014 the population has increased more than 50%. This has had significant consequences on the water cycle.

To a lesser extent, the agricultural sector has also exploited the aquifer. A further driver is the engineering works to create the seaport infrastructure of Barcelona, mainly from the construction of a new inland dock that has been accelerating the seawater intrusion process.

Uncertainty:

A high level of reliability is expected here because all pressures could be matched with drivers and all relevant pressures could be identified.

PRESSURES

Definition: The direct environmental effect of the driver, such as an effect that causes a change in water flow or a change in the water chemistry (MARS, 2014).

STEP 2.

Identify what are “the direct environmental effects” of the *Drivers* recognized in Step 1.

Once the *Drivers* existing in the study area have been shortlisted and described as explained in Step 1, the related *Pressures* can be identified. *Pressures* are defined as the direct environmental effects

of the *Drivers*. Examples are discharges of municipal waste water as a result of urban development or nutrient pollution caused by agricultural use of fertilizers.

Instructions:

Refer to the “Catalogue of Pressures” found in the third sheet of the [Supplementary Material File](#). There you will find the “Characterization Table for Pressures”. This table links the 11 types of *Drivers* with 6 categories of resulting *Pressures* proposed by the FP7 MARS project (MARS, 2014b). Notice that not all pressure categories are relevant for each single *Driver* - e.g. for forestry usually only diffuse pollution comes into account.

Table 2 gives a brief description of each of the pressure categories proposed by the FP7 MARS project.

Table 2. MARS pressure categories, descriptions and examples. Based on MARS (2014b) and IMPRESS (2003)

Pressure category	Description	Example
Point pressure	Pollution stems from a single, identifiable source, e.g. a pipe or a drain.	Effluent discharge from a sewage treatment plant
Diffuse pressure	Pollution stems from entries to surface areas and reaches water bodies on hydrologically driven pathways, surface runoff, soil erosion or leaching. Pollution might be caused by various activities and cannot be traced to a single source.	Nutrient input from agricultural land due to excess fertilizer application
Abstraction / flow diversion	Water is abstracted from a water body, changing the water level and flow regime.	Water abstractions for agricultural irrigation
Hydromorphological alteration	Flow characteristics are substantially changed, e.g. through dams and weirs. This includes physical alterations of the river bed, riparian area or the shore.	Deepening and/or widening of a navigation channel
Other pressures	Further pressures occur that do not fit into the categories above.	Introduction of alien species
Groundwater pressure	Groundwater is recharged, i.e. water is introduced into the subsurface. The groundwater level or volume is altered in order to carry out an	Activities to alter the level of groundwater in order to carry out large civil works.

	underground activity such as mining or large civil works. This does not include the alteration of the water level due to current or past overexploitation of the groundwater resources (this case is captured under the category 'Abstraction / flow diversion' above).	
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Use the filter option to select those *Drivers* that were identified in Step 1 above. The “Pressure Category” column will then display a list of all the types of *Pressures* related to the selected *Drivers* (see **Error! Reference source not found.**). Next, as done previously with the *Drivers*, select the relevant *Pressures* using the filter option.

For each of those pressure categories that are relevant in the study area, provide a brief description in the “Specification” column. As in the “Characterization Table for Drivers”, this column can be used to enter free text to describe each *Pressure* in a higher level of detail (see **Error! Reference source not found.**).

As a rule within the DESSIN assessments, *Pressures* will be described qualitatively. If later in Part III of this cookbook, the *Response* (i.e. the proposed measure) is found to have the capability to influence any of the *Pressures* identified in the study area, then exclusively those *Pressures* will have to be quantified. This is to allow the assessment of changes resulting from *Response* implementation.

2. Characterisation Table for Pressures		
<i>The relation between the pressure categories and the drivers is based on IMPRESS Guidance No. 3 and MARS, 2014</i>		
DRIVER IDENTIFIED IN THE STUDY AREA	<input checked="" type="checkbox"/> PRESSURE CATEGORY	<input type="checkbox"/> SPECIFICATION
Industry	Diffuse source	
Industry	Point source	
Industry	Activities using specific substances	
Industry	Abstraction	
Industry	Artificial recharge	
Industry	Morphological	
Industry	Other anthropogenic	
Urban development	Diffuse source	
Urban development	Point source	
Urban development	Abstraction	
Urban development	Artificial recharge	
Urban development	Morphological	
Urban development	Other anthropogenic	
Other:	Hydrological alteration	

Figure 6. List of pressure categories related to the selected drivers. Example taken from the Llobregat mature case study (infiltration ponds)

2. Characterisation Table for Pressures

The relation between the pressure categories and the drivers is based on IMPRESS Guidance No. 3 and MARS, 2014

DRIVER IDENTIFIED IN THE STUDY AREA	PRESSURE CATEGORY	SPECIFICATION
Industry	Diffuse source	Contaminated sites/abandoned industrial sites. Groundwater pollution (solvents, PAHs, industrial pollutants).
Industry	Point source	Industrial waste water.
Industry	Abstraction	Abstraction from industry.
Industry	Other anthropogenic	Groundwater alterations of water level or volume.
Urban development	Diffuse source	Discharges not connected to sewerage network: River water pollution (pesticides, pharmaceuticals, TOC, ammonium).
Urban development	Point source	Urban waste water.
Urban development	Abstraction	Abstraction urban development
Other	Hydrological alteration	Reduction of permeable surface for precipitation infiltration.

Figure 7. Filling in the Characterization Table for Pressures. Example taken from the Llobregat mature case study (infiltration ponds)

Reporting:

Use the information gathered in the “Characterization Table for Pressures” to formulate a brief descriptive text that provides a qualitative (or quantitative, when necessary) overview of the pressure categories in the study area and their relation to the identified *Drivers* (see

Box 4). This text will be used later to complete the evaluation report. Copy the selected *Pressures* into the annex of the [Case Reporting Template](#).

Uncertainty:

The uncertainty in this part of the evaluation is related to the possibility to miss certain *Pressures* as well as to not be able to quantify the ones affected by the *Response*. These limitations should also be mentioned in the results reporting.

Box 4. Synthesis of identified pressures in the study area. Example taken from the Llobregat mature case study (infiltration ponds)

In the Llobregat river region, industrial activities cause point pollution through industrial waste waters. In addition, industrial bad practices in the past have led to pollution of the groundwater (e.g. with solvents, PAHs). Water abstractions for industry put pressure on water resources.

The increase of urban populations in the region has resulted in various pressures on the water bodies. First, the drinking water demand has increased as drinking water is directly related to the number of inhabitants. Second, waste water production has increased in this period, including discharges not connected to the sewerage network (pesticides, pharmaceuticals, TOC, ammonium).

Hydrological alterations related to the creation of seaport infrastructure form an additional pressure.

Uncertainty:

A high level of reliability is expected here because all pressures could be matched with drivers and

all relevant pressures could be identified.

For more information see DEL 13.1 Llobregat case.

3. PART III – Description of Responses and identification of potential beneficiaries

Objective of this chapter:

The aim of Part III is to describe the *Responses* (i.e. the proposed measures) that can be implemented to address the problems in the study area, as identified in Part II. It also aims to identify the *case-relevant ESS* (i.e. the ESS hypothetically affected by the proposed measure). Finally, ESS are linked to *beneficiaries*, and this information is used to categorize the *case-relevant ESS* as *final ESS* or *intermediate ESS*.

RESPONSES:

Definition: The measures taken to address drivers, reduce pressures and/or improve the state of the ecosystem under study (MARS, 2014).

STEP 3.

Characterize each one of “the measures taken to address drivers, reduce pressures and/or improve the state of the ecosystem under study” by naming the *claimed/expected capabilities of the proposed measure*. For technical measures, capabilities will generally be claimed by the provider and will be described in the technical specifications of the solution (e.g. number/range of particulates removed per cubic meter of water). For management measures, capabilities may tend to be more generally described (e.g. reduction in agricultural runoff reaching the water body). Please note that DESSIN is concerned with *Responses* (technologies and measures) that directly target changes in *Pressures* and/or *State*. However, the proposed *DPSIR* methodology could potentially be applied also to other types of *Responses* (e.g. management, regulation, policy measures) that directly target *Drivers* to cause changes in *Pressures* and *State* at different temporal and spatial scales. In this case, the impact evaluation of such responses (Part IV of this cookbook) should also consider changes (before and after) in *Drivers*. Some examples of capabilities and how they are described are shown in **Error! Reference source not found.** below.

Support material necessary for completion:

- [Supplementary Material File](#): DESSIN State-Impact I (ESS Provision) Catalogue
- [Case Reporting Template](#)

Instructions:

3.1 - Describe the proposed measure by categorizing it as a technical (e.g. installation of new equipment) or management measure (e.g. regulatory thresholds for industrial discharges), outlining the problem being addressed.

3.2 - List and define the *claimed/expected capabilities of the proposed measure* and for each one state if they are theoretical or tested. These capabilities should be based on the offer of the measure and should be described as specifically as possible (see **Error! Reference source not found.**).

3.3 - Based on this, identify if these capabilities act on the *Driver, Pressure,* and/or *State* and list all *environmental parameters of State* hypothetically influenced by these capabilities. For this, use columns B, C and D of the “State-Impact I (ESS Provision) Catalogue” found in the sixth sheet of the [Supplementary Material File](#). This is a basic catalogue of *environmental parameters of State* based on the Water Framework Directive (WFD) and peer-reviewed literature. Choose which level of detail to follow (State category, subcategory, or parameter). If relevant *environmental parameters of State* for your case are not found in the catalogue, add them to your list. See Table 4 for this step.

3.4 - Using column D of the DESSIN State-Impact I (ESS Provision) catalogue identify and shortlist those ESS that are related to the *environmental parameters of State* that might be changed via the *claimed/expected capabilities of the proposed measure*. See Table 5 for this step. The shortlisted ESS will be further referred to as the *case-relevant ESS*.

Note that these *case-relevant ESS* correspond to the CICES class level, which is not very detailed. The level of detail will increase in Step 4.

Reporting:

Use the [Case Reporting Template](#) (see Table 5) to visualize the *case-relevant ESS* identified. These will be given in further detail and will be categorized in Step 4. For these, data collection will be necessary and indicators will have to be quantified in Step 8.

Uncertainty:

The correct identification of the *claimed/expected capabilities of the proposed measure* is important in this step for the selection of hypothetical effects of the proposed measure on *State* and ESS. Mention any uncertainties associated with this identification in the reporting template.

Table 3. Examples of capabilities of different Proposed Measures. Taken from the Llobregat mature case study (infiltration ponds)

Proposed measure	Claimed / expected capability	Qualitative description	Quantitative description
Construction and equipment of infiltration ponds	Enhancing water infiltration by additional permeable surface	Increase of infiltration surface available for the infiltration processes.	56,300 m ² 1 m ³ /m ² /day
	Increasing groundwater resources in the aquifer	River water is disconnected of the aquifer due to fine particles acting as clogging in the river bed. Infiltration ponds will increase groundwater resources by the infiltration of river water and/or reclaimed water. Periodic maintenance will allow maintaining infiltration surface available.	10 Mm ³ /year
	Improving water quality via soil-aquifer treatment	It has been proved an effective reduction of turbidity (sediment retention) and a reduction in chemical compounds.	Sediment retention Denitrification Organic matter reduction micro pollutants degradation
	Reducing pollutants in the aquifer	Anthropogenic substances as chlorinated solvents are present in groundwater. By the infiltration of non-polluted water, a plume of clean water is expected to dilute undesirable substances.	-
	Creation of a new surface water body (aquatic ecosystem)	The implementation of infiltration system (settling ponds and infiltration ponds) in a dry area will generate several impacts in terms of new ecosystem creation.	13 Ha

Table 4. Example of capabilities of different Proposed Measures and their effects on D, P, and S. Taken from the Llobregat mature case study (infiltration ponds)

Proposed Measure	Capability		
	Effect on DRIVER (from D catalogue)	Effect on PRESSURE (from P catalogue)	Effect on STATE (from S catalogue)
Construction and equipment of infiltration ponds	<i>n/a</i>	<i>(4) reducing pollutants in the aquifer</i>	<i>(4.1) Transparency (4.2) Nutrient conditions (4.3) Other pollutants: heavy metals</i>

Table 5. Case-relevant ESS, i.e. ESS from the CICES list associated to the affected parameters of State.
Example taken from the Llobregat mature case study (infiltration ponds)

STATE Parameter influenced by measure	CICES Class <i>(restricted to ecosystem type)</i>	CICES Group	CICES Division	CICES Section
(4.1) Transparency	(4.1.1) Surface water for drinking	Water	Nutrition	Provisioning
	(4.1.2) Surface water for non-drinking purposes	Water	Materials	Provisioning
	(4.1.3) Filtration/ sequestration/ storage/ accumulation by micro-organisms, algae, plants, and animals	Mediation by biota	Mediation of waste, toxics and other nuisances	Regulation & Maintenance
	(4.1.4) Chemical condition of freshwaters	Water conditions	Maintenance of physical, chemical, biological conditions	Regulation & Maintenance
	(4.1.5) Cultural	Cultural

BENEFICIARIES

Definition: Any persons, organizations, households, or firms whose interests are positively or negatively affected by either the direct use or presence of the ESS that are changed by the proposed measure (adapted from Landers and Nahlik, 2013).

STEP 4.

Once the *case-relevant ESS* have been shortlisted, the next step is to try and distinguish *final ESS* from *intermediate ESS* within this collection. Those ESS that are only provided by the ecosystem but not directly used or otherwise appreciated by humans are *intermediate ESS* (e.g. water purification as an ESS), while those ESS that are not only provided by the ecosystem but also directly used or otherwise appreciated by humans are *final ESS* (e.g. the actual use of pure water for drinking). This

distinction can be done by identifying “any persons, organizations, households, or firms whose interests are positively or negatively affected by either the direct use or presence of the ESS that are changed by the proposed measure” i.e. the so-called *beneficiaries*. While positive impacts will be mainly assessed in the ESS evaluation in Part IV, any possible negative impacts of the proposed measures will be addressed in the Sustainability Assessment (Part V). ESS that have a *beneficiary* will be classified as *final ESS* while those without a *beneficiary* will be *intermediate ESS*. This information will serve to define which of the *case-relevant ESS* will be monetized (the *final ESS*) using economic valuation methods in Step 7 of the cookbook and which will only be described qualitatively (the *intermediate ESS*).

Support material necessary for completion:

- [Case Reporting Template](#): DESSIN case-relevant ESS (identified in Step 3)
- [Case Reporting Template](#): List of stakeholders (identified in Part I)
- [Supplementary Material File](#): DESSIN beneficiary classification for water-related final ESS (based on US EPA categorization)

Instructions:

4.1 - Refer to the DESSIN beneficiary classification for water-related *final ESS* (labeled DESSIN Beneficiaries-final ESS) in the eighth sheet of the [Supplementary Material File](#). The column “Final ESS of relevance to the beneficiary” (see Figure 8) lists *final ESS* and relates them to specific *beneficiaries* (third column of Figure 8). By comparing the entries in those two columns to each of the *case-relevant ESS* listed in your [Case Reporting Template](#), potential *beneficiaries* of these *case-relevant ESS* can be identified. Make sure to eliminate redundant entries of *case-relevant ESS*.

As the level of detail on the ESS is higher in the column “Final ESS of relevance to the beneficiary” compared to the CICES class level in Step 3, the most appropriate option must be selected. In case there is no matching detailed ESS, add a custom one.

4.2 - Compare the list of *beneficiaries* elaborated in 4.1 to the list of *stakeholders* developed in Part I (see Table 1). This will serve to identify which of the *beneficiaries* affected by the *case-relevant ESS* are actually present in the study area, consequently allowing the distinction between *final ESS* (those for which a *beneficiary* is present in the study area) and *intermediate ESS*. The identification of *beneficiaries* would delimit the spatial scale of the analysis.

4.3 - Based on this information, categorize the *case-relevant ESS* into *intermediate ESS* and *final ESS*. Mark which *intermediate ESS* might be preconditions for *final ESS* (see Figure 9) and are, therefore, important to be assessed as well. This combined output of 3.4 and 4.3 now results in a list of ESS which are both impacted by the proposed measure and are final (i.e. used by the persons and organizations located within the study area). Highlight those *intermediate ESS* and *final ESS* that will be assessed.

Note the potential of *Regulatory Thresholds* in helping to identify the *beneficiary*, the benefit or to judge the quality of the *State* (e.g. bathing river water quality thresholds would help to identify swimmers as *beneficiaries* when water quality standards are met and swimming is allowed). Therefore, it is helpful to collect information on political aims or legal thresholds.

Figure 9 summarizes the entire process in Part III consisting of the description of appropriate measures and their capabilities as well as the identification of *environmental parameters of State* affected leading to potential ESS changed in Step 3. Step 4 presents the instructions for the identification of *beneficiaries*, which allows categorizing the *case-relevant ESS* into *final ESS* and *intermediate ESS*.

Reporting:

The list of *beneficiaries*, *final ESS* and *intermediate ESS* will be used in Part IV for the quantification of *environmental parameters of State*, *ESS Provision* and *ESS Use* via indicators.

Uncertainty:

In this case it is important to identify all *beneficiaries*, as missing these can lead to missing *final ESS*.

DESSIN cookbook Code	Main beneficiary type	Beneficiary sub-type (example)	Example of general beneficiary description (water focus)	Final ESS of relevance to the beneficiary	Equivalency with NACE codes (where available)
1	AGRICULTURE, FORESTRY AND FISHING	Irrigators	Irrigators interact with aquatic environments, as they consume water from aquatic environments for maintaining crops, often moving water through ditches and canals. Note that Farmers and Irrigators are different beneficiaries.	water for growing and maintaining crops	A. AGRICULTURE, FORESTRY AND FISHING
2	MANUFACTURING	Manufacturers of food products	Activities that utilize the natural abundance of edible organisms (i.e., non-cultivated or bred) for commercial use or sale. Includes commercial and native hunters (if legal). In aquatic environments, this beneficiary has potential contact with water.	1) edible organisms (i.e., flowers, plants, etc.) or associated products (i.e., fruit, greens, tubers, berries, sap) for commercial use or sale 2) edible organisms (i.e., birds, mammals, reptiles, etc.) for commercial use or sale	C. MANUFACTURING 30. Manufacture of food products
3	WATER SUPPLY; SEWERAGE, WASTE MANAGEMENT AND REMEDIATION ACTIVITIES	Providers of water collection, treatment and supply services	This beneficiary is responsible for providing water to a community and may do so by collecting water from rivers, reservoirs, lakes, wells, bays, or estuaries. Water is treated and distributed. Direct precipitation is not generally used as a water source.	water suitable for processing by a municipal drinking water plant	E. WATER SUPPLY; SEWERAGE, WASTE MANAGEMENT AND REMEDIATION ACTIVITIES 36. Water collection, treatment and supply

Figure 8. DESSIN beneficiary typology and links to water-related final ESS (excerpt)

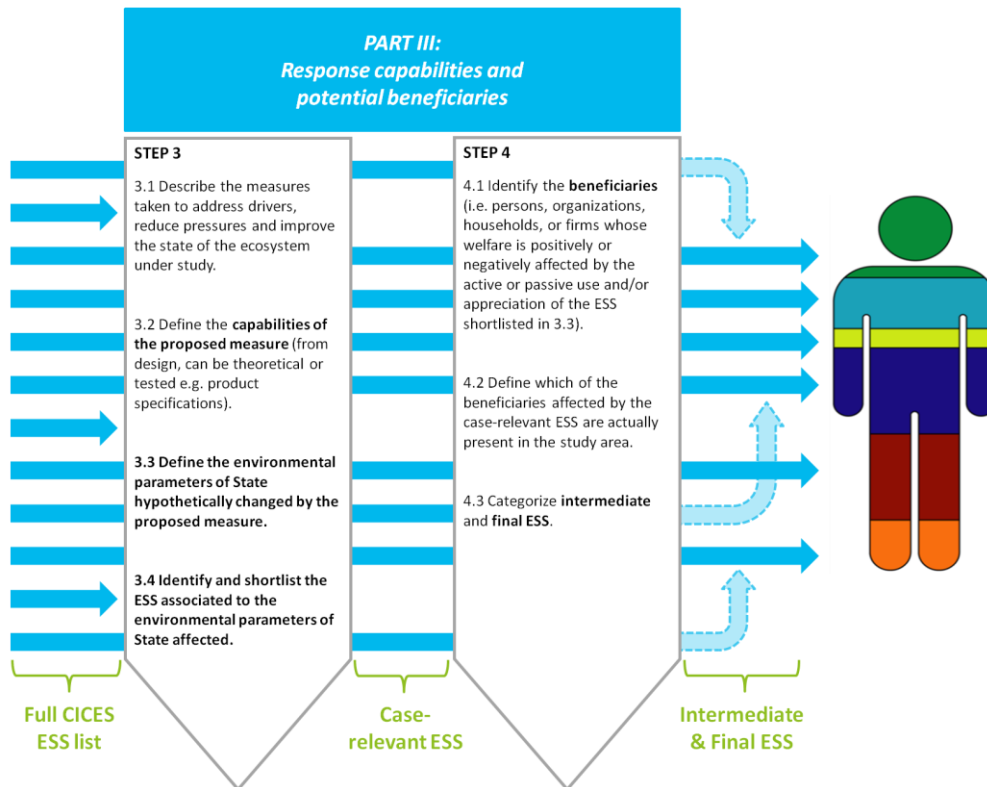


Figure 9. Distinguishing between intermediate (dotted arrows) and final ESS (full arrows) in the study area on the basis of the capabilities of the proposed measure and the beneficiaries identified

4. PART IV – Impact evaluation

Objective of this chapter:

The aim of Part IV is to assess the effect of the proposed measure (*Response*) on the system under examination by quantifying the *State* of the ecosystem, the *Impact I (ESS Provision)* and the *Impact II (ESS Use)*. *State*, *Impact I* and *Impact II* have to be estimated for 2 scenarios: a baseline scenario (before) and one where the proposed measure is already implemented (after). Finally the scenarios are compared and the change in these three elements of the *DPSIR* is evaluated.

Overview of the impact evaluation in Part IV:

To run the impact evaluation of the DESSIN ESS Evaluation Framework, it is important to distinguish between the concepts of *indicator* and *environmental parameter*. In DESSIN, changes in *State*, *Impact I* and *Impact II* are measured using *indicators*. According to the EEA, an *indicator* is “an observed value representative of a phenomenon to study. In general, indicators quantify information by aggregating different and multiple data. The resulting information is therefore synthesized. In short, indicators simplify information that can help to reveal complex phenomena” (EEA, 1999). *Indicators* are different from *environmental parameters*. In DESSIN we define an *environmental parameter* as a variable, measurable property (including physico-chemical, biological and hydromorphological properties of a water body) whose value is a determinant of the characteristics of an ecosystem. This definition is an adapted version of the one used by EIONET for the term ecological parameter (EIONET, 2013).

Figure 10 gives an overview of the impact evaluation process. In order to keep the evaluation manageable, the quantification of impacts is only done for those ESS identified in Step 3.4 as being *case-relevant ESS* and that either have a *beneficiary* (i.e. are *final ESS*) or are considered preconditions for certain *final ESS*. Furthermore, the economic valuation of impacts is only carried out for *case-relevant ESS* that have been categorized as *final ESS* in Step 4.3.

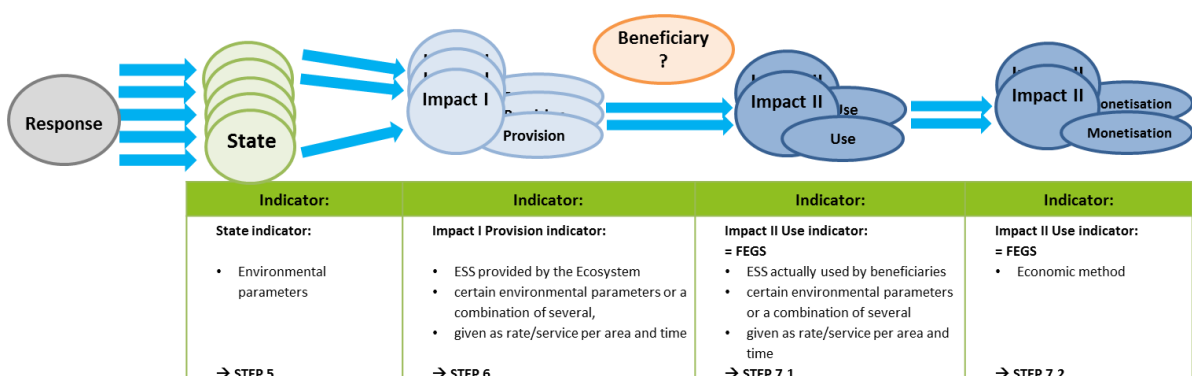


Figure 10. General scheme for the use of indicators within the DPSIR application (R=Response, S=State, I₁=Impact I, I₂=Impact II)

As shown in the figure, the process starts with a *Response* affecting the *State* of the ecosystem under study, or more precisely, the *environmental parameters of State* that determine the characteristics of that ecosystem. The change in the overall *State* of the ecosystem (i.e. in the integrated *environmental parameters of State*) is measured using *State indicators* that are selected in Step 5.

Out of all the *environmental parameters of State* that can be measured in an evaluation, only a subset will be associated with *ESS Provision*. The parameters making up this subset are known as *case-relevant parameters of State*. Once these *case-relevant parameters of State* have been identified, the *Impact I (ESS Provision) indicators* can be selected in Step 6. These indicators measure the level of goods and services provided by the ecosystem under scrutiny.

Similarly, of all the goods and services provided, only a subset will be actually utilized by a *beneficiary*. Indicators for these *case-relevant ESS* which are also *final ESS* are selected in Step 7.1.1 to assess the *Impact II (ESS Use)*. Finally, economic valuation methods used to attach monetary values to these case-relevant, *final ESS* are selected in Step 7.1.3.

Note 1: *Impact I (ESS Provision)* is not the same as the “provisioning ESS” category in the CICES classification.

Note 2: Indicators of *Impact I (ESS Provision)* are often given as a rate/service per area and time. For guidance, a list of exemplary *ESS Provision indicators* from the mature case studies of DESSIN and from peer reviewed literature is provided in the [Supplementary Material File](#) under the “Impact I (ESS Provision) indicators catalogue (ninth sheet of the file).

STATE

Definition: The environmental condition of an ecosystem as described by its physical, chemical and biological parameters (MARS, 2014) .

- *Physical parameters encompass the quantity and quality of physical phenomena (e.g. temperature, light availability)*
- *Chemical parameters encompass the quantity and quality of chemicals (e.g. atmospheric CO₂ concentrations, nitrogen levels)*
- *Biological parameters encompass the condition at the ecosystem, habitat, species, community, or genetic levels (e.g. fish stocks or biodiversity)*
- *Hydromorphological parameters encompass the quantity and quality of the hydromorphological features (e.g. river continuity, quantity and dynamics of the water flow)*

(adapted from US EPA, 2017)

STEP 5.

Select indicators/proxies to measure the *case-relevant parameters of State* previously identified in Step 3 and Step 4.

Support material necessary for completion:

- [Supplementary Material File](#): Catalogue of environmental parameters of State (based on FP7 MARS)
- [Case Reporting Template](#): Driver, Pressure, and/or State affected by the capabilities (output of Step 3.3) & case-relevant ESS (output of Step 3.4)
- [Case Reporting Template](#): Intermediate and final ESS table (output of Step 4.3)

Instructions:

5.1 - Using the output of Step 3.4 identify the *environmental parameters of State* that will be assessed. These state parameters will be called *case-relevant parameters of State*.

5.2 - Select *State indicators* for each of the *case-relevant parameters of State*. In some cases these indicators are represented by the *environmental parameters of State* themselves (see Table 6, row 1 and 2). Examples of *indicators* describing the *State* of an ecosystem are given in Table 6 below.

Note: Keep in mind data availability when selecting indicators.

Table 6. Examples from the DESSIN mature case studies for State indicators. Excerpt from the Indicator table of the Case Reporting Template

DESSIN ESS (based on US EPA)	Environmental parameters of State	State indicator	Unit of measure
<i>Water suitable for processing by a municipal DWTP</i>	<i>Connection to groundwater bodies</i>	<i>permeable area available</i>	<i>m²</i>
<i>Potential denitrification rate in total stream length per year</i>	<i>water-sediment surface</i>	<i>water-sediment surface</i>	<i>m²</i>
	<i>Nutrient conditions: N-concentration</i>	<i>initial N-concentration</i>	<i>kg/m³</i>
<i>Provision of opportunity to experience and view a landscape that provides a sensory experience, including sights and sounds</i>	<i>presence of surface water</i>	<i>percentage of analysis period that surface waters are visible</i>	<i>%</i>

Note that *State indicators* will be the link to the *Impact I (ESS Provision)* assessment in later steps.

Reporting:

Use the “Factsheet template” found in the [Case Reporting Template](#) to collect and document the results of your case in a structured way.

Uncertainty:

Try to describe the uncertainty linked to the quality of the selected *State indicators*. See Box 5 for a classification of indicator type.

IMPACT I

Definition: The effects that changes in ecosystem state have on the provision of ecosystem services (Müller and Burkhard, 2012).

STEP 6.

Select indicators/proxies for relating *case-relevant parameters of State* to *ESS Provision*.

Support material necessary for completion:

- [Supplementary Material File](#): DESSIN Catalogue of Impact I (ESS Provision) Indicators (i.e. List of exemplary Impact I indicators from the mature cases)
- [Case Reporting Template](#): Intermediate and final ESS table (output of Steps 3.4 and 4.3)
- [Case Reporting Template](#): Selected State indicators (output of Step 5)

Instructions:

6 - Use the “Impact I (ESS Provision) indicators catalogue” found in the [Supplementary Material File](#) (ninth sheet of the file) and the criteria in Box 5 below to select those *ESS Provision indicators* that are suitable for the study. If none of the listed indicators are suitable for your case, include custom ones.

Box 5. – Using a typology of indicators to outline their quality and the resulting uncertainty issues

The quality of indicators is linked to the type of indicator and is categorized into true/direct indicators and proxy indicators. Ideally, status-related indicators should be applied for status-related services and process-related indicators for process-related services. In case the latter is not possible, status-related indicators can be used as a proxy for process-related services.

For a more detailed explanation see the Chapter 4.2 of [Companion Document](#).

True/direct indicator =

- *status-related indicator for status-related service (e.g. indicator → amount of water provided; ESS → water provision) or*
- *process-related indicator for process-related service (e.g. indicator → denitrification rate; ESS*

→ self-purification)

Proxy =

- status-related indicator for process-related service (e.g. indicator → volume within riverbed; ESS → flood protection)

ESS Provision indicators can in most cases be represented as rates per area and time. These indicators are commonly, but not always, calculated based on certain *environmental parameters of State* that are associated with *ESS Provision*. Three examples of *ESS Provision indicators* for each section of ESS (Provisioning, Regulating & Maintenance, and Cultural) are shown below:

- *ESS Provision indicators* for *Provisioning ESS* might be:

- Potential water provision per stream per year. This indicator can be assessed via the discharge of the stream per time unit and be scaled up to the entire basin for the time period of e.g. one year.

- *ESS Provision indicators* for *Regulating & Maintenance ESS* might be:

- Increased potential water retention per stream km per year. This indicator is based on the maximum volume of water that can be retained inside the stream bed during rainfall events.

- *ESS Provision indicators* for *Cultural ESS* might be:

- Aesthetics of the landscape. This indicator is an aggregation of a number of single metrics rating e.g. the clarity of the water, its smell, sound, as well as colors and patterns of the surrounding landscape, combined with anthropogenic structures for recreation.

The examples in Table 7 below are for Provisioning, Regulating & Maintenance, and Cultural ESS, respectively. As discussed in the next section of this cookbook and in further detail in Chapter 5 of the Companion Document, the *Provisioning ESS* are often *final ESS*, while the *Regulating & Maintenance ESS* are often *intermediate ESS*, just as in this case. The last example is an *intermediate ESS* for a *Cultural ESS*.

Note that in the example in Table 7, the *environmental parameters of State* are not part of the FP7 MARS catalogue but were added as custom ones. The *ESS Provision indicator* cannot, in the first case, be directly derived from the *environmental parameter of State* but in the second and last case the *ESS Provision indicator* is based on the *environmental parameters of State* selected earlier in Step 5.1 and Step 5.2.

Table 7. Examples from the mature cases for Impact I reporting. Excerpt from the Indicator table of the Case Reporting Template

DESSIN ESS* (final or intermediate)			Environmental parameters of State	Unit of measure	Impact I (ESS Provision)	ESS Provision indicator	Unit of measure
final ESS	Provisioning ESS	Water suitable for processing by a municipal DWTP	permeable area available	m ²	Potential of surface water infiltration and aquifer replenishment	Increase of groundwater level (reducing energy costs) per year	m/a
intermediate ESS	Regulating ESS	Potential denitrification rate in total stream length per year	water-sediment surface	m ²	potential denitrification rate	potential denitrification rate	kg/a N removed in total stream length in the Emscher basin
			initial N-concentration	kg/m ³			
final ESS	Cultural ESS	Provision of opportunity to experience and view a landscape that provides a sensory experience, including sights and sounds	percentage of analysis period that surface waters are visible	%	Provision of opportunity to experience and view a landscape that provides a sensory experience, including sights and sounds	Beauty of the landscape (Composite indicator that aggregates indicators 1-6 in the list above)	Dimensionless index

*Based on Landers and Nahlik (2013)

Impact I (ESS Provision) can be quantified both for *final ESS* and *intermediate ESS*. *Final ESS* are commonly *Provisioning ESS* and *Cultural ESS* while *intermediate ESS* are frequently *Regulating & Maintenance ESS*. The assessment of *intermediate ESS* stops after the quantification of Impact I, since there is no direct *beneficiary* that is using the service within the study area. These *intermediate services* can, however, be prerequisites for certain *final ESS*. Thus, their quantification is still necessary as it will provide input data necessary for the evaluation of these *final ESS*.

Note also that a DPSIR analysis does not always proceed in a linear direction. Therefore, it may be required to skip single elements.

Reporting:

Use the “Factsheet template” found in the [Case Reporting Template](#) to collect and document the results of your case in a structured way.

Uncertainty:

Try to describe the uncertainty linked to the quality of the selected *ESS Provision indicators*. See Box 5 for a classification of indicator type.

IMPACT II

Definition: The effects that changes in ecosystem services have on human well-being (Müller and Burkhard, 2012), understanding human wellbeing as the economic value derived by beneficiaries from enhanced ESS USE.

STEP 7.

Taking into consideration the *beneficiaries* identified in Step 4.1 select the appropriate *ESS Use indicators* that match the *State indicators* and *ESS Provision indicators*. The *ESS Use indicators* have to be end-user/beneficiary oriented and thus always linked to *final ESS*. This will help to avoid double-counting.

Support material necessary for completion:

- [Companion Document](#): Chapter on Impact II
- [Supplementary Material File](#): DESSIN Impact II (ESS Use) indicator catalogue
- [Supplementary Material File](#): DESSIN Valuation Studies database
- [Case Reporting Template](#): Examples from mature case studies

Instructions:

7.1 - Impact II (ESS Use)

7.1.1 - Select *ESS Use indicators*. Identify appropriate *ESS Use indicators* that describe the actually used or demanded amount/level of each *case-relevant ESS* by the beneficiary/beneficiaries. Use the “Impact II (ESS Use) indicator catalogue” found in the tenth sheet of the [Supplementary Material File](#) and consider the list of criteria for indicator selection below (or refer to Chapter 5 the [Companion Document](#)). Select *direct indicators* where possible using available data or modelling, otherwise select *proxy-indicators*.

Table 8. Beneficiary classification for water-related Final ecosystem services in the Llobregat mature case study

Measure	ESS affected (use CICES and US EPA catalogue!)		Beneficiaries (use US EPA categorization!) ¹
	CICES class	DESSIN ESS (use US EPA nomenclature where applicable) ²	(no beneficiary = only intermediate service)
Construction and equipment of infiltration ponds	Groundwater for drinking	Water suitable for processing by a municipal drinking water treatment plant (DWTP).	Municipal Drinking Water Treatment Plant Operators
	Groundwater for non-drinking purposes	Water suitable for cooling or processing industrial products.	Industrial processors
	Educational	Research opportunities.	Researchers
		Opportunities to understand, communicate, and educate.	Educators and students
	Experiential use of landscapes in different environmental settings	(1) Opportunity to view the environment and organisms* within it, and groundwater phenomena. (2) Landscape that provides a sensory experience. (3) Sounds and scents that provide a sensory experience. * Organisms (i.e., flowers, plants, birds, mammals, reptiles, etc.) that can be viewed.	Experiencers and Viewers

Note: The identification of *ESS Use indicators* should be a straightforward exercise that would help with the identification of *beneficiaries* and *final ESS*. The user should be aware that very often a direct, and thus, quantifiable relationship between *State* → *Impact I (ESS Provision)* → *Impact II (ESS Use)* and the indicators for these cannot be found. Thus if the analytical cascade is incomplete, indirect or qualitative relationships may need to be established between *State* or proxy *State indicators* and *ESS Use indicators* which are relevant for the economic valuation of changes in ESS.

7.1.2 - Assess the selected *ESS Use indicators* qualitatively to understand all the expected impacts that specific changes in ESS will have on the identified relevant *beneficiaries* in the study area. The objective is to provide a qualitative evaluation of the extent of the impacts for those *final ESS* that cannot be monetized. This can be done by making qualitative descriptions of benefits with the help of *ESS Use indicators* and other available sources (local statistics and reports). This would be especially relevant as there are many *final ESS* that are difficult or impossible to monetize but that should be included in the evaluation. This can be done by qualitatively evaluating and discussing impacts and describing the significance of the predicted changes for each of the *beneficiaries*.

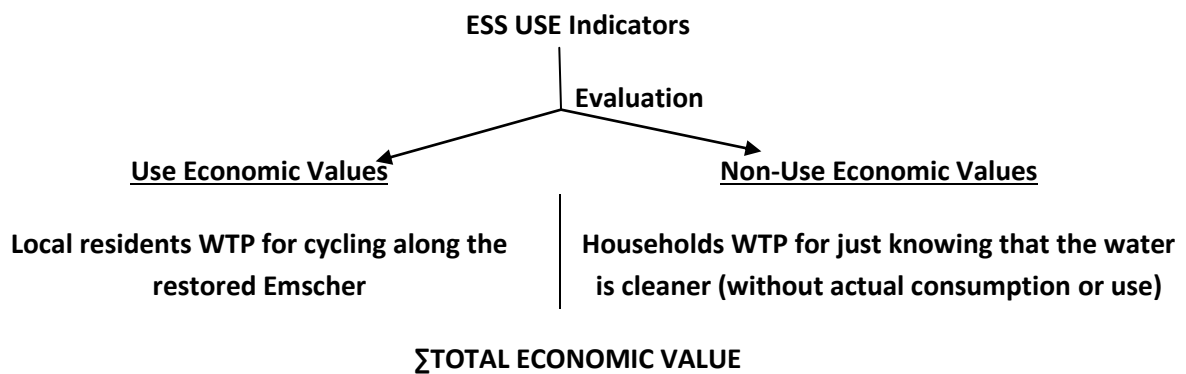
7.1.3 - Select appropriate economic valuation method(s) to attach monetary values to the ESS Use identified in the study area. Use the criteria for method selection included below and in the [Companion Document](#).

Note: The selected economic valuation method(s) will be used to assess the previously selected *ESS Use indicators* quantitatively in Step 8 by conducting an economic valuation of changes in *final ESS*.

Classification of economic value indicators

The value which users derive from an ESS is depicted in the total economic value. The total economic value placed on environmental assets can be disaggregated into economic use values (e.g. *direct use*

values and *indirect use values*), as well as *non-use values*, which can be linked to respective *ESS Use indicators*.



ESS USE INDICATORS -> TEV = USE VALUE INDICATORS + NON-USE VALUE INDICATORS

Figure 11. How ESS Use indicators relate to economic value indicators. Example taken from the Emscher mature case study. WTP = Willingness to pay

For further explanation about different concepts of economic value please refer to Chapter 5.1 of the [Companion Document](#).

This classification allows a categorization of *use value indicators* and *non-use value indicators* for different *ESS Use indicators* and helps to identify suitable valuation methods later on. Please refer to the list of beneficiary types and definitions of their *ESS Use* in Chapter 3 of the [Companion Document](#). The beneficiaries' typology already includes in the beneficiaries types the distinction between use and non-use type of values.

Linking *intermediate ESS* to *final ESS* for their valuation:

- *Provisioning services* can mainly be seen as *final ESS* that are directly used, e.g. water consumption.
- *Cultural services* can all be defined as *final ESS* and their *ESS Use indicators* can be classified as either *direct use value indicators* or *non-use value indicators*.
- *Regulation & Maintenance services* are mostly used indirectly and can often not be classified as *final ESS*. These *intermediate ESS* and their *ESS Provision indicators* should therefore be linked to either *Provisioning services* or *Cultural services* and their respective *direct use value indicators* or *non-use value indicators*. Here, also bundles of *Regulation & Maintenance intermediate ESS* and their *ESS provision* can be linked to one or more *final ESS*. Economic valuation can be performed only when *direct use value indicators* of *Regulation & Maintenance services* are found.

Table 9. Decision tree for the identification of indicators for the economic valuation of final ESS

IESS	Provisioning, Regulation & Maintenance, Cultural	Provisioning, Cultural		Regulation & Maintenance		
Beneficiary found?	No	Yes		Yes	No (indirect use)	
		Direct use	Non-use	Direct use	Direct use	Non-use
FESS	-	Provisioning, Cultural	Cultural	Regulation & Maintenance	Provisioning, Cultural	Cultural
Economic valuation	-	Direct valuation	Non-use valuation	Direct valuation	Direct valuation	Non-use valuation
Valuation method	-	Market valuation. Travel cost and hedonic pricing.	Stated preferences	Market valuation	Market valuation. Travel cost and hedonic pricing	Stated preferences

Criteria for the selection of valuation methods

The choice of the valuation method depends on the *final ESS* type, the *beneficiary* and the data availability. The first step here is to define if the *final ESS* in question is a marketed, indirectly marketed or non-marketed final ESS (in dependence of the beneficiary).

- **Direct market valuation** is only applicable where a market exists for the *final ESS* and data is readily available.
 - If the *final ESS* is marketed, use market prices/market valuation
- If no markets exist for the respective *ESS Use indicator*, an indirect or non-market valuation method must be chosen (description in table). Here,
 - primary data can be collected *or*
 - benefit transfer can be used

The choice of valuation method may also be affected by the type of *final ESS* being valued and the type of *beneficiary*. Table 10 gives an overview of the suitability of different methods for the different ESS types found in the DESSIN mature case studies, including benefits transfer. Though primary valuation research is generally preferred to estimate final ESS values, policy processes and financial limitations often dictate that benefit transfer is the only feasible option to obtain benefit estimates. Please refer to Chapter 5 of the [Companion Document](#) for further information about the different benefit transfer methods and the criteria for the selection of suitable studies for benefits transfer.

Table 10. Overview of possible valuation methods for different ESS types

ESS (direct use)	Type of value	Market prices	Production function	Avoided costs	Replacement costs	Travel cost	Hedonic pricing	Stated preferences	Benefit transfer
Provisioning	USE (direct and indirect use value indicators)	x	x	<i>Groundwater for non-drinking purposes (QUANTITY). Llobregat</i>	x	-	-	(x)	(x)
Regulation and Maintenance	USE (direct and indirect use value indicators)	-	x	<i>Groundwater for non-drinking purposes (QUALITY). Llobregat</i>	x	-	-	(x)	(x)
Cultural	USE (direct and indirect use value indicators)	x		-	-	x	x	x	x
	NON-USE	-	-	-	-	-	-	x	x

Reporting:

Use the “Factsheet template” found in the [Case Reporting Template](#) to collect and document the results of your case in a structured way.

Uncertainty:

Try to describe the uncertainty linked to the quality of the selected *Impact II (ESS Use) indicators*. See Box 5 for a classification of indicator type. Include information on the limitations of the economic method selected, the available data and the assumptions for benefits transfer (e.g. preferences).

QUANTIFICATION OF STATE, IMPACT I AND IMPACT II

STEP 8.

Quantify the indicators selected in the previous steps to describe the *State*, *Impact I (ESS Provision)* and *Impact II (ESS Use)* in the study area and compare the results for a baseline scenario (before) and an after implementation scenario (after). The baseline scenario can be based on already existing data. The after scenario should require estimated data.

Support material necessary for completion:

- [Case Reporting Template](#): Selected State indicators
- [Case Reporting Template](#): Selected ESS Provision indicators
- [Case Reporting Template](#): Selected ESS Use indicators

Instructions:

8.1 - Quantify the previously selected indicators that measure *case-relevant State parameters* for the baseline scenario and the after implementation scenario. The output will be biophysical units. Compare the quantified *State* before and after the intervention.

8.2 - Quantify the previously selected indicators that measure *ESS Provision* for the baseline scenario and the after implementation scenario. Compare the quantified *ESS Provision* before and after the intervention.

8.4 - Quantify the previously selected indicators that measure *ESS Use* for the baseline scenario and the after implementation scenario. Compare the quantified *ESS Use* before and after the intervention.

8.5 - Conduct an economic valuation of changes in *final ESS* through *Use Value indicators* and *Non-Use Value indicators*. Only final ESS can be valued. Where case study relevant *ESS Use* background data for the development of indicators are missing, there may be a need to apply (assume) relationships between *ESS Use parameters* from earlier studies in order to extrapolate information which is unavailable in your study. Conduct the valuation for the baseline scenario and the after implementation scenario. Compare the quantified *Resulting benefits* before and after the intervention.

Furthermore evaluate by:

- a) Calculating a ratio of *ESS Provision* to *ESS Use* (e.g. according to Paetzold et al., 2010). This gives additional information on whether the ESS is used in a sustainable or unsustainable manner.
- b) Analyzing spatial and temporal aspects of *ESS Provision* and *ESS Use*. Focus on those spatial and temporal scales most relevant for the beneficiaries identified.

Reporting:

Use the “Factsheet template” found in the [Case Reporting Template](#) to collect and document the results of your case in a structured way.

Note: The following recommendations are given for reporting the results of the quantitative *Impact II (ESS Use)* assessments.

1) It is preferable to report each valuation result for the use of a case study relevant *final ESS* separately, and clearly indicating the valuation method employed. Table 11 shows a template that can be used for this (the table template can also be found in the [Case Reporting Template](#)).

2) It is not recommended to aggregate the calculated results from the use of different case study relevant *final ESS*, even though they might originate from the same proposed measure.

The main reasoning behind these two recommendations is that while all economic valuation methods will be used for the same purpose (attaching a monetary value to the identified change in *ESS Use*), different valuation methods may have distinct conceptual basis and their implementation may entail distinct sets of assumptions. These intrinsic differences between valuation methods could thus result in inaccuracies when using the simple aggregation of their outputs as a total figure. Concluding, aggregation of different assessment results using different methods is not recommended, except if an exhaustive interpretation, eventually resulting in adjustment of the derived economic figures, has been conducted. A more detailed explanation of this reasoning can be found in Chapter 5 of the [Companion Document](#).

Table 11. Template table to summarize and present the results of the economic valuation of changes in final ESS.

Final ESS	Beneficiary	Valuation method	Assumptions/ comments/references	Values	Units	Uncertainty
FESS1	FESS1 BN1					
	FESS1 BN2					
	...					
FESS2	FESS2 BN1					
	FESS2 BN2					
...	...					

Uncertainty:

See Box 5 for a classification of indicator type and Box 6 for data type.

Defining the temporal scale for the quantification of State, Impact I and Impact II

The core results of the DESSIN ESS Evaluation Framework are drawn from the assessment of the difference between the scenarios before and after the implementation of the proposed measure. To achieve this assessment it is necessary to define the timeframe/temporal scale for the *State*, *Impact I (ESS Provision)* and *Impact II (ESS Use)* elements of the *DPSIR*. This timeframe depends on the scope of the assessment. Commonly when applying the DESSIN framework this scope is either for a decision-maker to decide between alternative measures to choose from to improve a freshwater environment or for an organization to quantify positive arguments to promote a specific solution. For both cases it is necessary to quantify expected future benefits. The benefits arise from a positive change in *case-relevant parameters of State*, *ESS Provision* and *ESS Use* and finally human well-being parameters. Generally it is recommended to estimate these benefits on an annual basis, for a timeframe aligned to the expected lifetime of the proposed measure under scrutiny. Assessing future benefits on an annual basis offers different advantages:

- It makes it possible to compare the change in *State*, *Impact I (ESS Provision)* and *Impact II (ESS Use)* for different measures, without the risk of biasing and eventually misleading seasonal influences;
- It offers the ability to compare alternative measures by summing up the expected monetary benefits (from Impact II assessments) for the full lifetime of each alternative.

The latter advantage is especially true, if e.g. the scope of the assessment for a decision-maker is to find the most promising solution for the long run, where solutions that are sustainable in the long-term are the main aim.

As has been discussed earlier in this chapter, *case-relevant parameters of State* and the indicators used to measure them describe those *environmental parameters* necessary for the selection and quantification of *Impact I (ESS Provision) indicators*.

Criteria for selecting data to quantify indicators

- a) For already completed measures/implemented solutions: Collect data on the system for the baseline scenario and alternative/after *State*; mark as “observed”
- b) For planned/future measures: Determine the effect of the measure/solution on the *State* of the system via field measurements/pilots/monitoring/modeling; mark as “estimated”

Procedure for recognizing and handling uncertainties associated to the quantification of State, Impact I and Impact II

- a) Transparency: establish and communicate the basis of your estimate.
In general it can be agreed that the level of uncertainty associated with an estimate can be seen as a function of the type of data on which the estimate is based. For instance, estimates of the different elements used to develop a future scenario for a given ecosystem can be more or less uncertain depending inter alia on the quality characteristics of the data used to calculate them. The data on which the estimate is based can be classified using the categories described in Box 6.

“A data”

Estimate is based on:

- existing data that are recently derived from the specific site and/or,
- data from field measurements that use protocols with large and unbiased sample sizes (e.g. WFD protocols, the Wetland Ecosystem Services Protocol for the United States, WESPUS¹) and/or,
- peer-reviewed published data derived recently from similar habitats near the site;

For all three sources listed above the data collection is based on sound methods in terms of accuracy and precision level, judged in relation to site boundary definition, area/ecosystem characteristics, type, number and distribution of measurement plots and measurement frequency.

➔ Estimates based on A data are expected to show a high level of confidence.

“B data”

Estimate is based on:

- existing data that are recently derived from reasonable sampling. The data is treated critically with their methodological limitations acknowledged; and/or,
- data from field measurements that use well-defined protocols but are derived from relatively low sample sizes and precision levels, or are subject to minor measurement and sampling restrictions and/or,
- peer-reviewed on in grey literature published data derived from similar habitats within your site’s climate domain and region. Also applies to estimates based on data from look-up tables that use region-specific sources based on compilations of data sources;

Estimate based on not too simplified modeling tools would also fall into this category.

➔ Estimates based on B data are expected to show a medium level of confidence.

“C data”

Estimate is based on:

- existing data that are derived from unknown methodology or poor sampling techniques (i.e. data are poorly representative, or inadequately sampled); and/or,
- data derived from an area that may not be a good surrogate for the site (e.g. moderately different habitat, very distant site, very old data) or data that are highly irregular (e.g. substantial range between upper and lower confidence limits); and/or,
- look-up tables that use habitat-related sources not specific to the region and/or on a sparse compilation of data sources

➔ Estimates based on C data are expected to show a low level of confidence.

¹ https://www.novascotia.ca/nse/wetland/docs/Manual_WESPUS.pdf

b) The known unknown: identify the inevitable uncertainty.

Uncertainty that can be identified but cannot be avoided can be understood as “the known unknown”. When uncertainty cannot be avoided, this cookbook recommends that the user should make an effort to clearly outline it, preferably providing a relative appraisal of it. For instance, when estimates are based on existing data, some data collection and processing issues such as sample size and reference location cannot be influenced. This limitation can be outlined by running a sensitivity analysis to provide indication of the level of influence that the variable sample size may have on the resulting estimate and reporting on this. Further, an appraisal of the limitation can be made by comparing the sample size of the original study to the one in the new assessment being conducted. Unknown site-specific characteristics (e.g. physical, chemical, biological or hydromorphological traits) can also be reported as part of the “known unknown”.

c) Filling the gaps (where possible): deal with low levels of confidence.

Simply put: one has to accept that details about the known unknown will remain unknown, but its extent should be outlined and, if possible, reduced. In case you are working with data which has a low level of confidence (e.g. due to poor data quality) we recommend to add/combine data into your series. This must be done in a systematic, consistent way and follow agreed procedures (e.g. normalizing indicator values to a common range and unit to ensure compatibility). While collecting additional field data might be expensive, adding data from regular monitoring programs might be a more accessible option. Incorporating qualitative data (e.g. from expert interviews) or using historic data to elaborate projections and future scenarios are other ways to address the lack of primary data.

Finally, transparency is of top relevance in this step as the reader must be aware of the assumptions and data processing undertaken to elaborate the new data series and of the subsequent uncertainty related to such assumptions. The gaps that remained unfilled must also be clearly outlined and communicated to the reader.

5. Reporting of ESS evaluation results

As could be seen in Chapters 1-4, the user can already collect the results of each part of the evaluation as he or she completes each step of the DESSIN Cookbook. This is done using the [Case Reporting Template](#), which offers dedicated fill-out tables for each of the steps. It is recommended that the users of the DESSIN ESS Evaluation Framework consult the outcome reports of the DESSIN mature case studies to see how the reporting template can help in presenting the results.

The main body of the DESSIN mature case study reports includes descriptive text presenting the key results, while the filled tables can be found in the annex of those documents. In the reports the main findings of Parts I-III (Steps 0-4) are presented in text form. For Part IV (Steps 5-8) the findings are presented one *case-relevant ESS* after the other. *Intermediate ESS* are presented first, followed by the *final ESS*. For each ESS the following was reported: a) a short introduction; b) the *case-relevant parameters of State* as well as the selected indicators and their quantification; c) the selected *Impact I (ESS Provision)* indicators, their quantification and a discussion of results; d) the selected *Impact II (ESS Use)* indicators, the indicators/economic methods applied to elicit the resulting benefits, and a discussion of results. The findings of Part V (Sustainability Assessment) are presented according to Steps A-E. In Step E, all sustainability indicators are named and classified according to the dimension they belong to. Furthermore, they are described and the quantified results are reported and discussed.

Both for the ESS Evaluation and the Sustainability Assessment it is important to qualitatively discuss those ESS and indicators of sustainability that could not be quantified due to data constraints. Unfortunately, however, these qualitative results cannot go into a final summary chart described below.

The suggested summary chart for presenting the overall results of the ESS evaluation is a spider plot accompanied by descriptive text. As *final ESS* can be measured in the same unit (monetary units/year), they can be shown in one comparative graphic. A spider plot allows presenting the change in monetary benefit from baseline scenario to after implementation scenario for each of the *final ESS*.

A summary graph for the *intermediate ESS* is more complicated due to the fact that they will commonly be measured in different units. If both Impact I (ESS Provision) and Impact II (ESS Use) have been quantified, they could be shown in bar charts for each ESS as suggested by Paetzold et al., 2010. Additionally, the change can be reported in % increase or decrease. In a second step, provision:use ratios can be calculated, which are unitless and can be presented in the same graph. Note that by comparing provision and use, conclusions on a sustainable utilization of the ESS provided by the ecosystem can be derived. In the graph the threshold between sustainable and unsustainable utilization is marked with the dotted line ($R = 1.0$).

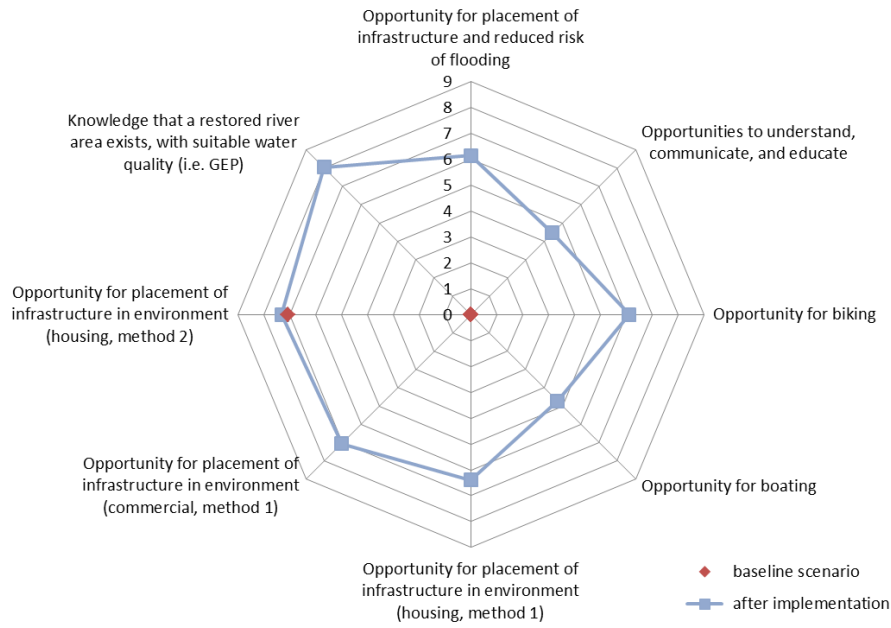


Figure 12. Spider plot showing all final ESS evaluated in the Emscher mature case. Axis: log10 transformed €/a (red points: BEFORE, blue points: AFTER)

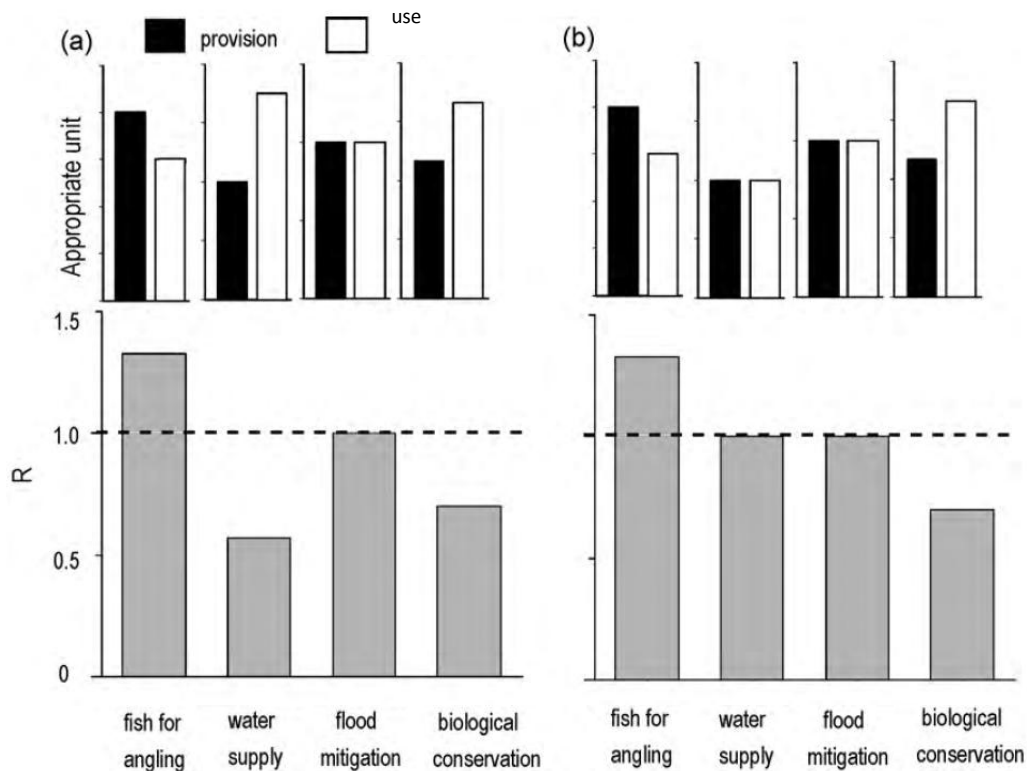


Figure 13. Ecosystem Service Profile (ESP; Paetzold et al., 2010). a) The upper panels show provision and use quantified for each of the four exemplary ESS. The lower graph depicts provision:use ratios (R) determined for each of the services. The dotted line indicates where provision equals use. b) A scenario of an improved ESP resulting from the reduction in use for one of the services, while provision is kept constant

In the end, those *final ESS* that could be quantified and monetized can be compared to the costs of the measure. In this case, costs and benefits should be compared in e.g. € per year. Note that it has to be considered that usually not all ESS can be monetized (or even assessed) inter alia due to lack of data, and are, thus, missing in the cumulative benefit. An example of how this cost-benefit can be plotted graphically is shown in Figure 13.

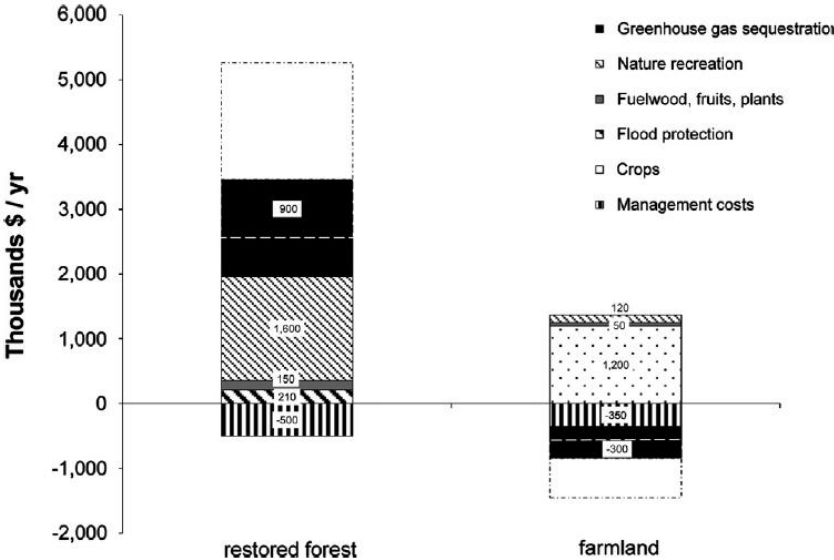


Figure 14. Bar charts. showing the economic costs and benefits associated with the ecosystem service flows for two states (restored forest and farmland) so that their net economic values can be compared. Source: Peh et al., 2013

For a full decision-support, at this point, the outcome of the ESS evaluation should be supplemented with the outcome of the SA. The findings from the SA should, thus, be included into the discussion and the comparison of costs and benefits. Some indicators assessed in the SA are reported in monetary terms and can more easily be supplementary to the ESS outcome. SA indicators with different units can only be included into the discussion qualitatively.

For the SA, the final outcome can be presented as per the options described in the next chapter.

6. PART V – Sustainability Assessment

Objective of this chapter:

The aim of this chapter is to supplement the ESS evaluation by advising how to conduct an additional sustainability assessment (SA) of innovative solutions aimed at mitigating water scarcity or water quality issues. The SA allows the user of the DESSIN ESS Evaluation Framework to widen the analysis, putting the evaluated changes in ESS into perspective by considering multiple dimensions. These multiple dimensions include wider social, environmental, financial, governmental, and asset performance aspects of the examined solution. This allows for the consideration of potential disadvantages like costs and environmental effects (e.g. additional greenhouse gas emissions) and their comparison with the advantages in terms of benefits expected from implementing the solution.

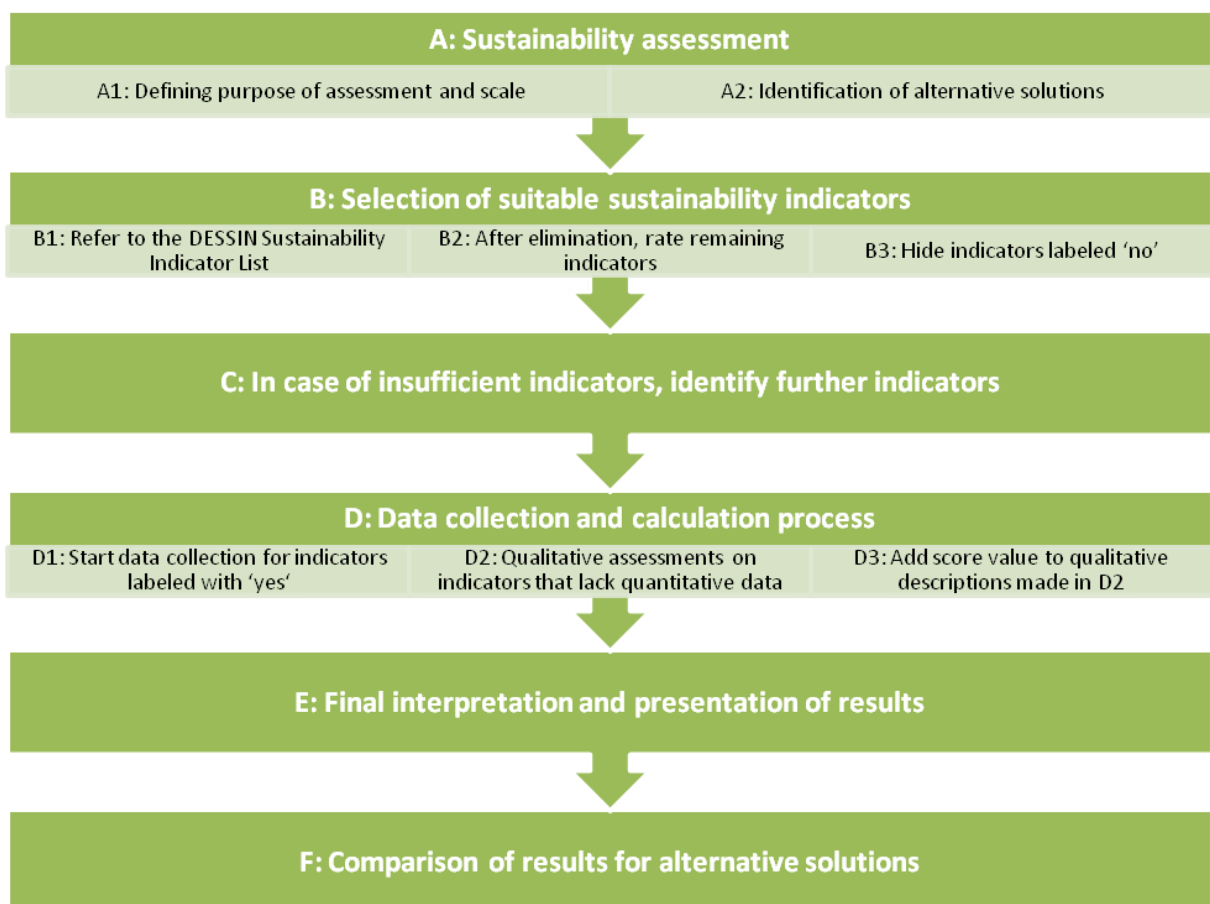


Figure 15. Proposed steps for sustainability assessment

The SA follows a case-specific multi-criteria assessment approach for the stated dimensions, and is based on the definition of sustainability presented below (see Box 7).

Box 7. Definition: Sustainability of technological solutions

Sustainability of technological solutions:

A given technology or solution implemented to mitigate water scarcity or water quality issues is sustainable when it can actively support the supply of ESS demand while contributing to social,

environmental and financial development in a way that meets the needs of the present without compromising the ability of future generations to meet their own needs and contributing to good governance.

The approach can be used to **evaluate the effects of a single solution** by assessing the baseline scenario and the after implementation scenario. Another application can be to use the SA to **compare alternative solutions** and identify the one that seems most promising, taking a broad set of perspectives into account. This can be performed (in **Step F**) by comparing the effects of the different solutions after running the main assessment (**Steps B to E**) for each of the alternative solutions identified (in **Step A**).

Support material necessary for completion:

- [Supplementary Material File](#): DESSIN Sustainability Indicator List
- [Companion Document](#): DESSIN Glossary
- [Case Reporting Template](#)

STEP A.

A sustainability assessment requires clear delineation of the system and technological solutions to be assessed. Key steps in setting up the assessment frame for a SA are provided in this first step.

Instructions:

A.1 - Define the purpose of the assessment and an appropriate temporal and spatial scale. Please note that the assessment frame is best defined in accordance with the ESS evaluation previously conducted, since this will ensure that *State*, *Impact I (ESS Provision)* and *Impact II (ESS Use) indicators* can be included into the SA without major adaptations. As the results of the assessment will depend strongly on the chosen system boundaries, this step should be carefully thought through.

A.2 - If a comparative study of possible (future) measures is desired and feasible, alternative solutions should be identified in this step. Adaptation of the table prepared in ESS Evaluation Step 3.2 of this [Cookbook](#) (see **Error! Reference source not found.**2) can help identify comparative technologies that fulfil the same *claimed/expected capabilities* as the proposed measure. Describe the alternative solution(s) to be assessed according to the specifications made in ESS Evaluation **Step 3.1 & 3.2** of this [Cookbook](#). Please note that in comparative studies those parts of the system that are not changed by the different options may be excluded, thus limiting the amount of data required and the complexity of the calculation.

Table 12. Exemplary template for identifying comparative solutions to the proposed measure. Example taken from the Llobregat mature case study (infiltration ponds)

Proposed measure	Claimed / expected capability	Comparative Technology(ies)
Construction and equipment of infiltration ponds	Enhancing water infiltration by additional permeable surface	n/a
	Increasing groundwater resources in the aquifer	
	Improving water quality via soil-aquifer treatment	
	Reducing pollutants in the aquifer	

STEP B.

The selection of suitable sustainability *indicators* is performed in this step. This is done using the DESSIN Sustainability Indicator List (thirteenth sheet) found in the [Supplementary Material File](#) as guidance.

Starting from five broad dimensions that are specified into several objectives, the DESSIN Sustainability Indicator List evaluation framework enters a more detailed level as the reader shifts from the left to the right hand side of the table, where specific assessment criteria and *indicators* are related to the respective objectives. To start with at the detailed level, select all *indicators* that are suitable for your assessment purpose from the DESSIN Sustainability Indicator List.

Instructions:

B.1 - Refer to the DESSIN Sustainability Indicator List and check all metrics and indicators, listed in column G and H, that are relevant for the valuation situation (column K) and the water system (column J) (see [Error! Reference source not found.5](#)). Please note, that it might be useful to include *indicators* that are recommended for comparative assessments even if you do not aim at comparing different solutions, since these *indicators* may highlight additional characteristics of the solution to be assessed and could be useful for further (comparative) assessments in the future as well.

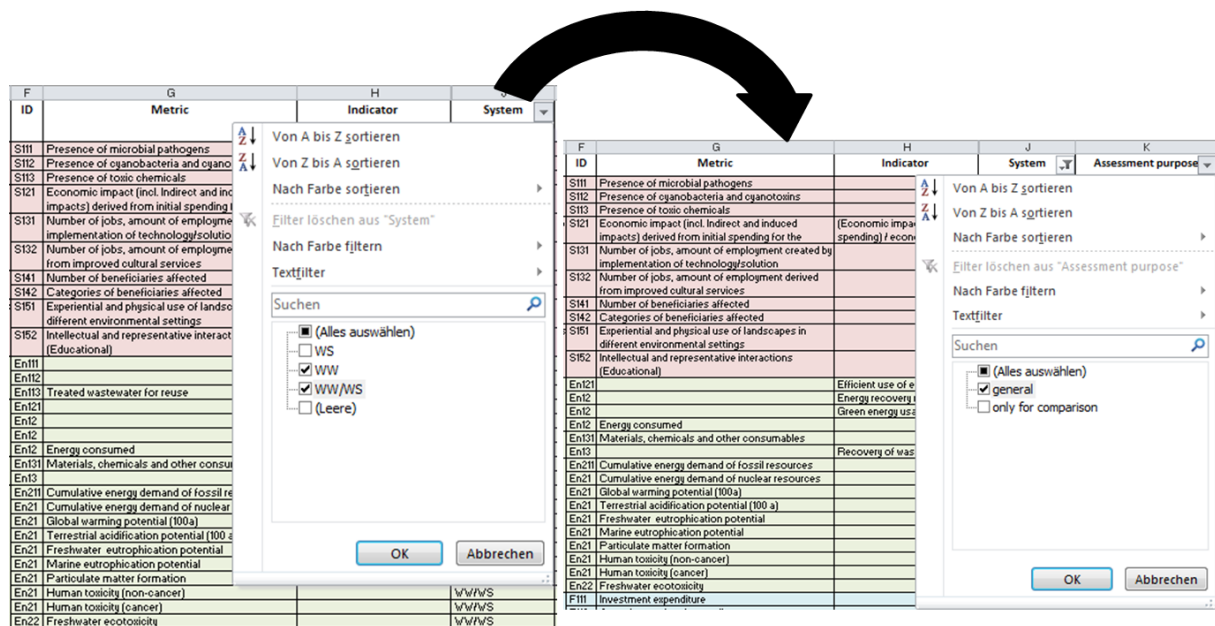


Figure 16. Filtering the indicators fitting to the valuation situation and the solution using the DESSIN sustainability assessment indicator list

B.2 - After eliminating all *indicators* which are not relevant for your specific case from the DESSIN Sustainability Indicator List, rate the remaining *indicators* according to the level of data availability. Fill in the empty boxes for data availability (columns N and O) in the excel sheet referring to the simple classification system proposed (see [Error! Reference source not found.16](#)):

- **Yes:** I know exactly where to find the figures(s) in my company's documentation **or**

even if I do not know the concrete numbers right now, I know that my company keeps record of data like this and I can contact a person to get it in the short term.

- **No:** I know that my company does not keep record of data like this **and/or** I know that there is no chance to get information like this from another source (within a reasonable time period).

F	G	H	J	K	N	O	P	Q
ID	Metric	Indicator	Unit	System <input type="checkbox"/>	Alternative <input type="checkbox"/>	Data Availability		
						yes <input type="checkbox"/>	no <input type="checkbox"/>	
S112	Presence of cyanobacteria and cyanotoxins			WW/WS	no			x
S113	Presence of toxic chemicals			WW/WS	no			x
S121	Economic impact (incl. indirect and induced impacts) derived from initial spending for the	(economic impact - initial spending) / economic impact		WW/WS	no			x
En111		Water Use Efficiency (WUE)	[%]	WS	no		x	
En112		Water Resources Availability	[%]	WS	no			x
En113	Treated wastewater for reuse	Recycle rate	[m ³] or [%]	WS	no			x
En121		Efficient use of energy	[%]	WW/WS	no			x
En122		Energy recovery rate	[%]	WW/WS	no			x
En123		Green energy usage	[%]	WW/WS	no			x
En132		Recovery of wastes	[%]	WW/WS	no			x
F111	Investment expenditure		[€]	WW/WS	no		x	
F112	Annual operational expenditure		[€/year]	WW/WS	no		x	
F113	Avoided costs and/or additional monetary benefits		[€/year]	WW/WS	no		x	
F114	Other sources of financing (e. g. subsidies) aligned to the solution		[€]	WW/WS	no			x
G111	Compliance improvement w/ relevant EU standards (WFD, BWD)	water status reached / water status level required		WW/WS	no			x
G112	Compliance with relevant national, local			WW/WS	no			x
A121		Sufficient capacity of the technology/solution to the expected use	[%]	WW/WS	no			x
A131		Adaptive capacity as: The probability that the item is able to function at time t (availability at time t)	[0-1]	WW/WS	no		x	
A141		[Hours of exposed or "dirty work" ¹] on the site/total hours of work per year*100	[number/reference time]	WW/WS	no			x
A142		Risk episodes, injuries on the site/total hours of work in test period	[number/reference time]	WW/WS	no			x
A211		Number of complaints about the technology (due to for instance Noise, Dust, Esthetics,	[number/reference time]	WW/WS	no			x



F	G	H	J	K	N	O	P	Q
ID	Metric	Indicator	Unit	System <input type="checkbox"/>	Alternative <input type="checkbox"/>	Data Availability		
						yes <input type="checkbox"/>	no <input type="checkbox"/>	
En111		Water Use Efficiency (WUE)	[%]	WS	no		x	
F111	Investment expenditure		[€]	WW/WS	no		x	
F112	Annual operational expenditure		[€/year]	WW/WS	no		x	
F113	Avoided costs and/or additional monetary benefits		[€/year]	WW/WS	no		x	
A131		Adaptive capacity as: The probability that the item is able to function at time t (availability at time t)	[0-1]	WW/WS	no		x	

Figure 17. Selecting SA indicators with regard to data availability using the DESSIN sustainability assessment indicator list. Example taken from the Llobregat mature case study (infiltration ponds)

B.3 – Hide all *indicators* labelled “no” afterwards since these cannot be followed up further with quantitative assessment (see **Error! Reference source not found.**). Have a look at your updated DESSIN Sustainability Indicator List. It is desirable (but not necessary) to have at least one indicator for each dimension as you proceed with the assessment.

- If you are confident with your DESSIN Sustainability Indicator List and/or you do not have any more data at hand that you wish to include in the assessment, continue with **STEP D**.
- If, in your point of view there are not enough *indicators* in the original list and/or you want to include additional ones on your own, continue with **STEP C**.

Reporting:

The DESSIN Sustainability Indicator List can be used as template for both selection and reporting of the *indicators* in use.

STEP C.

As previously mentioned, the *indicators* described in the DESSIN Sustainability Indicator List may not be suitable for every assessment purpose. This step therefore focuses on identifying further

indicators suitable for the defined environmental system and the solution of interest. To ensure that additional performance assessment *indicators* are developed in a coherent and consistent manner within the project, the framework proposes guidelines for selecting and developing *indicators* in the DESSIN context. The suggested procedure is based on a top-down approach in accordance with Chapter 7 of the “Framework for Sustainability Assessment of UWCS and development of a self-assessment tool” from FP7 TRUST (Alegre et al., 2012).

Instructions:

Have a look at the criteria proposed for each objective of the five dimensions and check whether you can add new *indicators* to the structure. Search in other sources and check whether there are available *indicators* that respond to your needs. Whenever the selection process ends up in identifying a new sustainability *indicator*, this *indicator* should be added to the DESSIN Sustainability Indicator List. In such cases the following columns (F-L) shall be filled in:

- ID
- Metric
- Indicator
- System (*optional*)
- Alternative needed? (*optional*)
- Unit

STEP D.

As all relevant *indicators* were identified in the previous steps, the data collection and calculation process can finally start.

Instructions:

D.1 - Start data collection for those *indicators* you labelled with “yes” by searching for the respective numbers and filling them into the appropriate fields of the table (cells Q to T). Generally, it is recommended to provide values on an annual basis aligned to the timeframe defined in **Step A.1**. Always give a short indication of the *indicator* type entered, fill in the values for the scenarios considered, and add a reference to the source used (see Figure 17).

F	G	H	R	S	T	U	V	W
ID	Metric	Indicator	value			source	comments	
			value type	before	after			
S111	Presence of microbial pathogens		Percent of time during simulation period that E.Coli concentration exceeds 15E+3/100mL	8,06%	3,07%	model output	Threshold concentration is based on typical concentration for wastewater effluent. Simulation period is 12 June 2015 to 29 August 2015.	
			Percent of time during simulation period that Enterococci concentration exceeds 5E+2/100mL	6,24%	1,75%	model output		Threshold concentration is based on typical concentration for wastewater effluent. Simulation period is 12 June 2015 to 29 August 2015.
S121	Economic impact (incl. Indirect and induced impacts) derived from initial spending for the solution itself	(Economic impact - initial spending) / economic impact	Amount spent on implementing project (€)	0	47.000.000 €	Aarhus Water	Amount reflects direct spending on the project itself, information about indirect and induced impacts not available (identical to indicator F111).	
S141	Number of beneficiaries affected		Number of beneficiaries	0	186.760	model output	Number of residents living within 8 km.	
S151	Economic impact via new or growing business from recreation/visiting activities or other types of economic growth linked to the solutions effects on the ecosystem		Economic value (€)	0	120.000.000 €	model output	Not possible to distinguish between two values (based on estimates of changes in property values that include both commercial and residential properties).	
S152	Non-market value of recreational/visiting activities							
F111	Investment expenditure		Expenditure (€)	0 €	47.000.000 €	Aarhus Water		
F112	Annual operational expenditure		Expenditure (€)	0 €	600.000 €	Aarhus Water		
F113	Avoided costs and/or additional monetary benefits		Economic value (€)	0	120.000.000 DKK	model output	Identical to S151/S152	
A112		MTBF	Mean time between failure	-	25 years	Aarhus Water	Estimated system lifetime used in project cost-benefit analysis	
A131		Adaptive capacity as: The probability that the item is able to function at time t (availability at time t) for any given loads	Annual overflow volume to Aarhus River given 20% increase in precipitation (m ³)	700000,00	318900,00	model output	20% increase is intended to represent climate change scenario	
A151	percentage of load removed		(E.Coli) Percent of load to river that is degraded during simulation period	36,87%	75,08%	model output	Simulation period is 12 June 2015 to 29 August 2015.	
			(Enterococci) Percent of load to river that is degraded during simulation period	30,5%	54,1%	model output	Simulation period is 12 June 2015 to 29 August 2015.	
			(BOD) Percent of load to river that is degraded during simulation period	33,3%	34,3%	model output	Simulation period is 12 June 2015 to 29 August 2015.	

Figure 18. Data collection (quantitative). Example taken from the Aarhus mature case study

D.2 – Afterwards, continue with qualitative assessments on the *indicators* you do not have quantitative data available for. Refer to previous studies where applicable, use concrete terms and provide reference to relevant sources (documents, key *stakeholders*) as well as basic assumptions, in order to be as explicit as possible and reduce the level of uncertainty.

Box 8. Qualitative description of indicator scores. Examples taken from the Emscher mature case study

Presence of microbial pathogens (S111)

Before the Emscher re-conversion was initiated, all Emscher tributaries as well as the Emscher river itself were open wastewater channels. Raw wastewaters from households and industry as well as mining effluent were flowing in these channels together with the original river water (groundwater) and rainwater. Thus, high concentrations of pathogens (E. coli, Enterococci) and chemicals were transported in the river network. After the construction of an underground sewer network, the first step of the Emscher re-conversion, all communal and industrial wastewater will be conducted underground. Therefore, the concentrations of pathogens and pollutants in the streams will be considerably lower. However, during rain events, discharge of CSO can still lead to occasional input of wastewater into the streams and also run-off during rain events as well as sewage from brownfields and waste deposits causes input of pollutants.

Global warming potential (En212)

The Emscher re-conversion is only feasible with intensive building, digging, and transport efforts. These go along with a high energy demand, and with this, high emissions of CO₂ throughout the 30 year conversion period. These activities are conducted by EG itself as well as by external companies. However, currently no data are available on these activities.

Number of actors/stakeholders involved (G121)

Stakeholder involvement has been given special attention over the whole course of the project. Several relevant actors/stakeholders were involved in planning and implementing the solution from the very beginning. The level of information dissemination aimed to be reached via communicative events can be evaluated rather high.

Number of complaints about the technology (A211)

Due to the fact that the sewer network (incl. CSOs) was rebuilt so that the river stream will be wastewater free from now on, the number of complaints due to noise and landscape aesthetics will decline strongly. Recent complaints about such unwanted side-effects caused by the solution itself are not expected.

D.3 – To include the qualitative information in the presentation of results (**STEP E**) and/or your comparative assessment of different solutions (**STEP F**) you can add a score value to the qualitative descriptions made in **Step D.2** for the status before and after the implementation of the solution referring to a scale from 1 to 5 (strong negative impact – some negative impact – neutral – some positive impact – strong positive impact). Please rate your solution qualitatively by filling the scores into cells R and S of the DESSIN Sustainability Indicator List.

Reporting:

The DESSIN Sustainability Indicator List can be used as template for reporting the values of the *indicators* in use. The tables included in the [Case Reporting Template](#) provide other aids for presenting the values collected.

STEP E.

After all quantitative and qualitative information has been collected a final interpretation and presentation of results should follow. The right way to interpret the results will commonly be highly case-specific, but should generally be inclusive with respect to *stakeholder* involvement. The results can be presented and communicated in several ways. An appropriate variant should be chosen according to the decision maker's and/or the audience's knowledge and needs. Therefore, the following paragraphs should be seen simply as a suggestion.

- Compare the performance per *indicator* of your solution for the baseline scenario and the after implementation scenario by normalizing the values and presenting these scores in a bar chart (see Figure 18) or spider plot (see Figure 19). This form of presentation will help the reader/audience get an impression of the benefits and impacts for each *indicator* per dimension at first sight. Spider plots can be further used to compare the results for alternative solutions by combining the values of their *indicators* for the baseline scenario and the after implementation scenario in one diagram.

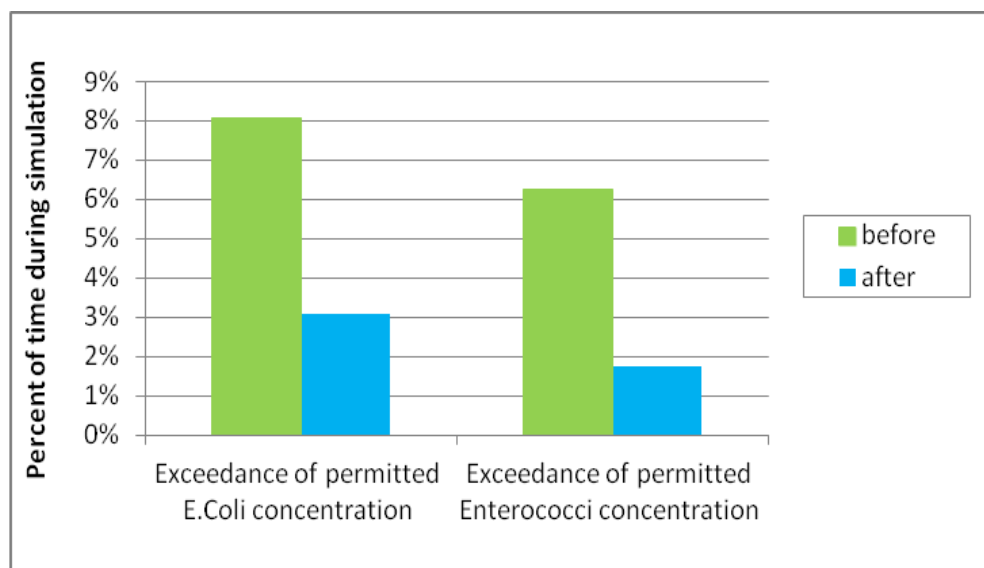


Figure 19. Bar chart for comparing the performance per indicator for the baseline scenario and the after implementation scenario. Example based on Aarhus mature case study

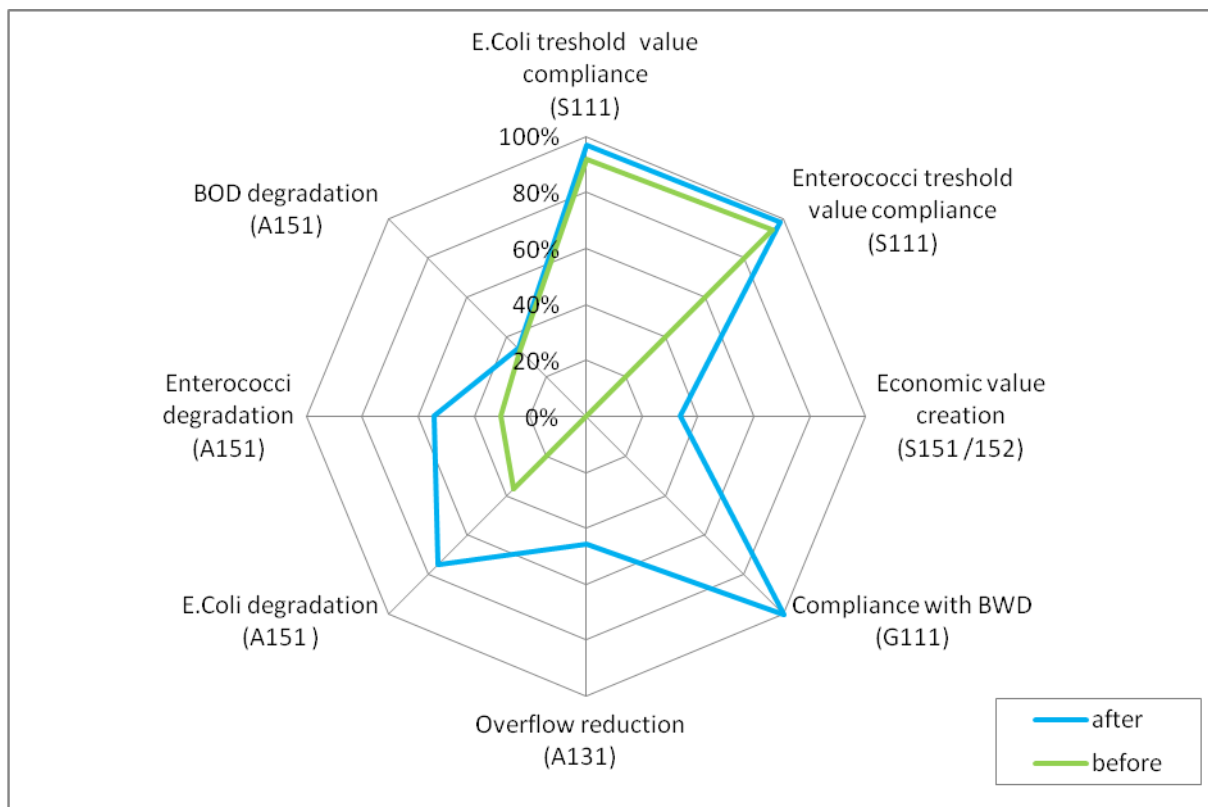


Figure 20. Spider plot for comparison of performance per indicator for the baseline scenario and the after implementation scenario. Example based on Aarhus mature case study

- Indicator* values that were calculated in monetary terms on an annual basis can also be used to perform a subsequent economic cost-benefit-analysis of the derived benefits and costs from a solution's implementation. Therefore, all expected monetary benefits and costs should be added up for the full lifetime of the solution with interest rates and an appropriate discount rate used. This additional testing can be especially valuable for a decision-maker to find a suitable solution for the long run with special regard to economic sustainability. Please be aware, that only those monetary values should be included into the assessment that a) are directly attributable to the solution's implementation, b) are benefits or costs directly occurring to *stakeholders* affected by the solution, and c) can be reasonably aggregated. For further information on the different concepts of economic value that can be used to decide whether a figure can be reasonably aggregated or not see the ESS Evaluation **Step 7** of this [Cookbook](#) and Chapter 5 of the [Companion Document](#).
- Analyse spatial and temporal aspects of the *indicator* values (before and) after the implementation of the technology (see Figure 20). Focus on those spatial and temporal scales most relevant for the *beneficiaries* identified.

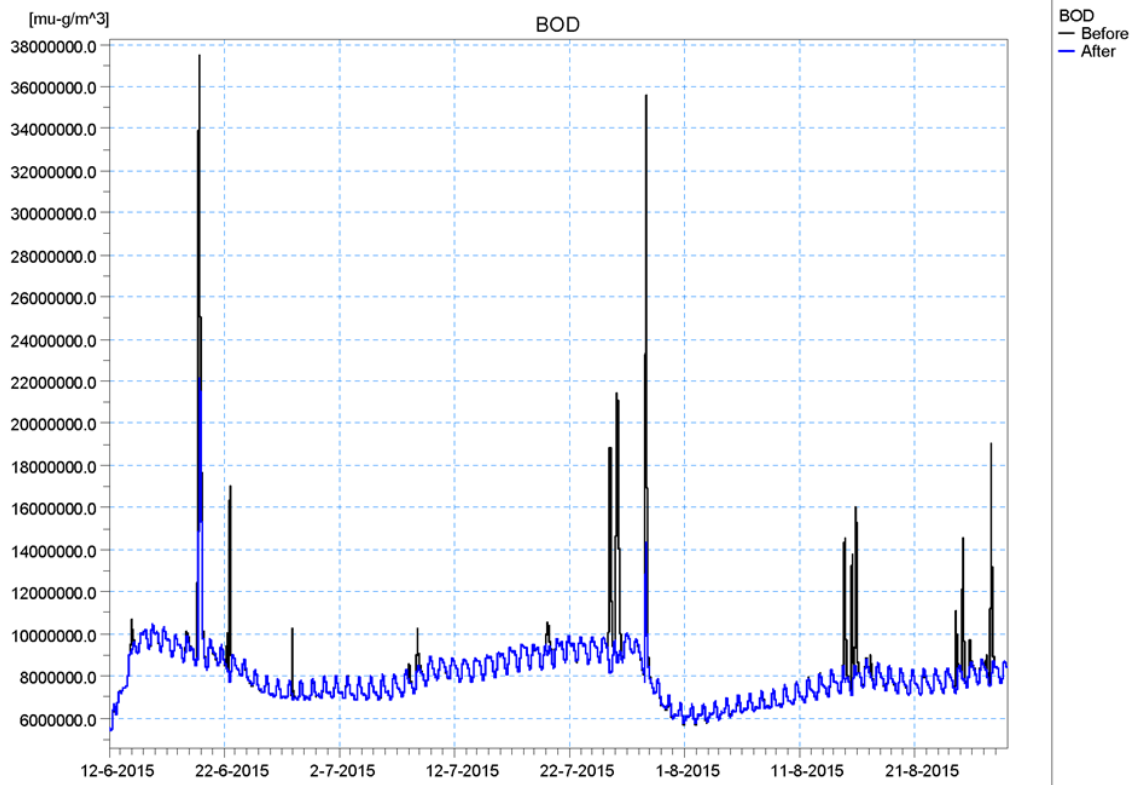


Figure 21. Comparison of BOD values before and after the solution's implementation over time. Example taken from Aarhus mature case study

When applying the framework to the DESSIN mature cases, comparison with the overall findings and *stakeholder* perspectives collected in WP12 is recommended, for additional insights and validation of results.

STEP F.

As highlighted in the **Objective of this section** part at the beginning to this chapter, the SA can also be used to compare alternative solutions. Where the framework is applied for this purpose, the assessment **Steps B to D** should be carried out separately for each of the solutions initially identified in **Step A**. **Step E** can be used to compare the results for the alternative solutions, respectively. Finally, in this last step a real multi-criteria decision analysis (MCDA) can be performed in order to assist a final decision making step. You can make use of the normalized values for each *indicator* derived from **Step E.1** and define weightings for them. The weightings can be defined for each *indicator* itself (or at a more aggregated level, either for the criteria, objectives or at least the dimensions proposed).

After putting emphasis on each *indicator* or grouping, the single (or aggregated values) should be multiplied with the weighting factor attached and summed up to a final score (for a fictitious example: see Table 13). Depending on the normalization and weighting scheme used, the alternative with the highest or lowest score is the best. Please note that in a common MCDA the weights used should add up to 100 %.

Table 13. Fictitious example for MCDA based on selected indicators taken from Emscher mature case study

Please not that this fictitious example based on selected indicators from the Emscher mature case is made for illustrative purposes only. Selection of indicators and weighting assumed are made randomly and do not reflect the opinion of the operator or any other party involved in the Emscher conversion project at all.

Selected metrics/ indicators	DESSIN ESS	unit	before	after	source	before (normalized)	after (normalized)	weighting A (random)	weighting B (random)
S121	Economic impact derived from initial spending	[-]	0	0.62	RWI study	0%	62%	8%	40%
S141	Beneficiaries affected	[M]	2.211	2.211	EG	100%	100%	15%	
S151	Economic impact (by hedonic pricing, biking and boating)	[€/a]	52.190	123.433	Impact II assessment	0%	3%	8%	
S152	Economic impact of educational excursions	[€/a]	0	25,400	Impact II assessment	0%	0%	8%	
En122	Energy production at WWTPs in EG and LV	[MkWh/a]	55	71	EGLV	0%	29%	10%	40%
En124	Reduction in energy consumption at WWTPs in EG and LV	[MkWh/a]	191	156	EGLV	0%	18%	16%	
En213	Reduction in CO2 emissions from CH4 and N2O emissions from WWTPs, digestion towers, and sludge drying sites	[Mkg CO2-eq/a]	158.56	63.09	EGLV	0%	60%	20%	
G111	Compliance with GEP standards	[%]	0	33	EGLV	0%	33%	15%	20%
<p>Calculation for Option A (weighting of single indicators): Score value (before): $(0*0,08)+(1*0,15)+(0*0,08)+(0*0,08)+(0*0,1)+(0*0,16)+(0*0,2)+(0*0,15) = \mathbf{0,15}$ Score value (after): $(0,62*0,08)+(1*0,15)+(0,03*0,08)+(0*0,08)+(0,29*0,1)+(0,18*0,16)+(0,6*0,2)+(0,33*0,15) = \mathbf{0,43}$</p>						<p>→ Based on the weighting A assumed implementing the solution is the preferred alternative.</p>			
<p>Calculation for Option B (weighting of dimensions): Score value (before): $(0+1+0+0)*0,4+(0+0+0)*0,4+0*0,2 = \mathbf{0,4}$ Score value (after): $(0,62+1+0,03+0)*0,4+(0,29+0,18+0,6)*0,4+0,33*0,2 = \mathbf{1,154}$</p>						<p>→ Based on the weighting B assumed implementing the solution is the preferred alternative.</p>			

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Annex: Additional documents

See the attached Companion Document, Supplementary Material File and Case Reporting Template.



The research leading to these results has received funding from the European Union Seventh Framework Programme (FP7/2007-2013) under grant agreement no. 619039
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