DESSIN

DEMONSTRATE ECOSYSTEM SERVICES ENABLING INNOVATION IN THE WATER SECTOR

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D11.2 – Framework for evaluating changes in ecosystem services

Part B: Companion Document

FINAL VERSION

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
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SUMMARY

This document provides the theoretical background that was used during the development the DESSIN ESS Evaluation framework and it represents the conceptual basis of the framework. It contains a glossary of agreed terminology that is necessary to conduct the evaluations. Thus, this document should be read carefully before applying the practical steps described in the DESSIN Cookbook.

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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

About this document

The DESSIN ESS Evaluation Framework is a structured approach to measuring changes in ecosystem services (ESS). It consists of the DESSIN Cookbook, the Companion Document (this document), a Supplementary Material File and a Case Reporting Template.

This document provides the theoretical background that was used during the development the DESSIN ESS Evaluation framework and it represents the conceptual basis of the framework. It contains a glossary of agreed terminology that is necessary to conduct the evaluations. Thus, this document should be read carefully before applying the practical steps described in the DESSIN Cookbook.

The DESSIN Cookbook presents the practical steps that the user should follow to apply the framework and is intended as a practical guidance for running the evaluations. 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 assessment. It is presented as a single MS Excel worksheet that aggregates the different catalogues that have been developed in DESSIN. Lastly, the Case Reporting Template gives the user an outline to structure and present the assessment outcomes.

DESSIN Glossary

One of the first challenges encountered by WA1 of DESSIN was that, despite the emergence of recent efforts to standardize definitions and classifications, the literature on ESS still exhibits a general lack of consistency in the use of terms. In order to ensure coherency and a smooth understanding of this document, this section provides a list of agreed definitions for the DESSIN project.

Term	Definition
DPSIR	Drivers-Pressures-State-Impact-Responses The causal framework for describing the interactions between society and the environment adopted by the European Environment Agency: driving forces, pressures, states, impacts, responses (Gabrielsen and Bosch, 2003).
Driver	A human activity that may produce an environmental effect (i.e. a pressure) on the ecosystem. Examples for drivers are agriculture or industry. (MARS Project Terminology, 2014)
Pressure	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 Project Terminology," 2014). Examples are the abstraction of water for industrial processes or an increased nutrient load caused by agricultural use of fertilizers.
State	The environmental condition of an ecosystem as described by its physical, chemical and biological parameters (MARS Project Terminology, 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 CO_2 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) (US EPA, n.d.)
Impact	Effects on ecosystem services (Impact I) and on human wellbeing (Impact II) resulting from changes in ecosystem state. An impact triggers social *Response* (The MARS Project Terminology, 2014).
Impact I	The effects that changes in ecosystem state have on the provision of ecosystem services (based on Müller and Burkhard, 2012).

	• e.g. reduced nutrient levels due to a new solution enabling safe bathing
Impact II	The effects that changes in ecosystem services have on human well-being (based on Müller and Burkhard, 2012). • e.g. by using the water retention capacity of floodplains, a riverside community can avoid the damages and costs of floods.
Response	The measures taken to address drivers, reduce pressures/or and improve the state of the ecosystem under study ("MARS Project Terminology," 2014) • e.g. implementing innovative water treatment systems, increasing storage and reuse capacities in water scarce areas, setting up automated control systems for effluent discharge
Ecosystem	The environmental system of interest within the DESSIN project (e.g. a surface or ground water body, sub-catchment or catchment).
Ecosystem service capacity	Refers to the capability of the ecosystem to provide a specific service in a particular area and given time period (based on Burkhard et al., 2012).
Ecosystem functions	Processes within an ecosystem which are needed to provide an ecosystem service (e.g. production of biomass, water purification) (TEEB 2010).
Ecosystem processes	Any change or reaction which occurs within ecosystems, either physical, chemical or biological. Ecosystem processes include decomposition, production, nutrient cycling, and fluxes of nutrients and energy (TEEB, 2010).
Ecosystem state	See *DPSIR – State.*
Ecosystem status	'Water status' according to the WFD. This is, the general expression of the status of a body of water as determined by the poorer of its ecological status and its chemical status (in the case of surface water) or the poorer of its quantitative status and its chemical status (in the case of groundwater). Ecosystem status is a subset of the *DPSIR - State* category.
Ecosystem structure	The biophysical architecture of ecosystems, which encompasses organisms and their non-living environment (TEEB, 2010).
Ecosystem services (ESS)	The contributions that ecosystems make to human well-being (Haines-Young and Potschin, 2011). • e.g. the provision of potable water *Alternative definition: The benefits ecosystems provide to humans (MA 2005).*
Ecosystem Services Approach (ESA)	A perspective that links humans, their activities and the services that ecosystems provide to humans.
Provisioning ESS	Ecosystem outputs that can be used by humans for nutrition, material use or energy sources. They are tangible things that can be exchanged or traded, as well as consumed or used directly by people in manufacture (Haines-Young and Potschin, 2013).

	• e.g. vegetables, timber, energy crops
Regulating and maintenance ESS	All the ways in which ecosystems control or modify organic and non-organic processes that define the environment of people. These ecosystem outputs are not consumed but affect the performance of individuals, communities and populations and their activities (Haines-Young and Potschin, 2013) • e.g. seed dispersal by plants and animals, global climate regulation, maintenance of soil fertility
Cultural ESS	All non-material benefits of ecosystems that affect the physical and mental states of people. Cultural services are primarily regarded as the physical settings, locations or situations which can be used for physical activities, intellectual or mental interactions, or religious / spiritual activities (Haines-Young and Potschin, 2013). • e.g. places for hiking, finding tranquillity in a forest
Stakeholder	"Any person, group or organisation with an interest or "stake" in an issue, either because they will be affected or because they may have some influence on its outcome." (Ridder et al., 2005)
Beneficiary	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).
ESS provision	The actual provision of ecosystem services.
ESS use	The actual utilisation of ecosystem services by people (beneficiaries).
Intermediate ESS	In the context of a DESSIN evaluation, those ESS that are only provided by the ecosystem but not necessarily utilised or otherwise appreciated by humans/beneficiaries (e.g. water purification as an ESS)
Final ESS	In the context of a DESSIN evaluation, those ESS that are not only provided by the ecosystem but also directly utilised or otherwise appreciated by humans/beneficiaries (e.g. the actual use of pure water for drinking).
Ecosystem benefits	The societal gain/s related to the actual use of an ecosystem service. See ESS use.
Human Well-being	A context- and situation-dependent state, comprising basic material for a good life, freedom and choice, health and bodily well-being, good social relations, security, peace of mind, and spiritual experience (MA, 2005). Among other factors, human well-being is dependent on the provision of ecosystem services (Haines-Young and Potschin, 2013).
Sustainability of ecosystem service use	Sustainability of the ecosystem service use is met when the actual use of an ecosystem service is not exceeding its capacity (Paetzold et al., 2010).
Double counting	When using available ESS classification schemes (MEA, CICES…) that do not specify "final" ecosystem goods and services, final ecosystem services may be

	intermingled with intermediate services. This often results in double-counting, as an "intermediate ecosystem service" may well be an important and unaccounted for component of another ecosystem service (Landers and Nahlik, 2013).
Economic use values	Values that arise from the actual and/or planned use of the service by an individual. Use values can be direct use values, such as when an individual makes actual use of the environmental asset improved, e.g. water consumption; or indirect use values, such as the benefits derived from ecosystem functions gained that do not translate into a direct use of the resource; such as: ESS derived from regulation functions, like flood control and storm protection.
Non-use values	Values that arise independently of any actual or prospective use by the individual. These are usually categorized as Existence Values, which arise from knowledge that the service exists and will continue to exist; and Bequest or Option Values, which measure individuals' preferences to ensure that the service will be available for their own use in the future and that future generations will also have access to the service.
Claimed/expected capabilities of the proposed measure	The effects that the proposed measure 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
Case-relevant ESS	Those ESS hypothetically affected by the proposed measure. The classification "case-relevant" denotes relevance specifically in the context of the case (measure and area) under study, and does not yet distinguish between final and intermediate services.
Proposed Measure	The new technology, management approach, policy measure, or combination of these that would be applied in a freshwater environment or a freshwater-related urban environment and whose effects are to be evaluated using the DESSIN ESS Evaluation Framework.
Environmental parameter	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).*
Environmental parameters of State	Environmental parameters that refer to the State of the ecosystem under study.
Case-relevant parameters of	Environmental parameters of State that are relevant for providing the case-relevant ESS (Impact I).

State	
Indicator	"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, n.d.)
Ecosystem structure-related indicators	Indicator of first choice when quantifying ESS related to Ecosystem structure. (to be elaborated)
Ecosystem process-related indicators	Indicator of first choice when quantifying ESS related to Ecosystem processes. (to be elaborated)
Direct indicator	Indicator that quantifies the service directly, irrespective of it being related to processes or structures. (to be elaborated)
Proxy-indicator	Indicator that quantifies selected premises or effects of the services in question and, thus, comes with higher level of uncertainty. (to be elaborated)
State indicators	Indicators that measure the change in the overall State of the ecosystem (i.e. in the integrated environmental parameters of State).
ESS Provision indicators	Indicators that measure the level of goods and services provided by the ecosystem under scrutiny.
ESS Use indicators	Indicators that measure the level of goods and services actually utilized by the beneficiaries in the study area.

Introduction - Components & foundations of the DESSIN ESS Evaluation Framework

The DESSIN ESS Evaluation Framework helps its user evaluate changes in ESS by linking biophysical, economic, and sustainability assesments 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) (**Fehler! Verweisquelle konnte nicht gefunden werden.**). 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). These supporting frameworks are described in detail in the sections below.

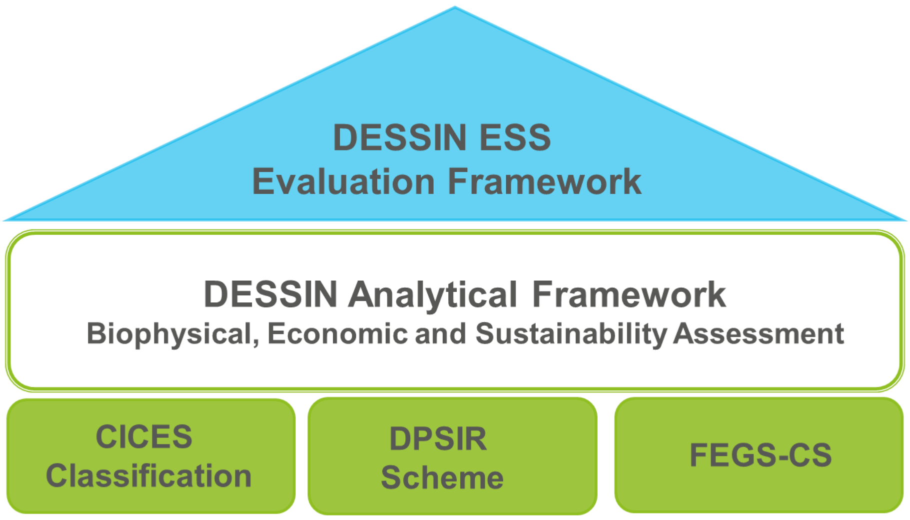

Figure 1: Components and foundations of the DESSIN ESS Evaluation Framework

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.

Ecosystem Services (ESS) and the Ecosystem Services Approach (ESA)

Ecosystem Services are the contributions that ecosystems make to human well-being (Haines-Young and Potschin, 2011). Therefore, ecosystem services approaches differ from historical siloed approaches to natural resource management because they provide a framework for anticipating a wide range of social and ecological consequences that may result from different decisions and provide tools for identifying, negotiating, avoiding, and managing potential negative tradeoffs (Ingram, 2012): With the emergence of modern environmentalism in the second half of the 20th century, specialised economic disciplines, like environmental and resource economics, started to address shortcomings in standard economic science to analyse environmental problems (Røpke, 2004). From the 1970s on, a series of contributions started referring to the way particular functions of nature serve human societies and a growing number of authors started to frame ecological concerns in economic terms in order to stress societal dependence on natural ecosystems, representing the origins of the modern ESA (Gómez-Baggethun et al., 2010). The recognition of the role of nature in supporting the economy and human well-being also motivated incorporation of the ESA into existing decision-making frameworks, such as cost-benefit analysis. As early as 1977, Westman (as cited in Fisher et al. (2009)) suggested that the social value of the benefits ecosystems provide could potentially be enumerated so that society could make more informed policy and management decisions. Over time, the need for an ESA to natural resources management has been recognised in policy, from an international level to regional and national levels worldwide and is nowadays – not just in DESSIN - applied extensively.

DPSIR

The DESSIN Ecosystem Assessment Framework has been designed on the basis of the *Driver, Pressure, State, Impact, Response (DPSIR)* scheme used by the EEA, with special features to account for ESS. Specifically, the proposed concept comprises an adaptation of the approaches by Müller and Burkhard (2012) and van Oudenhoven et al. (2012), which in turn follow the "ecosystem service cascade" of Haines-Young and Potschin (2010; 2013) also used in Maes et al. (2013). Besides making reference to the DPSIR elements, this approach shows the linkages between environmental state descriptions (ecosystems and biodiversity) and human systems (human well-being) as a part of the adaptive management cycle.

Fehler! Verweisquelle konnte nicht gefunden werden. outlines the DPSIR scheme as applied in DESSIN. In it, 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 ecosystem 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).

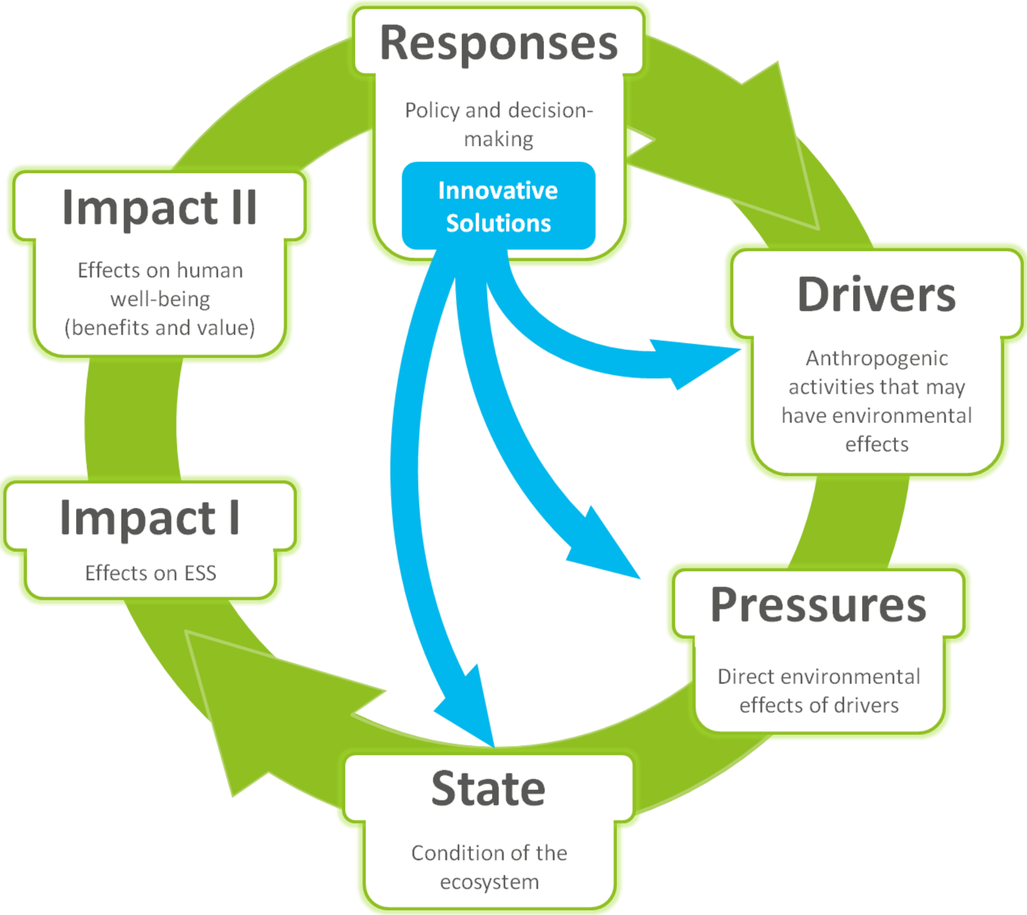

Figure 2: Conceptual approach of the DESSIN ESS Evaluation Framework (based on (Müller and Burkhard, 2012; van Oudenhoven et al. (2012); Haines-Young and Potschin (2011; 2013)).

In addition, the definitions agreed upon and listed in the DESSIN glossary are an important consideration.

Box 1: Relevant definitions Drivers-Pressures-State-Impact-Responses

DPSIR (Drivers-Pressures-State-Impact-Responses): The causal framework for describing the interactions between society and the environment adopted by the European Environment Agency: driving forces, pressures, states, impacts, responses (Gabrielsen and Bosch, 2003).

Driver: A human activity that may produce an environmental effect (i.e. a pressure) on the ecosystem. Examples for drivers are agriculture or industry. (MARS Project Terminology, 2014)

Pressure: 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 Project Terminology," 2014). Examples are the abstraction of water for industrial processes or an increased nutrient load caused by agricultural use of fertilizers.

State: The environmental condition of an ecosystem as described by its physical, chemical and biological parameters (MARS Project Terminology, 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)

(US EPA, n.d.)

- Hydromorphological parameters encompass the quantity and quality of the hydromorphological features (e.g. river continuity, quantity and dynamics of the water flow)

Impact: Effects on ecosystem services (Impact I) and on human wellbeing (Impact II) resulting from changes in ecosystem state. An impact triggers social Response (The MARS Project Terminology, 2014).

- ***Impact I:*** The effects that changes in ecosystem state have on the provision of ecosystem services (based on Müller and Burkhard, 2012).

  e.g. reduced nutrient levels due to a new solution enabling safe bathing
- ***Impact II:*** The effects that changes in ecosystem services have on human well-being (based on Müller and Burkhard, 2012).

  e.g. by using the water retention capacity of floodplains, a riverside community can avoid the damages and costs of floods..

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

e.g. implementing innovative water treatment systems, increasing storage and reuse capacities in water scarce areas, setting up automated control systems for effluent discharge

Common International Classification of Ecosystem Services (CICES)

To establish a conceptual approach and common classification of ESS within DESSIN's ESS Evaluation Framework, DESSIN has utilized the CICES classification system. CICES is a standardised classification system developed by the European Union. The first draft of CICES was tabled for discussion in December 2009 by the European Environment Agency (EEA), and updated versions have followed since as a result of consultations with members of the different user communities (the latest version, V4.3, was published in 2013) (Haines-Young and Potschin, 2011). CICES is the core of EU efforts to develop a consistent classification of ESS for ecosystem mapping. CICES provides a hierarchical system that builds on the MA and TEEB classifications and differentiates between provisioning services, regulating and maintenance *services and cultural services* (Sections) that can be subdivided into divisions, groups and classes of ESS.

FEGS-CS - Beneficiaries

"Ecosystem contributions are embodied in benefits and for each benefit there must be a beneficiary. Thus, to be included in the measurement scope of ecosystem services, there must be a direct contribution to an enterprise, household or government unit" (UN, 2014). The identification of direct beneficiaries allows separating the infinite list of ecosystem services relevant for any ESS assessment into intermediate ecosystem services and final services, which is the focus of the Impact II analysis of the DESSIN ESS Evaluation Framework.

DESSIN defines beneficiaries as 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).

The ESS beneficiaries system, which ultimately collects the interests of an individual (Landers and Nahlik, 2013), recognises that a person can be depicted as the multiple interests she/he has on/uses Final Ecosystems Goods and Services. In other words, a single individual can be seen as multiple beneficiaries since he/she may have more than one interest/make more than one use of what an ecosystem can offer. Arguably, the total economic value of these final services for the individual would be the sum of the benefits derived from each of his/her interests in/uses of them.

DESSIN uses the Final Ecosystem Goods and Services Classification-System (Landers and Nahlik, 2013) to classify beneficiaries of ESS. The USEPA identifies 37 different Beneficiary Sub-Categories in FEGS-CS (Landers and Nahlik, 2013). For the purposes of DESSIN, we link some of the USEPA beneficiary categories and subcategories to the NACE codes[1] used by EUROSTAT[2]. Thus, allowing for a better correlation between the identification of beneficiaries and the extraction of relevant available economic statistics to account for available market services. This applies to the following main economic sectors:

00.01. AGRICULTURAL

[1] The term NACE is derived from the French ***N**omenclature statistique des **a**ctivités économiques dans la **C**ommunauté **e**uropéenne*. In English, Statistical classification of economic activities in the European Community. NACE is a four-digit classification providing the framework for collecting and presenting a large range of statistical data according to economic activity in the fields of economic statistics (e.g. production, employment and national accounts) and in other statistical domains (EUROSTAT, 2015).

[2] EUROSTAT (2015) Eurostat Statistics Explained. Glossary:Statistical classification of economic activities in the European Community (NACE) http://ec.europa.eu/eurostat/statistics-explained/index.php/Glossary:Statistical_classification_of_economic_activities_in_the_European_Community_%28NACE%29

00.02. COMMERCIAL / INDUSTRIAL
00.03. GOVERNMENT, MUNICIPAL, AND RESIDENTIAL
00.04. COMMERCIAL / MILITARY TRANSPORTATION
00.08. LEARNING

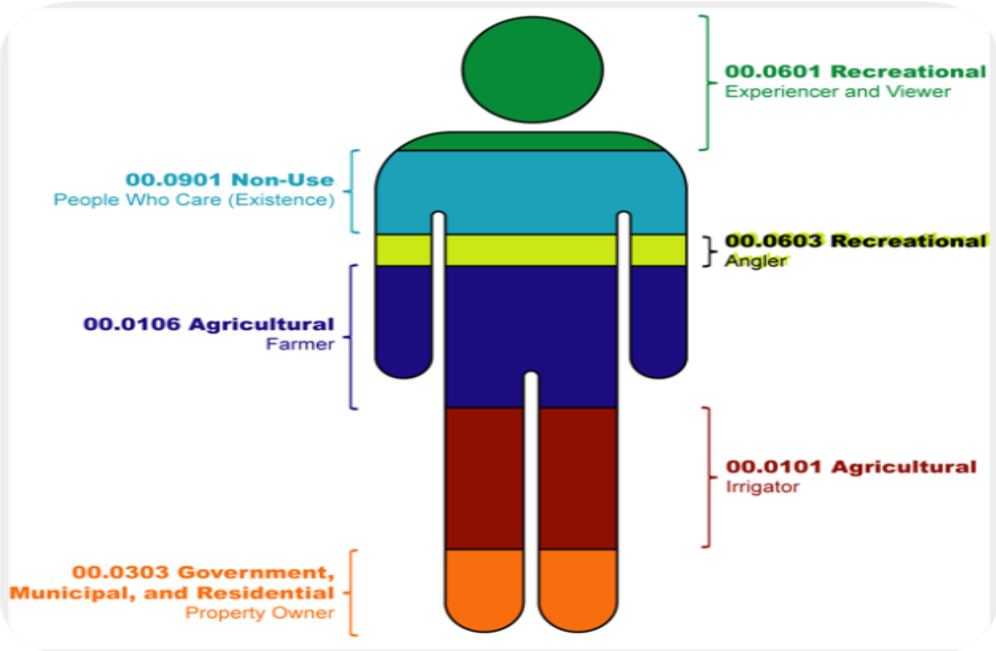

Figure 3: Illustration exemplifying the different interests of a beneficiary in certain ESS (Source Landers and Nahlik, 2013)

1. Study description (setting the scene)

<u>This chapter makes reference to Part I of the DESSIN cookbook!</u>

As has been argued in earlier DESSIN work, one of the many hurdles to the advancement and sound practical implementation of the Ecosystem Services Approach has been the inconsistency in the interpretation and use of its underlying concepts. This, at least in part, is driven by a lack of widely accepted standards and guidelines. In DESSIN we are making a collective effort to overcome this hurdle by building upon what most closely resembles "conventions" surrounding the concept of ESS. Ensuring compatibility with these carefully selected step stones is a task that we undertake to achieve outputs that go beyond the state of the art.

When it comes to Part I of the DESSIN cookbook, which is concerned with setting the scene for our assessments, the first thing to do to ensure a standardised, step-wise approach is to define the basic aspects that need to be included in the description of the study area. This will not only have direct implications for the actual assessment of changes in ESS, but also on the reporting of results.

By taking an in-depth look at the blueprint for ecosystem service assessments from Seppelt et al. (2012), this document aims to shed light on its potential for uptake into the DESSIN framework, and specifically to inform Part I of the cookbook.

1.1 The blueprint for ecosystem service assessments against the needs of DESSIN

By reviewing 153 ecosystem service studies from scientific papers, Seppelt et al. outlined their basic elements and the extent to which information on these elements was reported (see **Fehler! Verweisquelle konnte nicht gefunden werden.**) (Seppelt et al., 2011). Results fed into a subsequent article where Seppelt et al. developed a *blueprint for ecosystem service assessments* (Seppelt et al., 2012). The blueprint intends to facilitate the conduction of ecosystem services assessments.

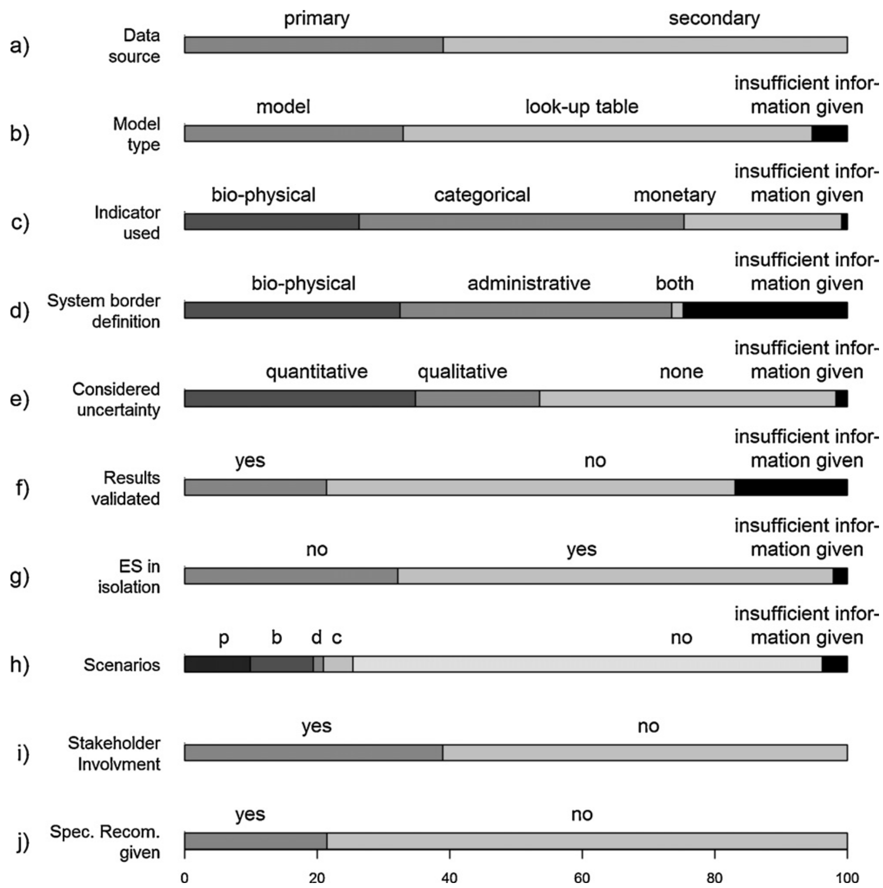

Figure 4: Statistical overview of the 153 studies reviewed by Seppelt et al., the basic elements examined (a -j) and their reporting. The factor levels for scenarios are: p, political; b, behavioural; d, demographic; c, climate change. Source: Seppelt et al. (2011).

According to Seppelt et al., "an ecosystem services assessment provides information on the crucial indicators for the overall environmental condition of the region". On the other hand, the assessments to be run using the DESSIN ESS Evaluation Framework are concentrated exclusively on evaluating the changes that ESS undergo when a measure (in the form of a technology) is implemented. This is the first key difference to consider as it has significant implications regarding the compatibility of the blueprint and the DESSIN framework.

According to the proponents of the blueprint, any ecosystem service assessment must clearly state its purpose (specific objectives) and its scope (inter alia its spatial and temporal scale). It must describe the methodology and indicators to be used in the analysis and provide guidelines for communicating results and recommendations. Finally, it must propose a means of monitoring changes that occur after the assessment as a result of implementing the recommended actions. The expected benefits of providing this information in a structured outline are shown in Table 1:.

Table 1: Expected benefits of the blueprint for ecosystem assessments (adapted from Seppelt et al., 2012).

Expected benefit	Is this important for the work in DESSIN?	Why/Why Not?
Achieving improved communication and collaboration in transdisciplinary[3] teams	Yes	The intricacies related to the development and use of the ESS Evaluation Framework, as well as the convergence of multiple disciplines into this work demand that concepts are communicated thoroughly and effectively.
Increasing transparency and clarification of methodological aspects which is relevant for the interpretation of results	Yes	Since the ESS Evaluation Framework is intended to support decision making, transparency and accessibility of its methodologies is key.
Supporting the robustness and reliability of assessments	Yes	One of our main interests is to provide a sound framework to users.
Providing structure to assessments and monitoring programmes	Partially	A structured approach is relevant. Monitoring programmes fall out of the scope of DESSIN.
Allowing for comparability between different studies and synthesising their results	Partially	Comparability is important but has not been defined as a main ambition of the ESS Evaluation Framework. Synthesis of results is relevant.
Promoting further implementation of ecosystem service assessments	Yes	The further development and use of the ESS concept is one of the premises of DESSIN.

As can be seen from the comparative table above, the aims of the blueprint are aligned with those of DESSIN to a great extent. On the other hand, they go well beyond the scope of Part I of the cookbook. This is the second key difference to be considered, as it already suggests that some elements of the blueprint might be relevant for Part I, while others might be better suited for other sections of the cookbook. This is explored in detail in **Fehler! Verweisquelle konnte nicht gefunden werden.** below.

[3] Seppelt et al. do not provide a definition of the term *transdisciplinarity*. One by Choi and Pak (2006) is as follows: "Multidisciplinarity draws on knowledge from different disciplines but stays within their boundaries. Interdisciplinarity analyzes, synthesizes and harmonizes links between disciplines into a coordinated and coherent whole. Transdisciplinarity integrates the natural, social and health sciences in a humanities context, and transcends their traditional boundaries. The objectives of multiple disciplinary approaches are to resolve real world or complex problems, to provide different perspectives on problems, to create comprehensive research questions, to develop concensus clinical definitions and guidelines, and to provide comprehensive health services. Multiple disciplinary teamwork has both benefits and drawbacks."

Table 2: The PSARM Blueprint template for reporting ecosystem service studies against the needs of Part I of the DESSIN framework (adapted from Seppelt et al., 2012).

Element of the Blueprint	Description	Comparison against the needs of Part I of the DESSIN framework
1. Purpose and Design	Define the purpose, including the specific objectives and the study design best suited to those ends. This purpose and design should be accompanied by some administrative information about the people involved, the funding agency to address potential conflicting interests, the intended audience for the ecosystem service assessment results, and desired outcomes/expectations.	- This is relevant for Part I of the cookbook - Purpose and objectives of the evaluation of changes in ESS can be defined within Part I - Administrative information can be defined within Part I - Study design is defined by default (?)
2. Scope of problemscape	Provide a sufficiently detailed system description that includes information on spatial and temporal scale, environmental attributes (e.g. climate, topography, etc) and socio-economical (landowners, land use, land use transitions, etc) and socio-cultural aspects (value systems, aesthetics, role of landscape and land use in identity formation). The relevant ecosystem services can be defined, measured in physical units or, for cultural services, described by ordinal classes. Sinks and sources of ecosystem service can be identified and flows of ecosystem goods and services are characterized. Stakeholders should be identified here as well. If the study uses scenarios, the related storylines should also be reported. Definitions of terms and relations should be given – for instance through a glossary or a conceptual diagram. A complete overview of all available (or missing) data and information in the study region needs to be provided.	- This is relevant for Part I of the cookbook. - Environmental attributes, socioeconomical and sociocultural aspects can be defined within Part I. - Stakeholders can be defined within Part I. - Terminology is defined in the DESSIN Glossary (case-specific definitions could be included in Part I) - Relevant ESS, sinks and sources cannot be defined yet (according to the DESSIN approach this is covered in Part III) - Scenarios are defined by default (?) - Spatial and temporal scale (?) - Giving an overview of all available/missing data would be more efficient if done for the relevant ESS only (i.e. in Part III or IV)
3. Analysis and assessment	Define the selected indicators for ecosystem services, including biophysical units of the cardinal indicators and the ordinal classes for cultural services. The inventory of ecosystem services should be documented. The calculation of indicators on ecosystem functions, ecosystem services and benefits should be given in clear reproducible (biophysical or ordinal scale) units together with a description of the methodology used. Explicit statements on the uncertainty in form of error bars, standard errors or confidence/credibility intervals should be given and non-quantifiable sources of uncertainty should be made explicit (such as unclear relations of ecosystem function and service, existence of time lags, thresholds, or tipping points).	- This is not relevant for Part I of the cookbook. This is covered in Part IV (response evaluation).

4. Recommendations and results	Provide guidelines for communicating the unique aspects of each ecosystem service assessment to the appropriate players who can act on the information. Results should be interpreted with regard to the underlying assumptions but also with respect to the stakeholders involved in the process. With the readily developed classification of ecosystem services and the indicators at hand to measure them, policy measures can be defined.	- This is not relevant for Part I of the cookbook. This would be covered in the cookbook section on communicating results.
5. Monitoring	This involves identifying core indicators for monitoring changes in respect to ecosystem services, biodiversity, economic, and social targets and identifying possible options for modifications of these measures or instruments.	- This is not relevant for Part I, but this rather resembles the overall main objective of the DESSIN framework.

1.2 Structure for Part I of the DESSIN Cookbook

Based on the examination of the blueprint against the backdrop of the DESSIN framework, the suggested structure of Part I of the cookbook is the following:

- Overview of administrative aspects of the assessment of changes in ESS
- Objectives of the assessment
  This would give the general background on what the purpose and expected outcomes of the assessment are.
- Overview of the case study area
  This gives an environmental, socioeconomic and sociocultural profile of the study area. It would provide a detailed overview of the study area in terms of its geographical location (e.g. Mediterranean region, Western Europe, Nordic region), climatic context (e.g. Mediterranean, Continental, Nordic), socioeconomic profile (e.g. population density, household income, age profile), macroeconomic indicators and economic activities taking place in the area (e.g. comparison by share of GDP), as well as the attributes of the ecosystem under study (e.g. WFD status, hydromorphology).
- Stakeholder list
  To provide an outline the actors involved (i.e. the proponents of the measure, the decision maker and the identified stakeholders).
- Case-specific terminology
  After reviewing the DESSIN Glossary, the user must bring define any further terminology which is considered relevant for conducting the assessment and interpreting the results.

All items mentioned above are included in the template for Part I (see Table 3 below). This template can be found in the DESSIN cookbook.

Table 3: Template for Part I

Element of Part I	Description	User entries
Administrative details	1. Provide general information about: - the entity/ies involved in carrying out the assessment - the provider/s of information for the assessment - the provider/s of funding for the assessment	
Objectives of the assessment	2. Define the intended audience of the results (*Who will be the main recipient of the outcome report?*) 3. Define and explain the specific purpose and the expected outcomes of carrying out the assessment (*What do you want to achieve by assessing changes in ESS in your area?*).	
Overview of the study area	4. Provide a detailed description of the study area considering: • geographical location (e.g. Mediterranean region, Western Europe, Nordic region) • spatial extension • 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) • socioeconomic profile (e.g. population density, average household income, age profile) • sociocultural aspects (e.g. value systems, role of landscape and land use in identity formation).	
Stakeholder list	5. Elaborate an exhaustive list of the stakeholders present in the area.	

2. Drivers and Pressures

This chapter makes reference to Part II of the DESSIN cookbook!

2.1 Analyzing the first two elements of the DPSIR

Preliminary testing of the DESSIN ESS Evaluation Framework evidenced that practical guidance/clearly defined methods for the identification and assessment of *drivers* and *pressures* is necessary to ensure the usability and functionality of the framework. In preparing such guidance the DESSIN team conducted a brief review of the academic and grey literature, including studies applying the DPSIR scheme in water-related projects and guidance documents supporting the implementation of the WFD. The review showed that while research efforts applying the approach seem to be frequently found in the literature (e.g. Pandey, Chapagain & Kazama, 2010; Borja et al., 2006, Pironne et al., 2005), and while the use of the DPSIR is engrained in the implementation of the WFD, a standardised set of instructions that can be easily picked up and applied by practitioners is not readily available.

Faced with this limitation and wanting to ensure the uptake of the DESSIN framework, the authors prepared an approach for the analysis of drivers and pressures that intends to offer the necessary degree of flexibility to the user while being practical enough to be synthesised into a software module, all of this maintaining a solid scientific basis. The approach builds to a large extent on the works of the IMPRESS working group[4] as well as the MARS project[5], which is introduced below.

Two key building blocks used to develop Part II of the DESSIN Framework

With the aim of facilitating the implementation of the WFD, the early IMPRESS work established a typology of pressures to support the Member States (MS) in using the DPSIR framework. In the Guidance Document No. 3 (IMPRESS, 2003), the IMPRESS group gives general instructions on how to quantify drivers. The document also presents tables that link these drivers to their resulting pressures and further on to *possible changes in state or impact*.
The MARS project builds upon the work of IMPRESS by adopting part of the terminology defined in the Guidance Document No. 3 and following the lists of drivers and pressures presented therein and in the recently updated WFD Reporting Guidance 2016 (EC, 2014).

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[4] IMPRESS is a group of technical experts from governmental and non-governmental organisations which was established in 2001 in the context of the Water Framework Directive (WFD). The informal working group aims to provide guidance to experts implementing the WFD in river basins in regard to the identification of pressures and assessment of impacts within the characterisation of water bodies, which is part of Article 5 of the WFD (IMPRESS, 2003).
[5] MARS (Managing Aquatic ecosystems and water Resources under multiple Stress) is a collaborative research project funded by the European Union. Its main focus is the study of multiple stressors on surface and ground waters. For more information visit: http://www.mars-project.eu/.

While the remit of DESSIN is limited to assessing the changes in ESS that result from the implementation of new measures (i.e. a highly focalized task in comparison to other projects and initiatives[6]), the categories and descriptions of drivers and pressures brought forward by IMPRESS and applied and expanded by MARS serve the purpose of facilitating the practical application of the DESSIN ESS Evaluation Framework very well. Furthermore, building upon this earlier and ongoing work ensures the compatibility of the DESSIN framework with the state of the art in Europe. The proposed approach is described and exemplified in the following sections.

2.2 Context and justification

As mentioned earlier, the academic literature reviewed presented significantly limited descriptions of the steps followed when identifying and characterising the drivers and pressures that affect aquatic ecosystems. The same seemed to be the case within the grey literature studied (e.g. WFD Guidance No. 3, Tutorial on Systems Thinking of the USEPA). Since DESSIN is set on the European context, a short explanation of why a set of precise guidelines for identifying and assessing drivers and pressures has not been developed is worthwhile to be given in this section.

In the case of the literature supporting the implementation of the WFD, one apparent reason for this lack of specificity is that the procedure for identifying the drivers and pressures affecting a water body is not intercalibrated at the EU level, i.e. each country determines whether or not a pressure is relevant according to its own methods[7]. This makes the range of defining factors so wide and strongly influenced by the local conditions that a high level of standardisation is not possible, or even desirable. For instance, whether a pressure exerted on a lake is defined as significant may commonly depend on physical characteristics like the lake’s volume and mean water depth. Thus, in the EU a case-by-case process is commonly followed for this type of analyses, with some very general guidelines being provided by national administrations.

Justification for developing a set of guidelines for DESSIN

The DESSIN ESS Evaluation Framework is based on the DPSIR scheme. Step 1 of the DESSIN cookbook aims to produce a qualitative overview of the drivers present in the study area. Step 2 follows with the identification and assessment of the direct environmental effects (i.e. the pressures) that result from these drivers. While the DESSIN framework is mainly concerned with measuring changes in ESS (synthesised in *Impact I* and *Impact II*), the justification for Part II of the framework is that it will allow the user to identify the probable causes of undesired conditions found downstream, i.e. further down the DPSIR chain. This preparatory screening exercise already sheds some light on the type of measures that could be implemented to ameliorate the said conditions Furthermore, having an overview of the relevant drivers and related pressures in the

[6] BESS project (Biodiversity and Ecosystem Service Sustainability), CONNECT project, RUBICODE project (Rationalising Biodiversity Conservation in Dynamic Ecosystems), OPERAs project, OPENness project, etc.
[7] Some of these methods or “rules of thumb” include using measures of area, length or proportion affected within a water body (e.g. km^2 of a lake affected by the pressure, % of the river affected by the pressure). There is however, no standardised set of methods available.

area can provide the first insights needed to discern who the key stakeholders are (i.e. those individuals or groups having power over the identified drivers, or those most likely affected by the resulting pressures and their subsequent impacts). Finally, having a list of the drivers present in the study area allows the user to focus the subsequent analysis only on the pressures resulting from these drivers. A key for the evaluation of changes in ESS provision due to implemented measures/technologies is the ability to assess the influence of that measure on drivers, pressures and/or state, leading to alterations in Impact I & II.

2.3 Defining drivers and pressures

What constitutes a driver according to the reviewed literature?

To ensure an adequate use of the DESSIN ESS Evaluation Framework within and beyond the project it was of utmost importance to lay out the basic terminology to be used in the assessments. In the case of the term *driver,* a number of definitions can be found in the literature. For instance, the IMPRESS group proposed that driving forces, or drivers, are "sectors of activities that may produce a series of pressures, either as point or non-point sources" (IMPRESS, 2003). Pirrone et al. (2005) use a similar definition that describes driving forces as processes and human activities that have the ability to cause pressures. Within these activities the authors include inter alia production, consumption and recreation. Borja et al. (2006) use a more streamlined but probably less tangible description, defining driving forces as "softer" conjectures like economic and social policies and the goals that government and industry aim to achieve by executing such policies. A more holistic definition is the one used by the US EPA in their *Tutorial on Systems Thinking* (US EPA, n.d.). This one states that drivers are "social, demographic and economic developments in societies and the corresponding changes in life styles, overall levels of consumption and production patterns." To pin this down, the authors also refer to drivers as the "socioeconomic sectors that fulfil the human needs for food, water, shelter, health, security and culture" (US EPA, n.d.).

What constitutes a pressure according to the reviewed literature?

In the case of the term *pressure*, definitions found in the literature seem to be more converging than those of drivers. The European Environment Agency portrays a pressure as being the direct result (or effect) of a driver on the environment. For instance, the emission of substances into the environment, the use of resources and the use of land are all examples of pressures (EEA, 1999). Mattas et al. (2014) use an almost identical definition and go beyond the anthropogenic examples by including weather phenomena like decreases in precipitation. Pandey et al. (2010) define pressures as the "direct stresses brought by expansion in the anthropogenic system and associated interventions in the natural environment".

How are drivers and pressures defined in DESSIN?

For the purpose of DESSIN it was important to adopt definitions that were sufficiently tangible and easy to apply in a freshwater ecosystems context while at the same time not being overly limited in their scope. From this viewpoint, the definitions which were found most appropriate were those proposed by the MARS project. According to MARS (2014), drivers are human activities that may produce environmental effects on the ecosystem under study. Examples for drivers are agriculture or industry. Further, MARS defines pressures as 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. Examples are the abstraction of water for industrial processes or an increased input of nutrients caused by agricultural use of fertilizers. These definitions are included in the DESSIN Glossary and are the ones that should be used for any assessments undertaken using the DESSIN ESS Evaluation Framework.

2.4 Categorizing and relating drivers and pressures

In order to support the identification of drivers and pressures in the study area, a Drivers and Pressures Catalogue (excel workbook included in Supplementary Material File) has been compiled. This catalogue lists 11 types of drivers that are linked with 6 categories of potentially resulting pressures, all within the context of aquatic ecosystems. The **drivers include agriculture, climate change, energy (hydropower), energy (non-hydropower), fisheries and aquaculture, flood protection, forestry, industry, tourism and recreation, transport, and urban development**. Respectively, the **pressure categories include point pressure, diffuse pressure, abstraction/ flow diversion, hydromorphological alteration, groundwater pressure and other pressures** (see Table 4).

Table 4: Driver types and related pressures categories. *Based on MARS (2014) and IMPRESS (2003).*

Driver	Related Pressure(s)
Agriculture	• Point pressure • Diffuse pressure • Abstraction/flow diversion • Hydromorphological alteration • Groundwater pressure • Other pressure
Climate Change	• Other pressure
Energy (hydropower)	• Point pressure • Abstractions/flow diversion • Hydromorphological alteration
Energy (non-hydropower)	• Diffuse pressure • Abstractions/flow diversion • Hydromorphological alteration • Groundwater pressure
Fisheries and aquaculture	• Point pressure • Abstractions/flow diversion • Hydromorphological alteration • Other pressure
Flood protection	• Hydromorphological alteration

	• Other pressure
Forestry	• Diffuse pressure
Industry	• Point pressure • Diffuse pressure • Abstractions/flow diversion • Hydromorphological alteration • Groundwater pressure • Other pressure
Tourism and recreation	• Hydromorphological alteration • Other pressure
Transport	• Point pressure • Diffuse pressure • Abstractions/flow diversion • Hydromorphological alteration • Other pressure
Urban development	• Point pressure • Diffuse pressure • Abstractions/flow diversion • Hydromorphological alteration • Groundwater pressure • Other pressure

An important feature of the DESSIN approach is the connection between drivers and pressures. As can be seen in Table 4 above, not all pressure categories are relevant for each single driver. For example, for the driver "industry", all of the six pressure categories could come into account, while the driver "forestry" is only linked to the pressure category "diffuse pollution". These relationships between drivers and pressures have been established based on the information and examples given in both MARS (2014) and IMPRESS (2003). Here, users are encouraged to insert additional driver types, pressure categories and further relationships between the two that have not been considered previously but exist in the respective study area.

Lastly, the users of the DESSIN framework are further supported through a compilation of illustrative and detailed examples for each pressure category relevant to each driver. Some of these examples and their descriptions can be seen in Table 5 below.

Table 5: MARS pressure categories, descriptions and examples. *Based on MARS (2014) 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 loss from agriculture due to excess application of fertilisers
Abstraction / flow diversion	Water is taken out of 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 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).	Activities to alter the level of groundwater in order to carry out large civil works.

The driver typology and pressure categories mentioned above stem from the MARS project (MARS, 2014). MARS (2014) provides a list of pressures on aquatic ecosystems based on the WFD Reporting Guidance 2016 (EC, 2014) and groups the pressures in categories. In fact, similar pressure categories are featured in IMPRESS (2003).[8] While the expert group basically covers the same pressures, their wording appears to be rather imprecise in contrast to the MARS categories and

[8] IMPRESS pressure categories are comprised of diffuse source, point source, activities using specific substances, abstraction, artificial recharge, morphological and other anthropogenic. See Table 3.1 in IMPRESS (2003), p. 27.

therefore is judged less suitable for the DESSIN framework. Moreover, the list of illustrative examples of pressures was compiled from the elaborate pressure checklist found in the IMPRESS guidance document no. 3 (see IMPRESS, 2003, table 4.2 on p. 53f.) with some further additions from MARS (2014).

By making use of this pre-defined catalogue, the user of the DESSIN framework can outline the situation in the study area and develop preliminary hypotheses describing the first two elements in the causal chain of the DPSIR. As mentioned earlier, this is expected to facilitate the identification, evaluation or design of potential measures to address environmental problems; assess the potential influence of a given measure on drivers and/or pressures (leading to alterations in State and Impact I & II); provide initial insights regarding up-scaling of these measures; and outline the expected position of different stakeholders.

2.5 Practical notes for the application of Part II

- Firstly it is important not to confuse drivers with pressures. Some examples to illustrate the difference between these two concepts are:
    - **Angling** is a recreational activity (driver) that may involve the **removal of fish** (pressure).
    - Water is abstracted (pressure) by **industry for cooling purposes** (driver), which leads to a **reduction in flow** (state).
    - **Damming up a river (pressure) in order to assure flood protection** (driver) results in **variations in the flow characteristics such as velocity and volume** (state).

- When developing the DESSIN framework, it was decided that quantifying drivers would not be considered a priority for the assessments. The main reason behind this is that the framework was designed to evaluate the potential impact of technological implementations which were not aimed at affecting drivers themselves.[9] Due in part to their smaller scale and limited extent, the technological implementations assessed within the DESSIN project were rather directed at mitigating the pressures resulting from drivers, and/or the subsequent impacts of the former. For this reason, and as stated above, the framework aims to produce only a qualitative overview of the drivers found in the study area.[10]

- Also as a general rule within the DESSIN assessments, pressures will be treated qualitatively. If later in Part III of the framework, the Response (i.e. the Proposed Measure) is found to have the capability to influence any of the pressures identified in the study area,

[9] While the assessment of wider measures that could address drivers (e.g. management measures or integrated approaches) is not ruled out completely, most of the case studies which were used to develop, test and validate the framework consisted of more punctual technological implementations.
[10] For those cases when the user intends or finds it useful to quantify drivers, the IMPRESS group suggests to compare aggregated data (e.g. population density in the study area, hectares or arable land) to aggregated environmental monitoring information across a defined time frame. This provides a way to evaluate quantitatively the likelihood of a certain driver being related to an environmental pressure (IMPRESS, 2003).

then exclusively those pressures will have to be quantified. This is to allow the assessment of changes resulting from response implementation. Different methods may be applied in order to assess the pressures in the study area, e.g. analysis of available data, collection of new data, involvement of expert judgement, or the use of models.

- Regarding the issues of scale in the characterisation of drivers (and pressures), the DESSIN ESS Evaluation Framework follows the approach proposed by IMPRESS. This approach recommends that the assessment of drivers and pressures initiates at the river basin or river basin district level to subsequently abstract the relevant data which is necessary for the examination of the individual water bodies (IMPRESS, 2003).

- In some cases, multiple drivers might contribute to a single pressure. For example, diffuse pollution of a water body (e.g. by a certain substance such as phosphorus) can be caused simultaneously by agriculture, forestry as well as urban development. Alternatively, a single driver like urban development could also result in a multiplicity of pressures (e.g. point pollution through storm water overflows and flow regulation through the construction of water supply reservoirs). Ultimately it is expected that the spatial scale at which the assessment is undertaken will be what determines how relevant the identification of these multiple linkages is for the assessment, as well as how evident they are. Here, issues of scale must be carefully considered to ensure that at least the most influential linkages are highlighted and included in the assessment.

- The DESSIN framework gives the user the opportunity to provide detailed specifications of the drivers and pressures which are identified in the study area. The information gathered in the Drivers and Pressures Characterisation Tables included in the DESSIN cookbook can be used to formulate a brief descriptive text that provides a qualitative (or quantitative, when necessary) overview of the drivers and pressures found in the study area. This is intended to feed directly into the reporting of the assessment results.

- In the Drivers and Pressures Catalogue as well as in this document (Table 4) it can be seen that not all pressure categories are relevant for each single driver. Since the DESSIN catalogue is intended to be a living document to be expanded even beyond the time frame of DESSIN, users are encouraged to insert additional driver types, pressure categories and further relationships between the two that have not been considered previously but exist in the respective study area.

3. Identification of Beneficiaries

This chapter makes reference to Part III of the DESSIN cookbook!

3.1 Selection of a suitable definition

Beneficiaries have been defined as "the interests of an individual (i.e., person, organization, household, or firm) that drive active or passive use and/or appreciation of ecosystem services resulting in an impact (positive or negative) on their welfare" (adapted from Landers and Nahlik (2013), p. 20). Another definition comes from United Nations, Beneficiaries are "*the economic and social entities (enterprises, households, governments) that receive the contributions from ecosystems*" (United Nations, 2014).

When using available ESS classification schemes (MEA, CICES…) that do not specify "final" ecosystem goods and services, final ecosystem services may be mixed together with intermediate services. This often results in double-counting, as an "intermediate ecosystem service" may be a component of another ecosystem final service (Landers and Nahlik, 2013), therefore the analyst may account the intermediate and the related final service separately. This is why it is important to identify final services associated with direct beneficiaries. Landers and Nahlik (2013) report advocates that this system considerably reduces the risk of double counting different components of ecosystem services. This is especially relevant for the economic valuation of changes in final ecosystem services.

Within DESSIN we follow the USEPA approach of Landers and Nahlik (2013) but propose to use an adapted version of their definition for the term "beneficiary". Once we have identified the ESS which are hypothetically changed by the proposed response (see Step 3 in Part III of the cookbook) we try to distinguish final ESS from intermediate ones in that list 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.** In other words, we create a short list of Final ESS that are changed by the proposed measure, i.e. the relevant ESS for the case study.

> *"Ecosystem contributions are embodied in benefits and for each benefit there must be a beneficiary. Thus, to be included in the measurement scope of ecosystem services, there must be a direct contribution to an enterprise, household or government unit" (UN, 2014).*

Boyd and Banzhaf (2007) define Final Ecosystems Goods and Services (FEGS) as the "*components of nature, directly enjoyed, consumed, or used to yield human well-being*". According to Landers and Nahlik (2013), the benefits of using such definition for FEGS are:

- Helps place boundaries on ecosystem services.
- Centers on ecosystems and guides measurements of biophysical features.

- Counts only direct interactions between a use (or beneficiary) and the ecosystem, which is critical to avoiding double-counting of ecosystem services.
- Clearly relates to human well-being.

In short, the identification of direct beneficiaries allows separating the infinite list of ecosystem services relevant for any ESS assessment into intermediate ecosystem services and final services, which is the focus of the Impact II analysis.

Box 2: How does the identification of Final Ecosystems Goods and Services place boundaries? Source: (Landers and Nahlik, 2013).

Consider water as an example, which is often considered an ecosystem service. If we, as ecologists, want to quantify water, what do we measure? Do we measure water quality? Or water quantity? Or water temperature? Or water clarity? Do we measure all of those things? **What to measure depends on who is using the water.** If a subsister is using the water, perhaps we measure water quality. If an irrigator is using the water, we measure water quantity. If a recreationalist is using the water, perhaps we measure water clarity. **Through the identification of beneficiaries, we can determine what to measure and connect those measurements to what people care about and ultimately human well-being.**

The ESS beneficiaries system, which ultimately collects the interests of an individual (Landers and Nahlik, 2013), recognises that a person can be depicted as the multiple interests she/he has on/uses Final Ecosystems Goods and Services. In other words, a single individual can be seen as multiple beneficiaries since he/she may have more than one interest/make more than one use of what an ecosystem can offer (see Figure 5). Arguably, the total economic value of these final services for the individual would be the sum of the benefits derived from each of his/her interests in/uses of them.

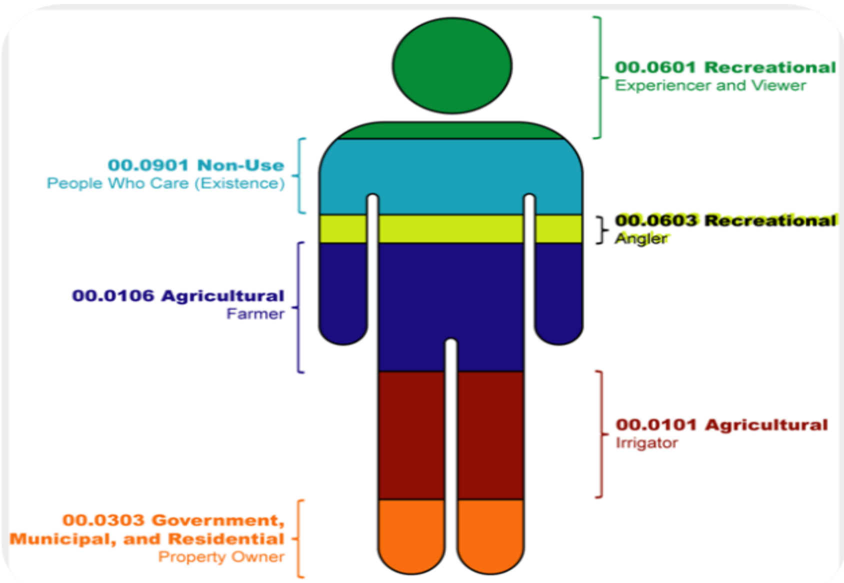


Figure 5: Illustration exemplifying the different interests of a beneficiary in certain ESS (Landers and Nahlik, 2013)

The USEPA identifies 37 different Beneficiary Sub-Categories in FEGS-CS (Landers and Nahlik, 2013). For the purposes of DESSIN, we propose to link some of the US EPA beneficiary categories and subcategories to the NACE codes[11] used by EUROSTAT[12]. Thus, **allowing for a better correlation between the identification of beneficiaries and the extraction of relevant available economic statistics to account for available market services**. This applies to the following main economic sectors:

00.01. AGRICULTURAL
00.02. COMMERCIAL / INDUSTRIAL
00.03. GOVERNMENT, MUNICIPAL, AND RESIDENTIAL
00.04. COMMERCIAL / MILITARY TRANSPORTATION
00.08. LEARNING

Box 3: Availability of regional statistics

EUROSTAT, the statistical office of the European Union, collects statistics that describe the structure, conduct and performance of businesses across the regions of the European Union (EU). Statistics are presented according to the activity classification, NACE.
http://ec.europa.eu/eurostat/statistics-explained/index.php/Statistical_themes
Information can be found at different levels of aggregation and scales depending on the economic sectors covered. See for example the regional statistics by NUTS classification:
http://ec.europa.eu/eurostat/web/regions/data/database
The current NUTS 2013 classification is valid from 1 January 2015 and lists 98 regions at NUTS 1, 276 regions at NUTS 2 and 1342 regions at NUTS 3 level across Europe.
Regional typologies and local information corresponding to NUTS 3

Please note that economic statistics do not cover non-market services. Therefore, the following categories from the US EPA list would be kept for the purposes of DESSIN:

- 00.05. SUBSISTENCE
- 00.06. RECREATIONAL
- 00.07. INSPIRATIONAL

[11] The term NACE is derived from the French ***N**omenclature statistique des **a**ctivités économiques dans la **C**ommunauté **e**uropéenne*. In English, Statistical classification of economic activities in the European Community. NACE is a four-digit classification providing the framework for collecting and presenting a large range of statistical data according to economic activity in the fields of economic statistics (e.g. production, employment and national accounts) and in other statistical domains (EUROSTAT, 2015).
[12] EUROSTAT (2015) Eurostat Statistics Explained. Glossary: Statistical classification of economic activities in the European Community (NACE) http://ec.europa.eu/eurostat/statistics-explained/index.php/Glossary:Statistical_classification_of_economic_activities_in_the_European_Community_%28NACE%29

- 00.09. NON-USE (including, 00.0901 People Who Care (Existence) and 00.0902 People Who Care (Option / Bequest)).
- 00.10. HUMANITY

Following this structure, within the DESSIN framework European statistics would be used to value those ESS for which a market exists, while the DESSIN valuation database would be used to value non-market ESS.

3.2 Beneficiary classification

The following table shows the beneficiary categories used in DESSIN which are based on the USEPA classification.

Table 6: Proposed beneficiary classification for water related Final ecosystem goods and services. Source: Modified from Landers and Nahlik (2013)

Main beneficiary type	Subtype (example)	**Example of general beneficiary description (water focus)**	**Equivalency with NACE codes (where available)**
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.	A AGRICULTURE, FORESTRY AND FISHING
MANUFACTURING	Manufacture of food products	Activities that utilise 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.	C MANUFACTURING 10 Manufacture of food pro-ducts
WATER SUPPLY; SEWERAGE, WASTE MANAGEMENT AND REMEDIATION ACTIVITIES	Water collection, treatment and supply	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 precip is not generally used as a water source.	E WATER SUP-PLY;SEWERAGE, WASTE MANAGEMENT AND REME-DIATION ACTIVITIES 36 Water collection, treatment and supply
	Sewerage	This beneficiary uses the environment [only] for discharging treated water.	37 Sewerage
TRANSPORTATION AND STORAGE	Water transport - Inland freight water transport	This beneficiary uses the environment as a media to transport goods - specifically, via boats (e.g., barges), airplanes, and overland/off-road vehicles (e.g., quads).	H TRANSPORTATION AND STORAGE 50 Water transport 50.4 Inland freight water transport
	Water transport - Inland passenger water transport	This beneficiary uses the environment as a media to transport people - specifically, via boats (e.g., cruise liners, ferries, tour boats), airplanes, and overland/off-road vehicles.	50 Water transport 50.3 Inland passenger water transport

EDUCATION	Education	This beneficiary includes both formal and self-taught educators and students. All parts of the environment are of interest.	P EDUCATION 85 Education
PROFESSIONAL, SCIENTIFIC AND TECHNICAL ACTIVITIES	Scientific research and development	Researchers are interested in the environment for academic and applied purposes and as a group do not discriminate over which parts of the environment are of interest.	M PROFESSIONAL, SCIENTIFIC AND TECHNICAL AC-TIVITIES 72 Scientific re-search and development
Real estate activities	Residential property owners	While changes in property value are not a FEGS, residential property owners are affected by the environment in which their property resides.	L REAL ESTATE ACTIVITIES
RECREATIONAL	Experiencers and viewers	This beneficiary views and experiences the environment via an activity, such as scenery gazing, hiking, bird watching, botanizing, ice skating, rock climbing, flying kites, etc. This beneficiary does not have physical contact with water.	N/A
	Food pickers and gatherers	This beneficiary recreationally picks or gathers from the natural abundance of [edible] flora, fungi, and some fauna (as long as it is not fished or hunted). This beneficiary has potential contact with water.	N/A
	Hunters	This beneficiary is primarily interested in hunting mammals and fowl (not flora or fungi) recreationally (i.e., not for survival). In aquatic environments, this beneficiary has potential contact with water.	N/A
	Anglers	Anglers fish recreationally (i.e., not for survival) and include catch-and-release or catch-and-consume activities. Stocked fish are not a FEGS, as they are considered a human input. This beneficiary has potential contact with water.	N/A
	Waders, Swimmers and divers	This beneficiary recreates in or under the water by either wading, swimming, or diving (i.e., snorkeling, SCUBA diving). By definition, this beneficiary has contact with water.	N/A
	Boaters	Boaters may use motorized (i.e., motor boats) or non-motorized boats (i.e., canoes, kayaks, rafts) to recreate. This beneficiary has potential contact with water.	N/A
INSPIRATIONAL	Spiritual and ceremonial participants and participants of celebrations	This beneficiary uses the environment for spiritual, ceremonial, or celebratory purposes, such as harvest festivals, seafood festivals, Native American observances, religious rites (i.e., baptisms, weddings), personal growth, etc.	N/A
	Artists	Artists, amateur and professional, utilize the environment or their experience in the environment to produce art. This category may include writers, cinematographers, and recording artist among others.	N/A
NON-USE	People who care (existence)	This non-use beneficiary believes it is important to preserve the environment because of a moral/ethical connection or for fear of unintended consequences.	N/A
	People who care (option/bequest)	Option/Bequest non-use beneficiaries consider that they or future generations may visit or rely on the environment. This includes beneficiaries that value the traditional aspects or features of an activity or FEGS.	N/A
HUMANITY	All humans	e.g. climate change	N/A

4. Identifying and assessing environmental parameters (State), ESS provision (Impact I Provision) and ESS use (Impact II Use) affected by proposed measures (Response)

This chapter makes reference to Part IV of the DESSIN cookbook!

4.1 DPSIR application

The DESSIN ESS Evaluation Framework is based on the DPSIR approach, offering a frame for and embedding the practical steps for the application of the Framework.

The general process to follow for the Impact assessment – consisting of the Steps 5 to 8 and assessing changes in State, Impact I and Impact II – is illustrated in Figure 6. The process differs between Intermediate ESS, which do not have direct beneficiaries, and thus, stop after Impact I Provision and final ESS, which have direct beneficiaries that Use the service provided by the ecosystem. For the latter the Use of the benefit can be assessed and monetized.

Drivers are the anthropogenic activity that may affect the system under consideration and it is important to identify and describe them qualitatively. However, their quantification is not required for the assessment of the change in ESS, and therefore, they are not included in this scheme. *Pressures* stemming from the *Drivers* act on the ecosystem (ES) under investigation. A *Response* can either alleviate this *Pressure* or improve the *State* of the ES. In DESSIN it is assumed that the *State* of the ES is related to the capacity of an ecosystem to provide services (*Impact I - ESS Provision*). As explained in Part III (Step 4) of the cookbook, a beneficiary can actually make active or passive use of final ESS, which represents a benefit for him (*Impact II*). Regulatory thresholds can help determine whether an ESS is being provided at a level at which it is useful for a beneficiary. Furthermore, regulatory thresholds can help in understanding the quality of the *State* by relating it to a political aim or a certain public interest. Examples for regulatory thresholds are the aims set within the WFD for reaching a good ecological status or potential. It is possible that the willingness to pay for an ESS is a bit higher when a regulatory target is met but this will not be substantial, and thus, would not alter the monetary benefit. The monetary benefit would, however, be altered if a regulatory threshold for e.g. nutrient concentration in drinking water defines the effort in technical water purification required by a beneficiary (e.g. DWTP operators), ultimately resulting in the value of costs avoided for this purification process.

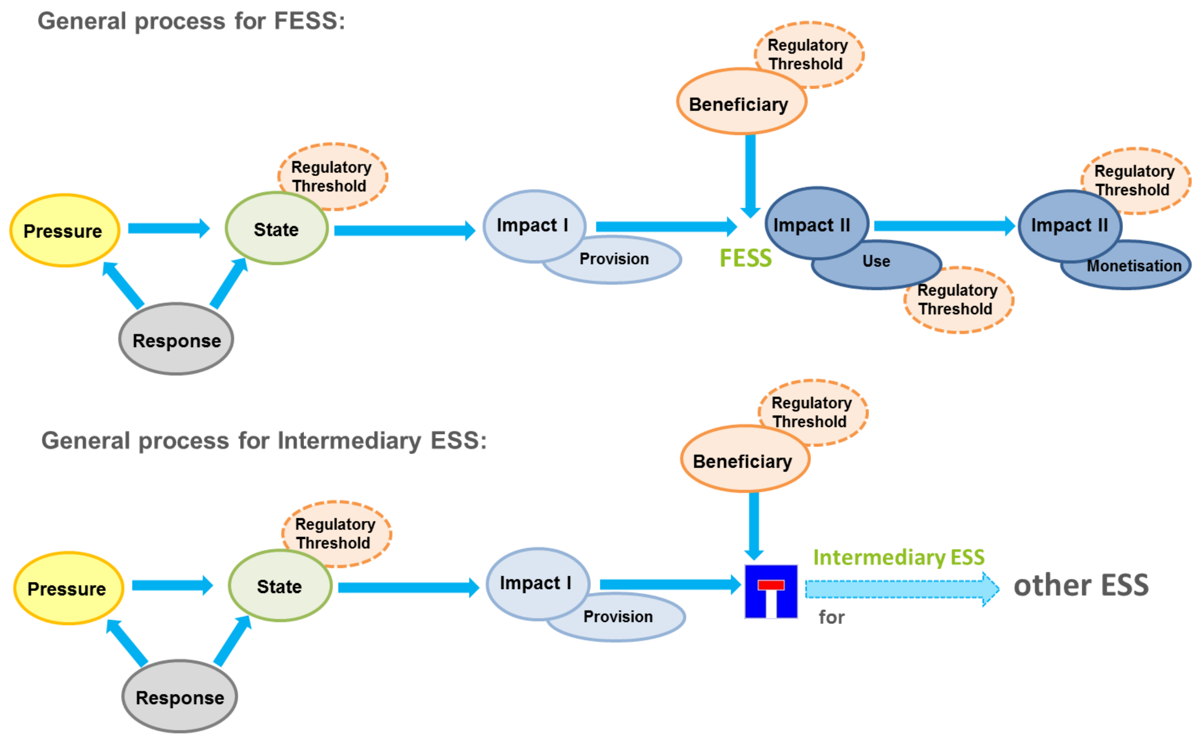
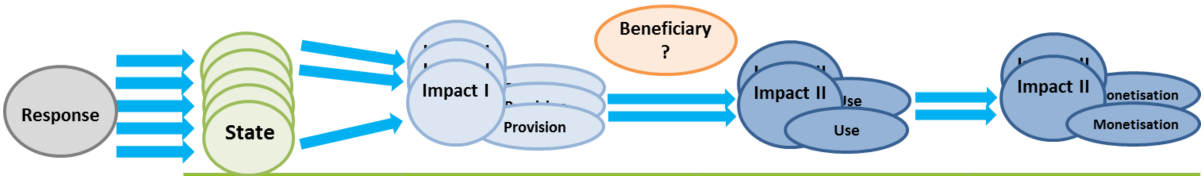


Figure 6: General scheme for Final ESS and Intermediary ESS for application of the DPSIR approach (P=Pressure, R=Response, S=State, I1=Impact I, I2=Impact II, B=Beneficiary, RT=Regulatory threshold)

In order to assess each of the elements in Figure 6, the application of indicators is required.

Figure 7 shows the type of indicators necessary for each single element. These are: The *State* of the ES under investigation is assessed via indicators for environmental parameters. Since we want to assess the changes in *State* and *Impact I Provision* and *II Use and benefits* resulting from a certain *Response*, the environmental parameters describing the *State* to focus on should be only those affected by that particular *Response*. Note that this dependency on *Response* helps limiting the effort to what is essential for the evaluation process. This dependency on *Response* can be found throughout the Framework in order to keep the focus.

Therefore, quantification is only necessary for those environmental settings (*State*) that are relevant for the *Impact I Provision*. We call them "ESS-relevant *State* indicators". Other settings do not need to be quantified, as they are not essential for the evaluation process. The DESSIN Supplementary Material File provides examples for relevant *Impact I Provision* indicators. In case a beneficiary of a service is identified within the study area, the use of the service can be assessed as well by applying indicators of *Impact II (ESS Use)*. Examples for these indicators can be found in the Supplementary Material File.



Indicator:	Indicator:	Indicator:	Indicator:
State indicator: • Environmental parameters → STEP 5	**Impact I Provision indicator:** • ESS provided by the Ecosystem • certain environmental parameters or a combination of several, • given as rate/service per area and time → STEP 6	**Impact II Use indicator:** **= FEGS** • ESS actually used by beneficiaries • certain environmental parameters or a combination of several • given as rate/service per area and time → STEP 7.1	**Impact II Use indicator:** **= FEGS** • Economic method → STEP 7.2

Figure 7: General scheme for the use of indicators within the DPSIR application.

Figure 7 demonstrates that the proposed measure (*Response*) affects several parameters of State. However, not all of them are important for assessing the relevant ESS (*Impact I*) selected as case-relevant from the full CICES list. These ESS represent intermediate and final ESS. After identification of the case-relevant ESS, the ESS-relevant *State* parameters can be selected for each ESS. *State* indicators should be applied to assess those *State* parameters relevant for ESS provision. Note again the dependency on *Response* mentioned above.

This chapter focuses on the identification of the *State* parameters, especially on those affected by proposed measures (*Response*) and those that are of relevance for ESS provision (*Impact I*) and use (*Impact II*).

4.1.1 Provisioning Services

For Provisioning ESS the general concept (Figure 7) can be adopted in a straightforward manner. This is demonstrated with the example of the ESS **Water provision** in Figure 8.

4.1.1.1 Example: Water provision

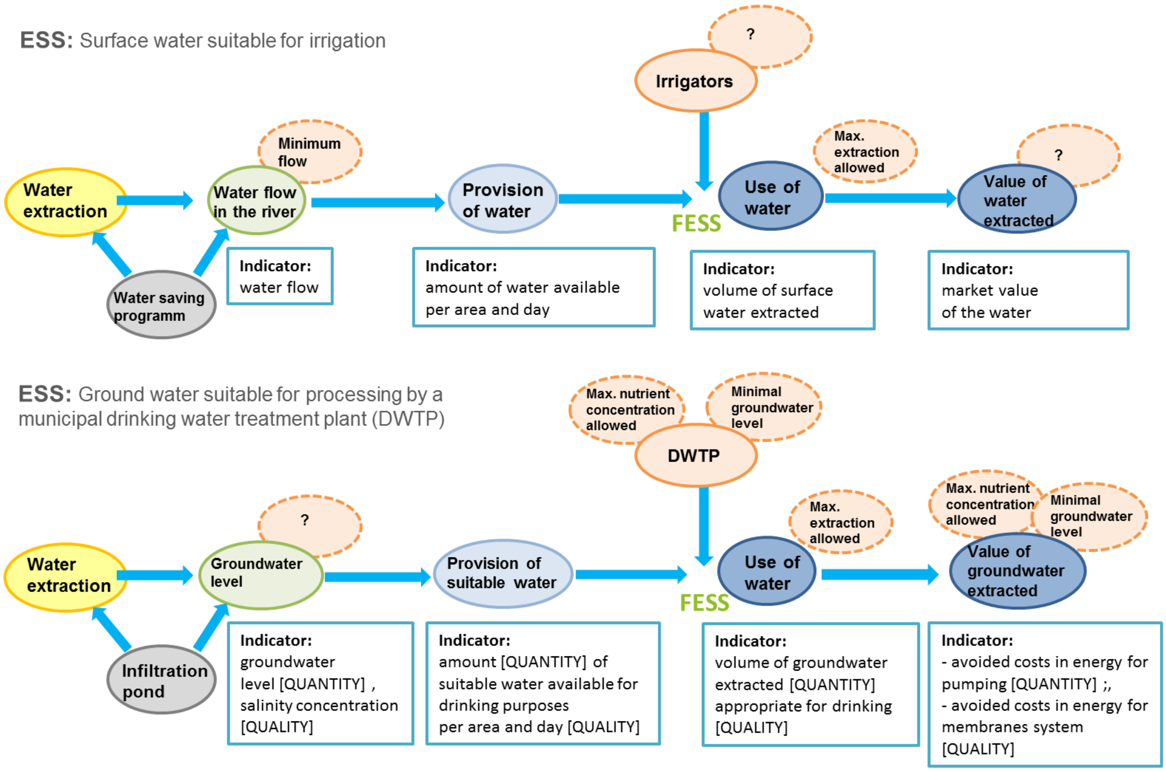


Figure 8: Provisioning services approach for the use of indicators within the DPSIR application

The two examples in Fig. 8 show the process for two different beneficiaries (irrigators and DWTP operators) which are using the resource water stemming from two different ecosystem types (surface water and groundwater). As both examples have direct beneficiaries, they are both final ESS.

Regulatory thresholds can be of help in various ways: In this case, the regulatory thresholds limit the use of the resource to a sustainable level, linking *Use* closely to the *State* of the ecosystem. The regulatory threshold does not define the beneficiary as in the Regulating ESS (see the 4.1.2). They do, however, help in assessing the benefit, e.g. the energy needed for extracting groundwater is higher when the groundwater level is lower. In the second example (DWTP), water quantity as well as quality are of importance to the beneficiary. The graphic focuses both on *State* quantity ("the groundwater level") and quality ("salinity concentration"). Accordingly, for quantity the "avoided costs for groundwater pumping" and for quality the "avoided costs for groundwater membrane filters" would need to be assessed to value the benefit.

4.1.2 Regulating & Maintenance Services

For Regulating & Maintenance ESS the general scheme can be followed in case a beneficiary is present, as e.g. for the ESS **Flood protection**, representing a final ESS. See Figure 9.

However, if no beneficiary is present, as in the example of the ESS **Nutrient retention/ Self-purification**, the process ends after *Impact I*, with no benefit provided. In the latter case, the service is not a final one but an Intermediate ESS for the provision of final ESS such as Cultural services. See Figure 10.

4.1.2.1 Example: Flood protection

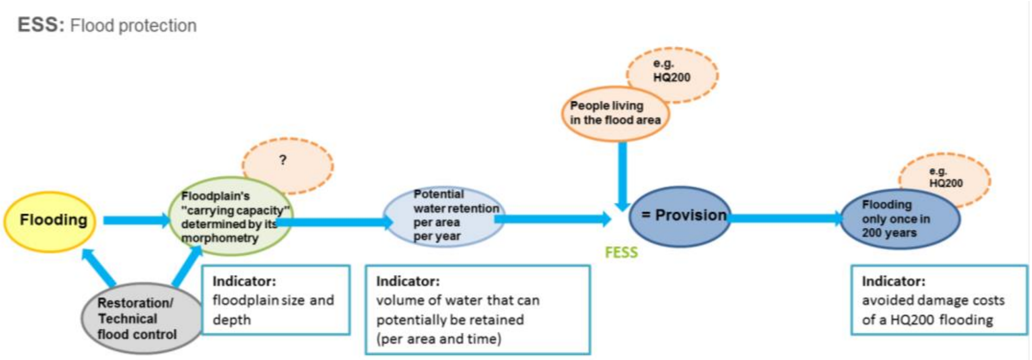


Figure 9: Regulating & Maintenance services approach for the use of indicators within the DPSIR application

In this case, the regulatory threshold defines the benefit and thus determines what constitutes the beneficiary. For instance, if legal requirements protect a city against floods that statistically occur every 200 years (i.e. HQ200 protected), then the people living in HQ200 protected areas can be regarded as beneficiaries. If the ES under investigation provides a flood protection of HQ200, then the people living in the area are beneficiaries and have a benefit (*Impact II*). However, even if the provision of the service is higher than required (e.g. a HQ1000 protection), the beneficiaries will still make use of the entire flood protection capacity of the ES, namely being protected against floods occurring every 1000 years. Therefore, the use and subsequently also the benefit are defined by, and thus are equal to, the provision. The provision can only be either sufficient or insufficient to comply with the regulatory threshold. If it is insufficient, the people living in the area are not beneficiaries and the process stops after *Impact I*. Or if the provision is insufficient, and thus, the legal aim is not met, either additional technical flood protection is required or people have to accept a lower protection, i.e. flooding occurring more often than once in 200 years (statistically).

4.1.2.2 Example: Nutrient retention/ Self-purification

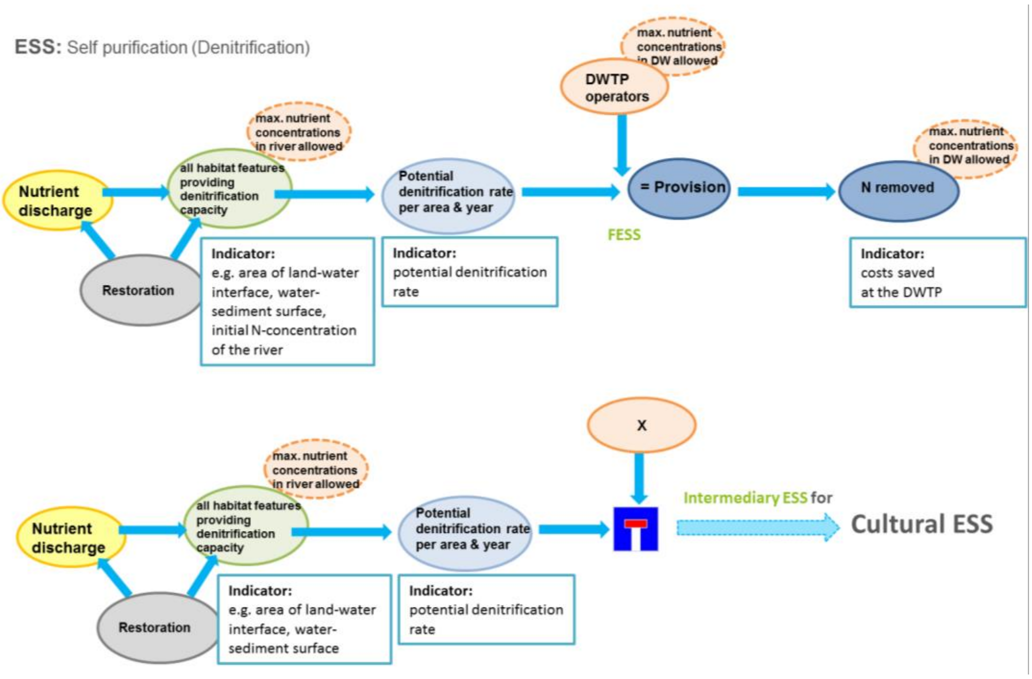


Figure 10: Regulating & Maintenance services approach for the use of indicators within the DPSIR application

For the ESS Self purification we present two examples. In the upper one the beneficiary "DWTP operators" is present in the area and using the ESS, while in the lower example no beneficiary is present.

The DWTP operators are beneficiaries, if the provision of the ESS is high enough to fulfill the regulatory threshold or if the ESS provision helps to achieve the regulatory threshold with lower costs. The regulatory threshold, therefore, defines also here the beneficiary and is closely related to the *State*, as one of the parameters describing the *State* is the initial N-concentration of the river.

If no DWTP operators are using the ESS provided, the process ends at the dead-end sign after *Impact I*. WWTP operators are no beneficiaries, since the WWTP has to achieve their requested N and P levels - irrelevant whether the environment into which the treated water is discharged has a low or high self-purification potential. The ESS provided can, however, be an Intermediary ESS for other services, for instance for cultural services.

4.1.3 Cultural Services

For the Cultural Services, the benefit for people (*Impact II*) is also based on *Impact I*, which can e.g. be assessed via landscape aesthetics, which are closely linked to the *State* of the ES.

4.1.3.1 Example: Recreation

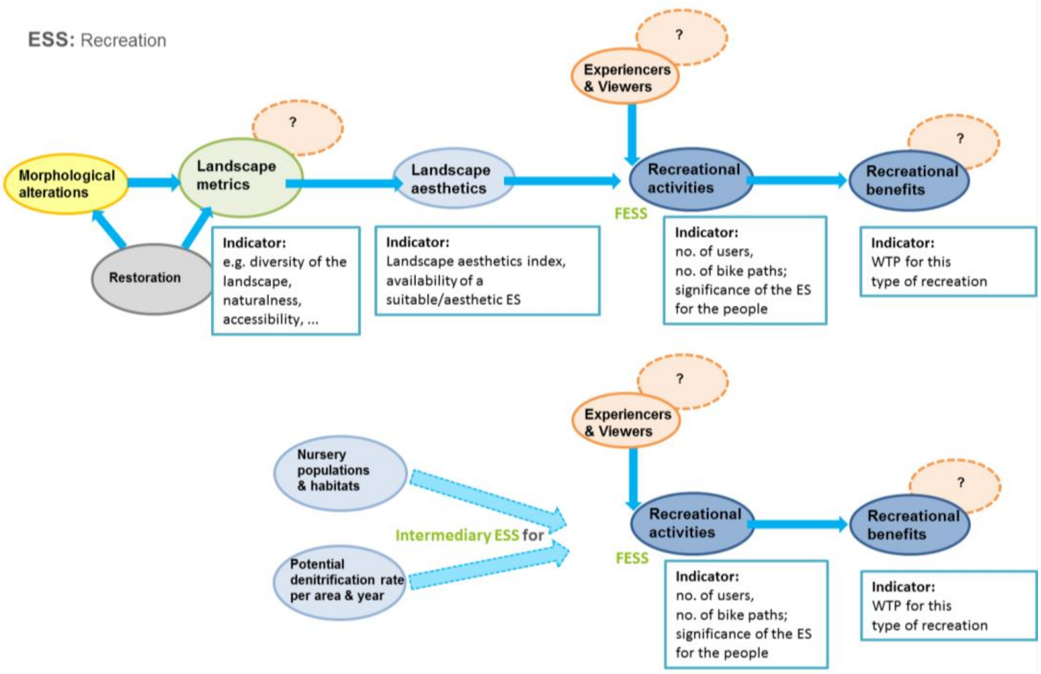


Figure 11: Cultural services approach for the use of indicators within the DPSIR application

In the example given here, the Landscape aesthetics are assessed via a Landscape aesthetics index resulting in the availability of aesthetic ecosystems suitable for recreational activities. These aesthetic ecosystems can be <u>used</u> by people, representing <u>beneficiaries</u>. It has to be considered, however, that it is only a <u>use</u> if people actually go to the ES. Otherwise it implies only the capacity of the ecosystem to <u>provide</u> such a recreation service. Note also that some <u>beneficiaries</u> can benefit more than others, e.g. those living closer to the ES.

4.1.3.2 Example: Opportunities to understand, communicate, and educate

"*Opportunities to understand, communicate, and educate*" is a final cultural service. Usually, educators and students or citizens are the beneficiaries of this final ESS. The service describes how an environment is suitable for educational activities. The Provision of a suitable environment is, thus, essential for this service. It relies on the Provision of several Intermediary ESS, being e.g. Landscape aesthetics, Self-purification potential (N, P, C) and Biodiversity. In ESS assessment studies, the Use of this final ESS is commonly evaluated via the number of educational excursions in the study area. This approach, however, is very simplistic as it only covers the quantity of educational activities but not their quality. The evaluation should (if data availability allows) be extended to cover also aspects of quality of environmental education. These can apply to the context, the learning process, and the learning effect/outcome.

Three indicators can, for instance, help to assess the Use and the Resulting benefits of this final ESS.

A) Offer: educational offers linked to the environment

B) Acceptance: participation in excursions

C) Outcome: persistence of knowledge and environmental awareness

Note that usually it is not possible to quantify the link between the Provision and Use of this final ESS.

4.2 Checklist/criteria for indicator selection for biophysical assessment:

Checklist: criteria for STATE/ Impact I Provision/ Impact II Use indicator selection

The checklist for the biophysical assessment is based on the criteria for policy relevance, ecological soundness, and methodological soundness as described in the DESSIN Deliverable 11.1. Also elements of the Guidelines for EEA Indicator Profile – Review and Update (Belchior, 2012), from the OpenNESS project (Czúcz & Arany, OpenNESS Synthesis Paper No 26), Heink et al. (2015) and BAFU – Bundesamt für Umwelt Schweiz (2011) were incorporated into the checklist.

For each of the selected ESS of relevance the checklist below should be considered. Naturally, not all criteria can be optimal for an indicator.

1) The indicator needs to be relevant for assessing changes in State/ Impact I (ESS Provision)/ Impact II (ESS Use)

2) The indicator should have validity, i.e. the indicator needs to have a direct link to the identified ecosystem element & ecosystem service.

3) Identify if the ESS is process- or structure-related (see DESSIN Glossary). Select direct indicators for Impact I Provision where possible. I.e. process-related indicators for process-related ESS or structure-related indicators for structure-related ESS. If no process-related indicators for process-related ESS are available, apply structure-related indicators as proxies. Usually, field data are not available for process-related indicators, therefore, apply models or simplified models which are based on literature values/rule-of-thumb values.

4) Impact I Provision should be given as a rate per time unit.

5) The biophysical unit of Impact I Provision and Impact II Use indicator should ideally be identical. This would allow to compare Provision and Use, indicating sustainable or non-sustainable Use of this ESS.

6) Select indicators of Impact II Use that are end-user/beneficiary oriented.

7) Identify the spatial and temporal scale that is relevant for assessing the ESS & explain. Data resolution needs to allow for changes in ESS to be identified.

8) Select indicators according to your data availability. If none of the indicators can be calculated based on the data available, this should be stated. In the discussion of the results it should be mentioned that only part of the relevant ESS could be assessed due to data constraints.

9) Double counting, i.e. overlap between various indicators, is to be avoided. Of course, various indicators determining similar output can be assessed in parallel, however, their results cannot be used in combination.

10) Check uncertainty issues concerning data quality. Data quality should be according to internationally accepted standards, guidelines and principles and is therefore considered ‘robust’ by the international scientific community.

11) Determine the level/category of uncertainty and limitations. Describe the indicator.

5. Economic valuation of changes in ESS (Impact II Resulting benefits)

<u>This chapter makes reference to Part IV of the DESSIN cookbook!</u>

The concepts of 'value' and 'valuation' have many meanings and a long history in several disciplines (Farber et al., 2002). Ecological valuation is generally based on bio-physical accounting most often with total neglect of human needs and/or wants. Contrarily, economic valuation is based upon consumer preferences and therefore takes human needs into account (Spangenberg and Settele, 2010). In this context, the value which users derive from an ecosystem service 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:

- Economic *use values* arise from the actual and/or planned use of the service by an individual. Use values can be *direct use values*, such as when an individual makes actual use of the environmental asset improved, e.g. water consumption; or *indirect use values*, such as the benefits derived from ecosystem functions gained that do not translate into a direct use of the resource; such as: ESS derived from regulation functions, like flood control and storm protection.
- *Non-use values* arise independently of any actual or prospective use by the individual. These are usually categorized as Existence Values, which arise from knowledge that the service exists and will continue to exist; and Bequest or Option Values, which measure individuals' preferences to ensure that the service will be available for their own use in the future and that future generations will also have access to the service.

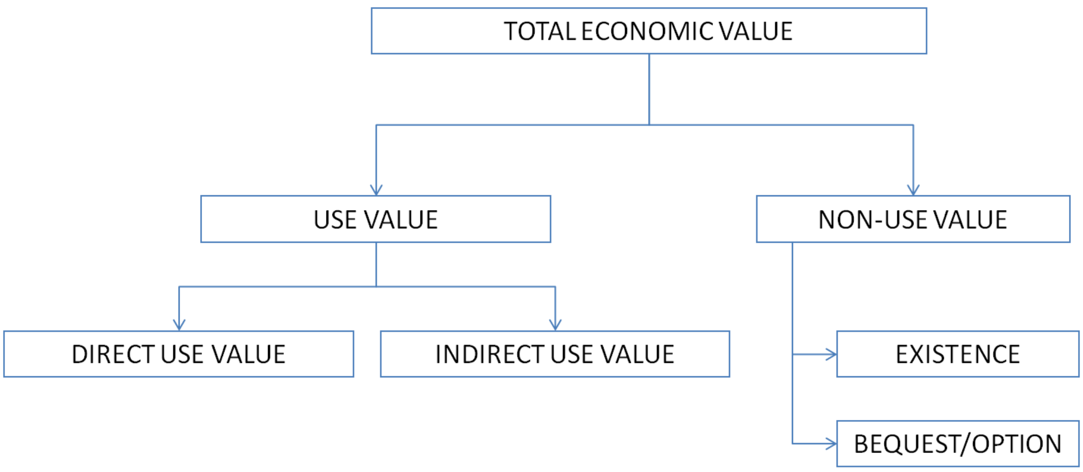


Figure 12: Components of total economic value. Source: Own elaboration.

All of these types of values can be estimated using market-based valuation methods or by analysing revealed and/or stated preferences of users. The variety of existing valuation methods is described later in this chapter.

5.1 Economic value indicators

In the context of the evaluations using the DESSIN ESS Evaluation Framework, it is important to appropriately select and quantify indicators for the different types of values described above. This value 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. Furthermore, the list of beneficiary types and definitions of their ESS Use included in Chapter 3 of this document already includes in the beneficiaries types the distinction between use and non-use type of values. The table also introduces the equivalency with NACE codes which would be useful to find economic related data and indicators from available statistics at different spatial scales for relevant beneficiaries. This is relevant for the monetization of resulting benefits and is dependent on the selection of the valuation method to be employed.

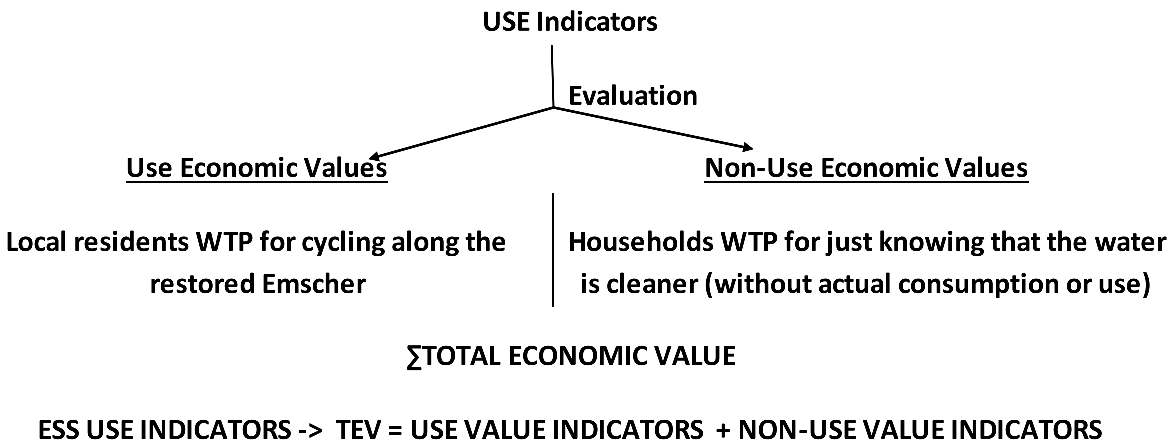


Figure 13: How ESS Use indicators relate to economic value indicators. Example taken from the Emscher mature case study.

How can Intermediate ESS be linked to Final ESS and be valued?

Provisioning ESS can mainly be seen as final ESS that are directly used, e.g. water consumption. Therefore Direct Use Value indicators can be selected and quantified, e.g. amount of water consumed and price of water consumed. Exceptions, however, exist in which the provision of provisioning ESS can be linked to other provisioning ESS (e.g. surface water for non-drinking purposes can serve as an input for the cultivation of crops) or cultural ESS (e.g. wild animals and their outputs can be enjoyed in recreation). For this step about the identification of the object that is actually valued in economic terms, the identification of beneficiaries and final ESS is key. It is in this step where the distinction between an intermediate ESS that leads to a final ESS that will ultimately lead to changes in welfare for an identified beneficiary becomes important. Economic valuation can only be applied to final ESS for an identified beneficiary associated with changes in the use of the specific ESS.

Regulation & Maintenance ESS 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 final Provisioning ESS or final Cultural ESS and their respective Direct Use Value or Non-Use Value indicators. Here, also bundles of intermediate Regulation & Maintenance ESS and their provision can be linked to one or more final ESS. It is then when Direct Use Value indicators of Regulation and Maintenance ESS are found that an economic valuation can be performed. Cultural ESS can all be defined as final ESS and their ESS Use indicators can be classified as either Direct Use Value or Non-Use Value indicators. This categorization depends on identified beneficiaries. Table 7 provides an overview for the classification of Use Value indicators.

Table 7: Linking Final ESS broad categories to types of Use Values

ESS broad category	USE VALUE indicator	Final ESS and beneficiary orientated?	Example
Provisioning	DIRECT USE VALUE	Yes	Ground or surface water for drinking or non-drinking purposes
	INDIRECT USE VALUE	No -> have to be linked to final ESS and their beneficiaries	Some provisioning indicators can be linked to cultural ESS, e.g. wild animals and their outputs (fish) can be linked to fishing for recreation
Regulation and Maintenance	DIRECT USE VALUE	yes	Disease control, flood protection, or the mediation of smell/noise/visual impacts can directly be appreciated by humans
	INDIRECT USE VALUE	No -> have to be linked to final ESS and their beneficiaries	Filtration/sequestration/storage/ accumulation by ecosystems
Cultural	DIRECT USE VALUE	Yes	Physical and experiential interactions
	NON-USE VALUE	Yes	Existence and bequest values

Guidance for Use Value and Non-Use Value indicator selection

a. Identify appropriate Use Value and Non-Use Value indicators and classify them as Direct, Indirect or Non-Use.

b. Link Indirect Use Value indicators to Direct Use Value indicators of final ESS, being the actually used or demanded amount/level of each ESS.

A perfect example of Indirect Use Value indicators could come from flood protection as an intermediate ESS. Where there are a lot of ways to introduce indicators to measure use of the flood protection service. However, the actual Direct Use Value indicators that will be used for the valuation of final ESS relate to more tangible indicators of houses in flood protected areas and a "feel safe feeling" by house owners that it is reflected in higher house prices.

c. The Direct Use Value and Non-Use Value indicators have to be beneficiary oriented. If a beneficiary is not or cannot be identified for a particular indicator under investigation, the selected indicator probably does not make reference to ESS Use; neither can it be defined as a final ESS. Therefore, it is most likely an intermediate ESS.

Values can be estimated for bundles of beneficiaries or a single beneficiary. An improvement in water quality can e.g. be linked to the possibility of more or improved physical and experiential interactions, from which hikers, boaters, swimmers and anglers can benefit. Those can be bundled into beneficiaries of recreational possibilities. If the use of bundles or single beneficiaries should be chosen is case specific and depends i.a. on available data that (in the case of benefit transfers) is comparable to the data of the studies from which values are transferred.

5.2 Monetization of resulting benefits

The total economic value of changes in ESS is measured from the preferences of the beneficiaries for those changes or by measuring the different levels of utility that people place on these changes. The value for the entire population affected is established by the sum of each person's value for changes in ESS or in other words, the area under the demand curve of the environmental good that is improved. After the identification of Direct Use Value indicators of final ESS and their beneficiaries, values can be estimated by using a variety of existing economic valuation methods. As mentioned earlier, mainly this can be through market-based valuation methods or non-market valuation methods by analyzing revealed and/or stated preferences of users that would give an indication of their value. Regarding the classification of valuation methods, DESSIN proposes a very simplified typology, using the most consistent elements of earlier academic work. Figure 14 below provides an overview of the DESSIN typology for valuation methods. Descriptions of the methods shown therein are given in the subsequent sections.

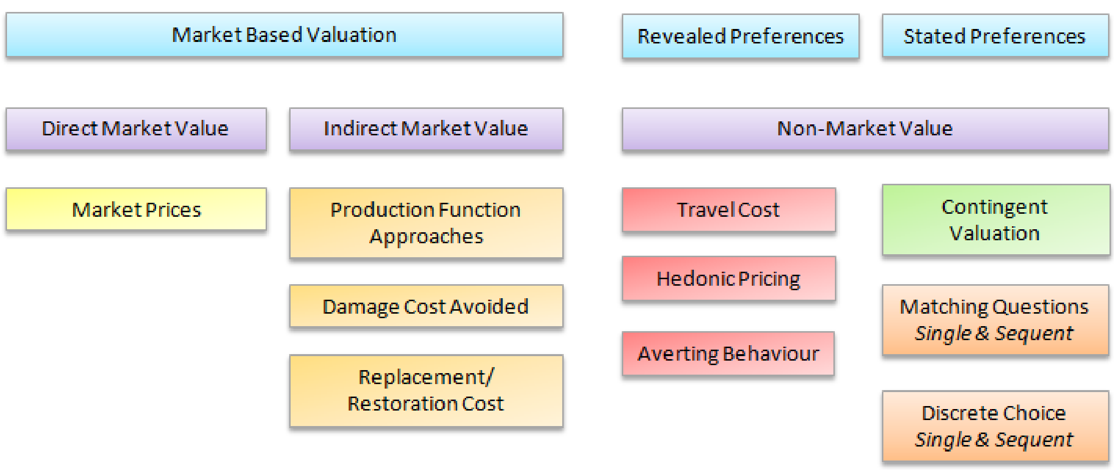


Figure 14: DESSIN Typology of Economic Valuation Methods

Market-based environmental valuation methods

These methods use information from conventional markets, are based on physical linkages, and derive value indirectly using various statistical sources and dose-response functions. The most popular method is the Replacement Cost method, which focuses on costs spent in order to abate, restore or replace a previously damaged marketed or non-marketed good due to degradation of a certain environmental quality.

Direct market valuation

Direct market valuation is only applicable where a market exists for the ESS and data is readily available. In this respect, market prices can be seen as valuations directly obtained from what people or firms must be willing to pay for a service or good (Farber et al. 2006). Direct market valuation acts as a means of assessing the value of ESS in monetary terms, i.e., the exchange of ESS for money within a market (De Groot et al. 2002; Spangenberg and Settele 2010; Farber et al. 2006). However, caution must used when considering this valuation method due to price distortions from market-based interventions (e.g. taxes, price ceilings or floors, subsidies) as well as externalities which do not include the true social cost or benefit of a service in the market price (Turner et al., 2010).

In relation to water ESS valuation, market-based methods may be difficult to implement. One reason is that market prices are not directly established by society's "willingness to pay" in the drinking water market (essential service), as it is considered a natural monopoly with high capital requirements and is typically regulated. Another reason is that water provision might be nationally subsidised, as done within many member states of the EU. For these reasons, any direct market-based economic valuation done for water services can result in inappropriate estimations for water-related ESS.

Indirect market valuation

When no explicit markets for ESS exist, indirect market valuation methods are used as indirect means of assessing values (de Groot et al., 2002; Spangenberg and Settele, 2010; Turner et al. 2010; Birol et al. 2006). Consequently, market prices act as an accounting procedure that can also be extended to other non-market ecosystem service benefits by observing how changes in their provision affect the prices or quantities of other related marketed goods (Turner et al. 2010).

Production function approaches

Production can be influenced by the environment in various ways, e.g., by changing the productivity of inputs, by altering the quality of the output or by reducing the effective supply of inputs. These effects can be modelled by treating the environment as an input in the production function (Bockstael and McConnell, 2007). Different methods exist where the physical changes in output due to environmental changes and damages are measured through the usage of market prices or costs to value these impacts, e.g., dose-response, change in productivity and damage function models (Hanley et al., 2009).

Production function approaches generally estimate the contribution an ESS makes to the production of some marketed/marketable service (Chee, 2004; Farber et al., 2006) or, in other words, isolate the effect of ESS as inputs to a production process (Bateman et al., 2011).

With respect to water ESS, production function approaches can be useful to estimate a partial value of a water ecosystem when there is a clear link between a water ecosystem and the production of an economically valuable commodity. The approach cannot be used to estimate non-use values. According to Bateman et al. (2011) examples of water related ESS valued with production function approaches exist for: supporting aquaculture, groundwater recharge and drainage and natural irrigation. For example, estimations can be made from the reduction in agricultural or business output resulting from a reduced volume or quality of in-stream (aquifer) or off-stream (reservoirs) water (WBCSD, 2013).

The existence of market prices for water-produced commodities (e.g. commercially harvested fish) makes production-based valuation of use values for water ecosystems less controversial than most non-market methods. However, there remain a number of difficulties, especially in valuing urban water cycles with the production function approach. Reasons for this include spatial application bias (most studies applied in rural settings), limited valuation of water ESS (e.g. focus on increased fishery productivity), estimation influence from property rights and regulation, and difficulties establishing a clear quantitative link between water ecosystems and productivity due to influences from natural variation (Boyer and Polasky 2004).

Replacement cost, Restoration cost

The idea behind the replacement/restoration cost method (RCM) is that services could be replaced with human-made systems (de Groot et al., 2002; Farber et al., 2002). The RCM estimates the value of a change in a non-market natural system service by evaluating the cost of replacing the lost or reduced service with a manmade substitute service or by evaluating the cost of an ecosystem restoration (Chee, 2004; Farber et al., 2006; Turner et al., 2010; Bockstael and McConnell, 2007). This method cannot estimate non-use values.

According to Spangenberg and Settele (2010) the RCM can only be used as an approach, if certain conditions are satisfied. These include (1) the replacement system must provide functions/services that are qualitatively and quantitatively equivalent to the original ESS; (2) the replacement option must be the least cost option of all possible replacement options so as to avoid overestimation of the replaced ESS; and (3) the aggregated willingness to pay for the replacement must exceed the cost of the replacement in face of the loss of the original ecosystem functions, so as to avoid welfare loss.

All these points raise issues related to the real degree of substitutability among alternative projects. In addition, alternative artificial solution investment must ensure that adequate maintenance costs are included for a long enough period of time.

Within the water sector, RCM has been used to value disturbance regulation, water regulation, water supply and waste treatment ESS (de Groot et al., 2002). The replacement service valued typically focuses on a single ESS (e.g. water purification) capturing only a part of the value rather than the complete range of values associated with a water ecosystem. In this respect, human-made ESS replacements are rarely successful in substituting all of the services generated from the original ecosystem. RCM is particularly applicable where there is a standard that must be met, such as certain level of water quality.

Damage Cost Avoided, Avoidance Cost

The idea behind this approach is that services allow society to avoid costs that would have been incurred in the absence of those services (de Groot et al., 2002; Farber et al., 2002). A service is valued on the basis of costs avoided by not allowing ESS to degrade (Bateman et al., 2011).

Avoided costs can be used to evaluate the benefits of resource alternatives on the supply-side, including leak-detection and repair programmes, water purchases from alternative suppliers and source-of-supply or treatment options for complying with drinking water standards (Beecher, 2011). Other water-related ESS valuations include the avoided costs of dredging and avoided health costs of water or seafood contamination through value of a statistical life (VSL) estimates (Griffiths et al., 2012). The use of this valuation method is often found in welfare economic studies.

(Net) Factor Income

The (net) factor income approach is generally described as the enhancement of incomes a service provides (Farber et al., 2002; de Groot et al., 2002). The net factor income approach estimates changes in producer surplus by subtracting the costs of other inputs in production from total revenue, and ascribes the remaining surplus as the value of the environmental input (Brander et al., 2006; Birol et al., 2006).

Examples of this ESS valuation method in the water sector include water quality improvements which increase commercial fisheries catch (and thereby the incomes of fishermen), improvements in agricultural productivity and decreased costs of purifying municipal drinking water; as well as wetland ESS (de Groot et al., 2002; Birol et al., 2006; Brander et al., 2006).

Preference-based environmental valuation methods

The vast majority of ESS have no market price (Heal, 2000; Naidoo and Ricketts, 2006; Daily et al., 2000; Turner et al., 2003; as cited in Cowling et al., 2008), as neither directly nor indirectly real or hypothetical market prices can be determined (Spangenberg and Settele, 2010). In this case, Non-Market Valuation Methods can be used to derive price and value calculations using collected data from which one may infer social preferences (Carson and Louviere, 2011). These methods can be divided into two very well differentiated groups: those based on revealed preferences and those based on stated preferences. Methods based on revealed preferences, which obtain ESS values through an analysis of the behaviour of beneficiaries, can only estimate use values from Willingness To Pay (WTP) (i.e. travel cost method (TCM), Hedonic Pricing applied to the property market (HPPM), and Averting Behaviour (AB)). Stated Preference technique methods, which involve asking ESS beneficiaries directly about their choices when confronted with an hypothetical situation that involves tradeoffs between their money and changes in the environment, can be used to estimate use and non-use type of values, but very often benefits estimates coming from these valuation methods cannot be disaggregated according to use and non-use type of values. This is because very often any single beneficiary has, at the same time, use and non-use values on the environment.

Revealed preference methods

Revealed preference methods (RP) are based on indirect calculations, deriving value figures from the effects of behavioural change associated with a service or the lack of a service (Spangenberg and Settele, 2010).

Averting behaviour

The averting behaviour approach can be defined as the examination of expenditures to avoid effects of environmental damage (Bateman et al., 2011). The method is based on the household production function theory of consumer behaviour (Birol et al., 2006), where marketed goods can act as substitutes for environmental quality or goods in certain circumstances. When a decline in environmental quality occurs, expenditures can be made to mitigate the effects and protect the household from perceived welfare reductions (Pearce and Howarth, 2001). This is largely limited to services related to properties, assets and economic activities, and is therefore limited to measuring use values. Averting expenditures obtained provide a lower bound estimate of the total costs imposed (Turner et al. 2010). The divergence between the averting expenditures and the total costs of environmental degradation arises as many consequences cannot be avoided (Courant and Porter, 1981).

Concerns regarding the use of this method focus on its ability to accurately measure willingness to pay. Courant and Porter (1981) argue that in general, the averting behaviour method is not a good measure of willingness to pay, with issues concerning the real degree of substitutability among alternative choices. The best case scenario would be that the goods are prefect substitutes or show a very high degree of substitutability (Turner et al., 2010). More difficulties arise when joint products are used as substitutes, as the value estimates have to be disentangled (Turner et al., 2010). The households should also not obtain direct utility from the averting behaviour (Committee on Valuing Ground Water, 1997).

For water related ESS, the averting behaviour method is applicable to water purification (Turner et al., 2010). However, the Committee on Valuing Ground Water (1997) points out that in most cases, information from averting behaviour studies will need to be coupled with and in some cases compared to results from studies using other valuation techniques to arrive at a complete measure of value.

Travel Cost

The basis of the travel cost approach is that the use of ESS may require travel. The travel costs incurred to enjoy those ESS can be seen as a reflection of the willingness to pay for those services, reflecting the implied value of the services (de Groot et al., 2002; Farber et al., 2002; Farber et al., 2006; Turner et al., 2010). However, difficulties occur when considering the point of origin for visitors. Some visitors may be local while others live farther away, thus incurring different travel cost values. Additionally, multipurpose trips and defining and measuring the opportunity cost of time add further complications to the application of this method.

There has been very limited application of this approach to water ecosystems. The approach is limited to direct use recreational benefits and typically has been applied in the cases of recreational areas, national parks and ecotourism facilities. In many cases, the applicability to urban water cycle valuation seems therefore limited.

Some argue that the travel cost approach can be used to determine water-related recreational values of water reservoirs such as boating, angling and general visiting and to determine water-related recreational values of wetlands such bird watching and general visiting (Boyer and Polasky 2004). However, the travel cost approach only evaluates part of the total value of water ecosystems and cannot be used to value their respective public goods aspects (e.g. flood control, groundwater recharge and discharge) that are unrelated to recreation.

Hedonic pricing

Hedonic pricing method (HPM) relies on the theorem that the value an individual places on a service is based on the attributes it possesses (Chee, 2004) and that the service demand may be reflected in the willingness to pay/accept for associated goods (de Groot et al., 2002; Farber et al., 2002; Farber et al., 2006; Turner et al., 2010). In that regard, the economic value of a characteristic of the service can be derived from the market price of the service (Chee, 2004).

The main application of this method is to estimate the willingness to pay for real estate. According to Palmquist (2005) property value studies are one of the most frequently applied techniques for benefit measurement, as one of the only places where environmental quality is traded on explicit markets is for real estate. However, problems arise from the fact that hedonic pricing relies on the underlying assumption that property prices are sensitive to the quality and provision of ESS. Realistically, property markets are not perfectly competitive and ecosystem quality and supply are not the only characteristics of where people buy real estate. It is difficult to isolate specific ecosystem effects from other determinants of property prices and accurate statistical inference must be done in order just to identify the relation between homes prices and ESS presence.

There are only a few hedonic pricing studies dealing with water quality in the environmental economics literature (Leggett and Bockstael, 2000; Springate-Baginski et al., 2009; Steinnes, 1992). This is because many water quality indices measure pollutants that are impossible for residents to observe or that do not directly impair the enjoyment the individual derives from his/her waterfront home. People only recognise perceptible changes, limiting the method to capturing people’s willingness to pay for perceived differences in environmental attributes, and their direct consequences (Leggett and Bockstael, 2000). Thus, if people aren’t aware of the linkages between the environmental attribute and benefits to them or their property, the value will not be reflected in home prices (Springate-Baginski et al., 2009).

The approach may only capture direct-use values of water-related ESS as perceived by the consumers of the good, who are the (nearby) property owners. Services such as flood control, water-quality improvement, habitat provision for species, and ground-water recharge and discharge, may provide values that accrue far away to individuals other than local property owners. If so, HPM will not accurately capture the full value of services provided.

Lastly, the application of HPM to water-related ESS, and a weakness in this technique, is the very large data sets and detailed information that must be collected, covering all of the principal features affecting prices (Springate-Baginski et al., 2009).

Stated preference methods

In stated preference (SP) survey respondents are asked questions that embody information about social preferences. Here, hypothetical markets are introduced and respondents have to define a value, in different ways, for the respective ESS within these markets (Spangenberg and Settele, 2010).

SP approaches are criticised for overlooking concerns about procedural justice, non-utilitarian ethics and the role of social norms (Lo and Spash, 2013). Therefore "social value" approaches were introduced, a classification which contrast the role of individuals versus groups in the process of valuation and differentiates between individual and social values as products of any such process (Spash, 2007).

Contingent valuation

According to Carson and Louviere (2011) contingent valuation conveys three main elements: (1) information related to preferences is obtained using an SP survey, (2) the study's purpose is placing an economic value on a good, and (3) the good being valued is a public one. One elicitation methods is a matching approach, where respondents are asked to provide a number (their willingness to pay or willingness to accept compensation) that will make them indifferent in some sense.

Another elicitation method is discrete choice experiments, where respondents pick their most preferred alternative from a set of options. Respondents are asked to make a discrete choice between two or more alternatives in a choice set, where the alternatives presented are constructed by means of an experimental design that varies one or more attributes within- and/or between-respondents to be able to estimate economic quantities tied to preference parameters (Carson and Louviere 2011).

Independent of the chosen method, it is important to recognise that contingent valuation can lead to certain types of bias within the survey results: operational, hypothetical, information, design and strategic bias (amongst others) (Mitchell and Carson, 2013). Therefore, careful consideration must be placed into the design and conduction of the survey in question.

Despite the challenges posed in addressing the numerous types of bias, almost any ESS can potentially be valued with the application of contingent valuation approaches (de Groot et al. 2002). Examples include the willingness to pay for increases in water quality, fishing improvement conditions, flood protection, wetland habitat and services preservation (Boyer and Polasky, 2004). More importantly, stated preference methods like contingent valuation are the only approaches available for the valuation of non-use values of water-related ESS. These include existence values like the enjoyment of seascapes; and bequest values like the willingness to preserve water ecosystems for the experience and use of future generations.

Benefits transfer environmental valuation method

Due to time and financial constraints, some studies employ the valuation results of other primary studies to predict welfare estimates for other sites of policy significance for which primary valuation estimates are difficult to attain or are unavailable (Johnston and Rosenberger, 2010). The benefits transfer method ranges in form from unit-value or point-estimate transfers, function transfers and meta-analytical approaches that synthesise results of numerous studies deemed somewhat related to the study in question (Iovanna and Griffiths, 2006).

In general, a consensus of the literature suggests that function transfers typically outperform unit-value transfers as they attempt to calibrate value estimates to the study site in question through population and socio-demographic adjustments (Rosenberger and Stanley, 2006). However, critics of this approach caution the inherit flaws of this method due to the fact that the characteristics of the consumers or client group for which data exist may differ from those of the transfer site. These factors can limit the extent to which values can be transferred or generalised (HM Treasury, 2003). Additionally, the meta-analysis approach is based on studies that a researcher deemed 'somewhat related' to the transfer site, calling in question subjective bias of the studies included.

Despite criticism of this approach, there is an increase in the use of benefits transfer method as primary valuation databases expand and more sophisticated benefits transfer methods are generated (HM Treasury 2003; Johnston and Rosenberger 2010). Though primary research is generally preferred to estimate ESS values, policy processes and financial limitations often dictate that benefit transfer is the only feasible solution (Johnston and Rosenberger 2010; Iovanna and Griffiths 2006). For example, the EU WFD mandates the consideration of benefits and costs for river basin management, including many large and small water bodies across multiple countries. This mandate has encouraged the increasing use of the benefits transfer method as a cost-effective means of benefit estimation (Hanley et al., 2006a; 2006b).

Benefits transfer has been applied in numerous water-related ESS valuation cases at varying levels of scale (Iovanna and Griffiths, 2006; Desvousges et al., 1992; Johnston and Rosenberger, 2010). Examples of water-related benefits transfer range from increases in fish populations, recreation benefit of contaminant-free fishing, changes in water provisioning service flows, water quality improvements, and willingness to pay for flood control and wetland conservation (Iovanna and Griffiths, 2006; Brouwer and Bateman, 2005).

5.3 Selection of an economic valuation method

The choice of the valuation method depends on the ESS type, the beneficiary and the data availability. To select an appropriate/matching economic valuation method that can translate the results of Value indicators into economic measures of human well-being/benefit, the criteria listed in Box 4 can be used.

Box 4: Criteria for the selection of valuation methods

The first step here is to define if the ESS in question is marketed, indirectly marketed or non-marketed ESS (in dependence of the beneficiary).

- **Direct market valuation** is only applicable where a market exists for the ESS and data is readily available.
  - If the ESS is marketed, use market prices/market valuation (description in table)
- If no markets exist for the respective ESS USE indicator, an **indirect or non-market valuation** method must be chosen. 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 ESS being valued. Table 8 below gives an overview of the suitability of different methods for the different ESS types.

Table 8: 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	x	x	-	-	(x)	(x)
Regulation and Maintenance	USE (direct and indirect use value indicators)	-	x	x	x	-	-	(x)	(x)
Cultural	USE (direct and indirect use value indicators)	x		-	-	x	x	x	x
	NON-USE	-	-	-	-	-	-	x	x

5.4 How to obtain monetary estimates: Benefits transfer when original valuation is not an option

Though primary valuation research is generally preferred to estimate ESS values, policy processes and financial limitations often dictate that benefit transfer is the only feasible option to obtain benefit estimates. The most commonly used variants of the benefits transfer are: 1) unadjusted unit value transfer, 2) adjusted unit-value transfer; and 3) benefits function transfer.

Box 5: Definitions of the BT method variants

Unadjusted Unit Value transfer

The estimates of economic impacts are directly 'transferred' from the original site to the case study site. Basically, a mean value estimate (and confidence intervals) from one or several studies is directly transferred. The values transferred from the study site could have been measured using any of the valuation techniques mentioned in Box §§. An effort should be made to use studies that consider a similar environmental stressor as the site of interest (e.g. industrial pollution), or studies that are motivated by a similar Directive (e.g. the Water Framework Directive) and therefore share the same policy framework, or focus on areas with similar climatic/ geographical/ environmental characteristics (e.g., studies undertaken in the Mediterranean); or same ESS type to assess (e.g. water purification). The main advantage of the value transfer method is that it is quicker and cheaper than undertaking original primary economic valuation research.

Adjusted Unit Value Transfer

The estimates of economic impacts are 'transferred' with minor adjustments from the original site to the case study site. The mean value from one or several original valuation studies is adjusted to account for the differences between the study and policy goods with regards to one or more factors that are expected to influence economic value (e.g. income is the most common adjustment factor since it is known to influence value and it is easy to find data on) (Eftec, 2009).

Benefits Function Transfer

The Benefits Transfer Function method allows the incorporation of differing socio-economic and site quality characteristics between the original study site and the study site under evaluation. In this type of benefits transfer, only one original valuation study is typically selected. The main assumption being that the statistical relationship between WTP for improvements and independent variables are the same for both the study and policy site. In other words, BFT applications assume that preferences are the same between both locations and differences are only related to differences in socio-economic and/or environmental context variables.

Unlike unadjusted BT exercises where mean WTP at the policy site it is assumed to be equal to mean WTP values at the original site ($WTP_S = WTP_P$), BFT exercises attempt to adjust values by accounting for any possible differences (e.g. socio-economic and environmental quality variables included in the aggregated benefits function) between both sites.

BFT is regarded as a suitable tool for the adjusted transfer of WTP estimates between different locations when the vector of attributes and socio-economic characteristics (X_1, X_2) that determine the similarities and differences between the policy and the survey site can be established. Where these differences exist and their magnitudes are known, it is possible to substitute those known variables into the survey site's original aggregated benefits function to provide valid BT estimates. This exercise involves the choice about which factors to include and which to omit in the analysis, which is usually limited by data availability.

For the identification of a relevant original valuation study, the following steps should be considered:

1. Identify usable studies for the benefit transfer, consider the usage of the DESSIN valuation studies database

    The DESSIN valuation studies database contains information on valuation case studies usable as an example for different valuation methods or benefit transfer. The database includes bibliographies, data information, relevant ESS, environmental attributes, biophysical indicators, policy scenarios, valuation methods, values and topographical details.

2. The relationship between the original valuation study and the case study site has to consider the following elements (Eftec, 2009):
    (1) The ESS studied; previously identified state or status as well as USE indicators are the same
    (2) The change to be assessed needs to be equivalent
    (3) The location is comparable
    (4) The affected population (characteristics) is comparable -> affected beneficiaries
    (5) The number and quality of substitutes are equivalent
    (6) The market constructs are similar: This element makes reference to a series of circumstances surrounding the change to be assessed: the (implied) property rights, the economic conditions under which the change occurs, the institutional and cultural contexts.
    (7) Study quality: Normally it is judged if the original valuation study has been published in a peer-review journal as opposed to the grey
3. Selection of relevant benefits transfer method depends on certain criteria based on the elements identified above. Choose the value transfer approach on the basis of the availability of the suitable studies and supporting data (in particular whether such data enable value transfer). Table 9 below offers an indication of the type of benefits transfer method that could be applied depending in the elements introduced above:

Table 9: Selection criteria for applying the benefits transfer method. Source: modified from Eftec (2009).

Selection Criteria	**A selection of possible matches between the original study and the assessment case**							
(1) *The ESS*	*y*	*y*	*y*	*y*	*Y*	*y*	*n*	*y*
(2) *The change*	*y*	*y*	*y*	*y*	*x*	*Y*	*n/a*	*y*
(3) *The location*	*y*	*y*	*y*	*x*	*x*	*y*	*n/a*	*y*
(4) *The affected beneficiaries (characteristics)*	*y*	*x*	*y*	*x*	*x*	*x or y*	*n/a*	*y*
(5) *The number and quality of substitutes*	*y*	*y*	*x*	*x*	*x*	*x or y*	*n/a*	*y*
(6) *The market constructs*	*y*	*y*	*y*	*y*	*y*	*x*	*n/a*	*y*
(7) *Study quality*	*Y*	*y*	*y*	*y*	*y*	*y*	*n/a*	*x*
Rules of thumb								
Unit value transfer	+	-	-	-	-	-	-	-
Adjusted unit value transfer	+	+	+	?	?	?	-	-
Function transfer	+	+	+	+	+	?	-	-

Criteria comparison:
y = close match between the original study context and the assessment case context;
x = not a close match between policy good context and study good context;
y or x = Indicates that policy good and study good context match for the criteria is unlikely to be the determining factor for the choice of adjusted unit value transfer or value function transfer; n/a = not applicable.
Rules of thumb:
+ Approach likely to be appropriate provided sufficient supporting information is available (for adjusted or value function transfer)
- Approach unlikely to be appropriate
? Uncertain, will depend on how different the policy good context and study good context are.

Some advice:

- If the original valuation study and the case study site meet the 7 criteria, all forms of value transfer are possible.
- If the original valuation study does not conform to a minimum level of quality it is recommended not to use it.
- It is always preferable to select an original valuation study from the location that is being analyzed. But only if the good and the change to be assessed between the case study and the original valuation study match.

5.5 Valuation barriers and limitations

The inherent uncertainties and lack of agreement surrounding the practical application of ESA have resulted in different understandings and adaptations of the approach. While it is considered controversial by some actors, expressing the value of nature and its services in monetary terms is key to the approach and intends to promote better informed decision-making. As the vast majority of ESS have no market price, price and value estimations must be obtained using alternative methods. The multiplicity of options to do this and the lack of a standard procedure for choosing between them raise the already high level of complexity and abstraction of the discussion surrounding ESA.

A number of general barriers exist which are commonly encountered by scientists and practitioners conducting economic valuation of ESS. Due to their visibility and policy relevance, large-scale collaboration projects like DESSIN represent great opportunities to address these issues. Some of these general barriers are listed and explained here with the intention of providing the context from which this report will go forward and propose a plan of action.

- **Inconsistent definitions/conflicting typologies:** there are diverse or even conflicting meanings for various environmental valuation methods found in the existing literature (i.e. Carson and Louviere, 2011). Different authors may employ different underlying assumptions and typologies to classify the methods used to assess the value of ESS. This development has rendered the comparison of the individual strengths and weaknesses of the different methods a highly complex task, at a time when the current economic/environmental setting demands higher efficiency and reliability in the practical application of the ESA.
- **Unjustified preference/attention to a certain method/ESS type:** ESS valuation methods are extensively used in the production of academic literature. However, some methods have

few existing applications (especially for water related ESS). This may result in a great deal of literature available on a specific type of service or methodology, while knowledge and progress on others is limited.

- **Combination of different methodologies in a single assessment:** obtaining a quantitative figure to measure ecosystem change following the total economic value approach can easily lead to issues of aggregation of different concepts of value (coming from the application of different methodologies applied to different services), double counting, substitution, etc. In some cases, two valuation methods are mixed, combined, or used in parallel without any clear distinctions being made.
- **Lack of benchmark studies/practically applied methods:** there is a lack of complete educational case studies that can be used as benchmarks to explain the whole sequence of the valuation process: data sources and data mining, selection of method(s), application, validation of results and discussion. The main challenge lies in the applicability of environmental valuation methods in real management, as most project assessments are only based on cost-benefit analyses and do not consider environmental externalities.
- **Lack of data:** a situation where accessibility to accurate, high resolution data that is relevant to the site/ecosystem being assessed is low can greatly limit the process of economic valuation, with only small distinctions depending on the method used.

In light of the multiple obstacles to the successful implementation of environmental valuation methodologies, some potential solutions are proposed. Firstly, conduct a review of current environmental valuation methodologies to set the stage and ensure that no relevant knowledge has been overlooked. Secondly, develop harmonized definitions of concepts and terminology that fosters common understanding and collaboration between different sectors (e.g. economists and ecologists). Concurrently, develop a demonstrated/validated environmental valuation approach with a unified classification of methodologies at its core. More precise definitions and a common classification of the existing methods could serve to overcome the complexities commonly related with conducting integrated assessments of the services provided by ecosystems.

Optimally, the solutions proposed above should be complemented by clear guidance on how to select an appropriate valuation method for a specific type of ESS. This would necessitate the identification of relevant and suitable indicators to measure changes in ESS provision in relation to specific changes in ecosystem status. In turn, such indicators should be relevant for current policy targets and priorities. In this regard, sharing experiences with other related EU projects and initiatives would facilitate the calibration and validation of outcomes and ensure their practical application at a wider scale. The use of real case studies should help to increase the understanding of the various methods, their underlying assumptions and their possibilities and limitations.

A note on aggregating results of the valuation exercises

In general, it is not recommended to aggregate the calculated results for different *uses of different case-relevant final ESS*, even though they might originate from the same measure. This is because depending on the valuation method as well as data used, the economic figure can have a different "economic meaning", to state it using simple means. For instance, the results using the travel cost method to assess the enhanced use of a restored river for swimming do reflect rather the economic *impact* which follows an enhanced ESS use than the economic *value*. This is because the results from the travel cost method express the additional amount of money (travel expenses) an individual is paying to get to the place where she/he enjoys the ecosystem. So this amount is per assumption spent in the economy to get to the river. But the whole benefit an individual is gaining from swimming in the river can be much higher than that. If the same individual would have been asked for what her/his WTP would be to enjoy swimming in the restored river would be, his answer could be higher than his travel expenses. In other words the economic *value* added from the individual's point of view might be higher than the assessed *impact* in terms of money spent for enjoying the ecosystem. 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 (e.g. in order to make sure that only the economic value added is aggregated or only the economic impact, depending on the scope of the analysis) has been conducted. Further background information to distinguish between economic impact and value is summarized in the box below.

Box 6: Distinguishing between economic impact and economic value.

Economic impact

An economic impact analysis investigates the **flow of economic activity** through the (local) economy (Miller and Blair 1985, Parkkila et al. 2010) following a specific action, like an investment. This kind of analysis reveals which sectors in the economy are affected by the action. This type of analysis was for instance done to investigate the economic impact of all investments done during the Emscher conversion (Barabas et al. 2013). The calculation of the annual economic impact does not only incorporate the direct impact, which is for instance the amount of the initial spending for an investment, but also indirect effects and induced effects of this spending. The indirect effects for instance are the purchases the construction company of the investment has to make, in order to offer it. In this example the induced impact would ripple from the employees of the construction company receiving wages for their work and spending these for consumption (Parkkila et al 2010).

Economic value

The **economic value** refers to the **net benefits** received **by society**, which is reflected in the total economic value for environmental assets. These may consist of use values and non-use values (Wattage et al 2011). Use values arise from the actual and/or planned use of the environmental asset by an individual and non-use values arise independently of any actual or prospective use by the individual, e.g. existence, bequest or option values (Lago et al. 2014 DESSIN D11.1). There are different techniques and methods to estimate those values people attach to environmental assets (Lago et al. 2014 DESSIN D11.1, Pearce et al. 2006). Whenever it comes to value the use or non-use of environmental assets it is important to note that people often do not pay for it. Thus, even though a lot of people may have a positive willingness to pay for using an environmental asset, for instance an ecosystem which is enhanced by a DESSIN solution, there is no economic impact from this use as long as no money is charged for the use. Still this positive willingness to pay for the use

would reveal an economic value added for society resulting from this improved ecosystem.

6. Sustainability Assessment

DESSIN aims to promote new technologies, especially solutions to water scarcity and water quality challenges. This chapter forms the basis for the sustainability assessment framework in DESSIN, which is to support the promotion of the technologies with broader assessment results. Generically sustainability can be referred to as a status, in which the present interests/needs can be covered without compromising (the system's) ability to cover those of future generations. Decisions to implement new solutions, technologies, projects or measures shall therefore take into account relevant actors' interests and needs of today and the future (WCED 1987, Ness et al. 2007, Gasparatos & Scolobig 2012). DESSIN takes a holistic approach to sustainability based on previous research in TRUST (Brattebø 2012).

Sustainability Assessment (SA) results may help to promote a DESSIN solution by broadening the scope of the DESSIN ESS Evaluation Framework. Besides the effects on the ecosystem (ESS evaluation), the SA takes into account additional impacts of the technologies: **environmental** figures (effects related to efficient use of water, energy and materials – e.g. carbon footprint of a solution), **financial** parameters (affordability of the solution for the organization as well as sustainable cost covering in the long run - e.g. life-cycle-costs), the **social** dimension (additional impacts on quality of life – e.g. in terms of health and equity), **governance** issues (e.g. alignment with regulation standards and knowledge as well as stakeholder participation) and performance indicators of the **asset** (e.g. reliability and efficiency of the technology), that may throw light on the advantages and disadvantages of the solutions. The combination of perspectives may also help reveal conflicts of aims. Being aware of such conflicts is essential for change management (e.g. to convince parties with formerly opposite positions to go for solution implementation) and may thus also support the market uptake of new technologies.

This chapter outlines the conceptual approach of the SA for innovative solutions as additional part to the DESSIN ESS Evaluation Framework. Besides proposing a methodological approach and providing brief descriptions of all dimensions, objectives and criteria to be covered in the assessment process, the chapter deals with the relation between the ESS evaluation and SA in DESSIN.
The following section lays out the theoretical background information on sustainability and its assessment. Section 6.2 highlights the goal and scope of the assessment, the linkage between SA and ESS evaluation and the basic structure of its underlying concept. After this, the dimensions, objectives, criteria (section 6.3) are described for each of the five dimensions. Finally the proposed metrics and indicators to be used for the DESSIN SA can be seen in the last sheet of the Supplementary Material File (Annex to the DESSIN Cookbook).

6.1 Theoretical background

6.1.1 Defining Sustainability

As part of the background, it is important to be aware of the concept of sustainability implied within the DESSIN SA. There are several definitions on sustainability. While in the past, there were two different threads in literature, one addressing ecological sustainability as a basis for biodiversity conservation and another addressing socio-economic sustainability in terms of human well-being, more recent concepts try to merge these concepts into one comprehensive framework (Chapin et al. 2010).

The triple-bottom-line concept is probably the best known concept of sustainability. Its central point is the distinction between three general dimensions of sustainability: social, economic, and environmental (Elkington, 1997). As these three dimensions are potentially overlapping or in conflict, the result of a sustainability assessment is strongly depending on the degree of sustainability allowed (Olschewski & Klein 2011). Here, the ideas of `weak´ and `strong sustainability´ have to be considered. Assuming `strong sustainability´, an action can only be considered sustainable if the value in each dimension of sustainability is increased or remains the same at least. Assuming `weak sustainability´ there can be also negative impacts in one sustainability dimension as long as the overall value is not impaired (Singh et al. 2012).

The ambition of the 7FP project TRUST (https://www.trust-i.net) was to enable transitions to the urban water services of tomorrow, with sustainability as a holistic premise. In accordance with this ambition, TRUST developed a balanced approach, identifying a set of sustainability objectives and criteria for the social, economic and environmental sustainability dimensions. However, since water utilities in the most powerful way can influence these three (end) sustainability dimensions by how they actually manage their assets and how they govern their external affairs, TRUST decided to also include the two dimensions of assets sustainability and governance sustainability. Thus, the following definition of sustainability was proposed: *Sustainability in urban water cycle services (UWCS) is met when the quality of assets and governance of the services is sufficient to actively secure the water sector's needed contributions to urban social, environmental and economic development in a way that meets the needs of the present without compromising the ability of future generations to meet their own needs* (Brattebø, 2012).

6.1.2 Prevailing sustainability assessment approaches

With regard to the triple-bottom-line concept of sustainability, evaluating sustainability can simply be seen as assessing the value of an action based on its contribution to the goals of sustainability. According to *Ness et al. (2007)* the purpose of sustainability assessment is, furthermore, *"to provide decision-makers with an evaluation of global to local integrated nature–society systems in short and long term perspectives in order to assist them to determine which actions should or should not be taken in an attempt to make society sustainable."*

Currently, there are multiple sustainability assessment approaches and tools suggested in literature. These can be subdivided in different ways. According to *Srinivasan et al.* and *Gasparatos & Scolobig*, sustainability assessment approaches can be categorized into three types: assessment frameworks, analytical evaluation tools and composite indicators/indicator lists (Figure 15).[13]

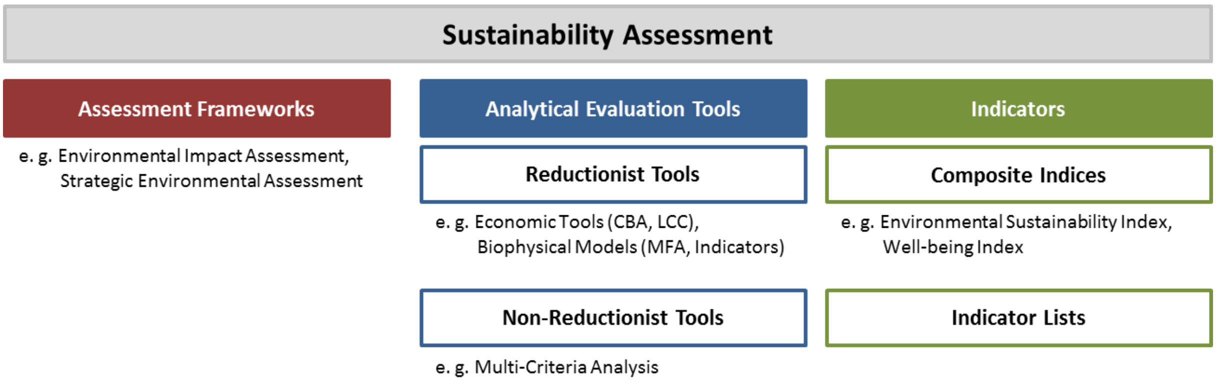


Figure 15: Classification of sustainability assessment approaches. Source: Own figure adapted from Srinivasan et al. 2011 and Gasparatos & Scolobig 2012.

The first type of assessment approach can be summarized under the term `sustainability assessment frameworks´. Sustainability assessment frameworks provide integrated and structured procedures for the comparison of project or policy alternatives. Usually such frameworks can be seen as guidelines including step-by-step descriptions of the evaluation process but lacking detailed evaluation methods or tools (Gasparatos 2010).

The second category includes analytical evaluation tools to conduct analysis. These tools aim to support decision making by identifying the best solution to a specific problem within the given framework. Analytical evaluation tools can be further subdivided into reductionist tools and non-reductionist tools with regard to the amount of indicators, dimensions, objectives, scales or time horizon for evaluation to be investigated. Reductionist tools are much focused and therefore consider only one dimension. They can again be subdivided in monetary, ecological or social assessment tools whereof economic tools, like Life Cycle Costing (LCC) and Cost-Benefit-Analysis (CBA), are the most widely used. However, none of these reductionist tools are comprehensive enough to analyse impacts on all pillars of sustainability. In other words, a suite of these tools would be required to assess the overall sustainability of an action (Committee on Incorporating Sustainability in the U.S. Environmental Protection Agency 2011). In contrast, non-reductionist tools are based on various indicators that are weighted and balanced in a series of methodological choices, which is why they are also known as multi-dimensional tools. The weighting of the single dimensions of sustainability is mostly done according to the goals and worldviews of the actors involved (Costanza & Folke 1997). Although most multi-dimensional sustainability assessment tools are based on quantitative evaluations, this is not required for all non-reductionist tools (e. g. Downing et al. 2014).

[13] A way more comprehensive framework for sustainability assessment tools can be found in *Ness et al. 2007*.

Finally, the third category contains sustainability indicator lists and composite indices (e.g. environmental sustainability index, well-being index). These are mainly reductionist tools as well, but with the difference that they normally sum up comprehensive and complex contexts in a single figure, providing information on improvement as well as warning information on declining values for the various dimensions of sustainability (Gasparatos 2010). The development of a suitable indicator system should be case-specific. In general two approaches for sustainability indicator selection can be distinguished (Singh et al. 2012):

- `Top-down´ approach:
  Experts and researchers define the overall structure for achieving sustainability that is subsequently broken down into a set of indicators.
- `Bottom-up´ approach:
  Based on systematic participation of various stakeholders key sustainable development indicators are selected from a list of various indicators proposed.

Taking into account the literature review and the expertise of a panel of experts (from the TRUST research project), a not – reductionist, multidimensional, top-down approach to sustainability was developed in TRUST. The dimensions (social, environmental, economic and the supporting dimensions of assets and governance sustainability), objectives and criteria of UWS sustainability were defined. The metrics that will allow to measure performance in each criterion were deliberately not defined in detail by the TRUST team (Marques, 2012). The suitable qualitative or quantitative descriptors should be sought with the aid of the relevant decision-makers in each city, region or country (depending on the scope of the assessment) through structured participatory methods. However, some suggestions or examples of how the criteria can be operationalized were also developed (Marques and van Leeuwen, 2012). In total, the TRUST sustainability assessment framework includes a set of 23 sustainability criteria, according to 13 sustainability objectives, within 5 sustainability dimensions (Brattebø, 2012), as depicted in Figure 16.

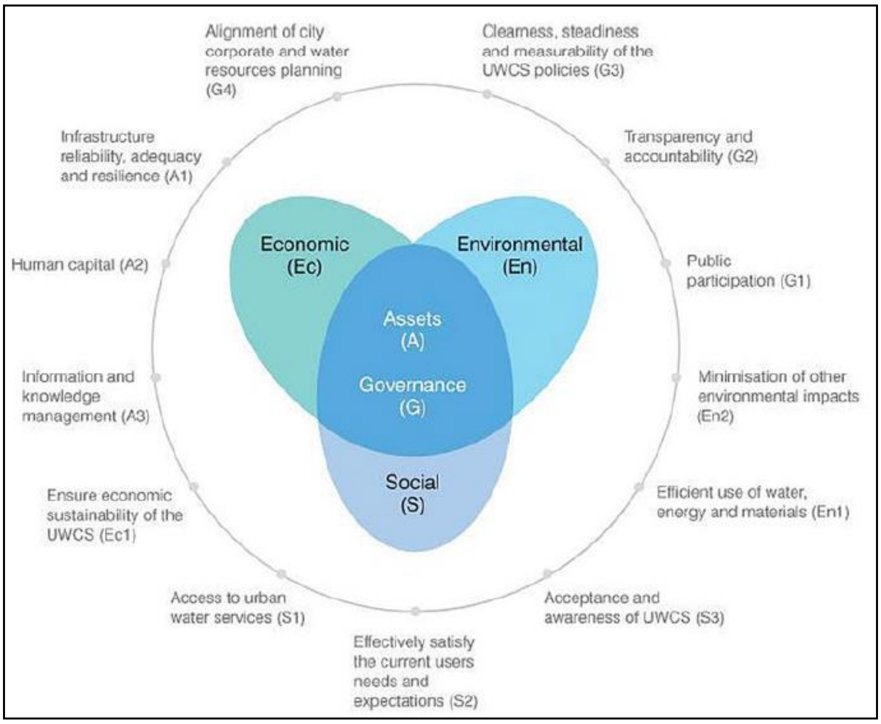


Figure 16 Dimensions and objectives in urban water cycle sustainability (Venkatesh et al, 2015)

The objectives for the UWCS, set out in TRUST, can be of greater or lesser importance for each water utility depending on policies and objectives and on stakeholders. The sustainability assessment proposed in TRUST is made operational by critically and carefully examining a chosen set of performance metrics, i.e. indicators, and how they comply with a predefined set of sustainability objectives and criteria. The performance metrics/indicators may be quantitative or qualitative, and are specifically chosen in order to account for the particular context and challenges of a given urban water cycle system, in a medium- and long-term transition context. The assessment method should be inclusive with respect to stakeholder involvement and decisions regarding target setting and trade-off as part of a multi-criteria decision analysis process. This implies that it is adaptable to different circumstances and that it is possible to emphasize particular dimensions acccording to the user´s needs and preferences.

6.1.3 Development of a SA framework for DESSIN

There are several frameworks, methods, and tools available but not all are suitable for an application in the context of DESSIN. In TRUST the focus of sustainability assessment was related to urban water systems and the capacity of water utilities to deliver sustainable services. DESSIN focusses on specific solutions and their capacity to enhance ecosystem services and contribute to sustainable urban water systems. Thus, the scope is slightly different, but the ultimate objective is the same. Other general SA frameworks, like those briefly mentioned above, do not have a clear focus on urban water systems and therefore have been out of scope for DESSIN. Reductionist tools do not fulfil the general requirement of a comprehensive view on sustainability, and MCDA methods have very extensive data requirements that may exceed the data availability of the case studies within DESSIN. Besides, weighting of criteria is a very huge issue that probably cannot be appropriately done to everyone´s satisfaction. Developing an indicator list inspired and adapted from the example list proposed in TRUST and tailored to the aim of DESSIN was selected as the most appropriate approach for SA within DESSIN. However, the data sets required to serve the indicators proposed in this list may not be available in each case. Especially in a decision making process on future actions to be taken, the possible lack of modelled or at least appropriately estimated data might be critical. Thus, the framework proposed is open for qualitative assessments using a scoring approach and/or final decision making by continuing the assessment with a simple MCDA approach.

The next section outlines the SA framework for DESSIN. This includes a description of its relation to the ESS evaluation framework as well as its originating from the TRUST SA framework.

6.2 Scope and goal of sustainability assessment in DESSIN

6.2.1 Purpose of SA and relation towards the ESS evaluation

The ecosystem service evaluation covers with its methodological steps, from part I to part IV, a generic frame for evaluating enhancement in ecosystems resulting from new DESSIN solutions and its deriving benefits for human well-being. The DESSIN solutions incorporate several innovative technologies and procedures to improve water quality or enhance water quantity available for various purposes. Thus part I to IV is a central instrument in exemplifying the prospective **outcome for beneficiaries that may take advantage of enhanced ecosystems** (see Figure 17). The assessment includes a “before” and “after” evaluation of the ecosystem linking change in its state (condition of the ecosystem), its impact I (capacity to deliver provisioning, cultural and regulating services) and impact II (enhancement of human well-being derived from enhanced ecosystem use). The latter is supposed to be monetized, ideally showing with one figure what kind of **“valued benefits” can be associated to the change in ecosystem service** achievable with the DESSIN solution.

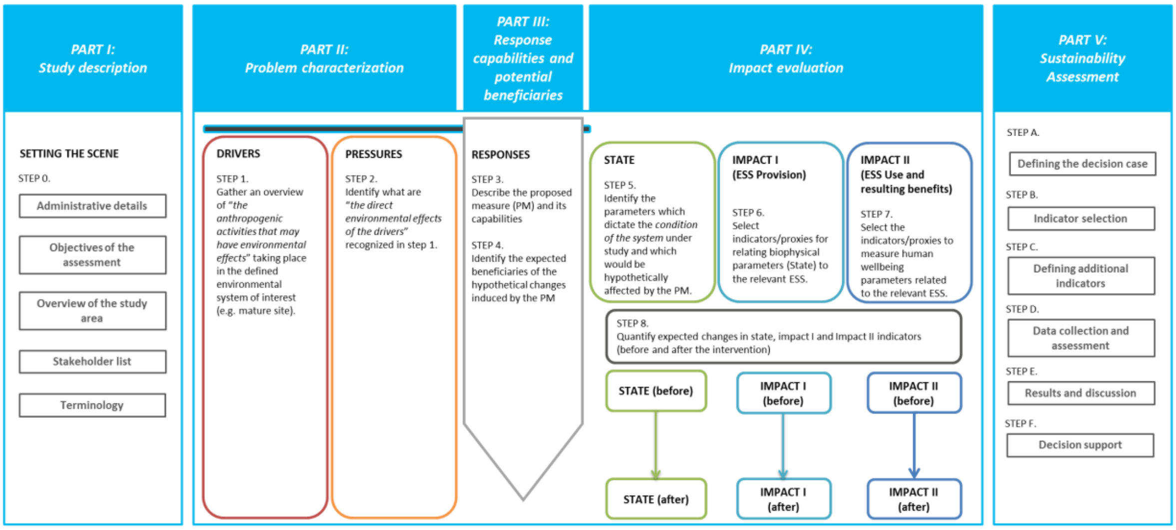


Figure 17: ESS evaluation framework including SA

But as the enhancement of existing ESS is only one small aspect of a solution´s impact, the ESS evaluation may not be enough to assess the usefulness of implementing a solution. The **SA is an additional tool** included in the overall evaluation framework. DESSIN's SA looks towards the future and provides a methodology for assessing the technical solutions also with respect to other dimensions, beyond the benefits derived from ecosystem enhancement. Thus it broadens the scope and offers support for the decision maker. Nevertheless, some benefit findings from the impact II evaluations should be passed to the SA to complete the picture and avoid double work.

The SA is designed to serve different assessment purposes because of the variety of the DESSIN technologies. This variety expresses itself as differences in the characteristics of the technologies themselves (e. g. infrastructure investments, information and communication technology), their grade of innovation (e. g. modifications of existing technologies, rather unconventional solutions), and flexibility in use (e. g. implementation in different variations concerning scale, place and complexity). So, one purpose of the SA can be to **evaluate the effects of a single solution** by assessing the change in situation before and after its implementation. This will be reflected in the assessment by the use of indicators describing deviations in metrics relating to the status before and after implementation ("delta-indicators"). By proceeding like this it is possible to assess single solutions one by one. Another purpose can be to use the SA to **compare alternative solutions** and identify the most promising. This can be performed by comparing the effects of the different solutions which can be done in an appropriate way of presentation (see section 6.4).

Either way, it should be highlighted that the SA is always performed from a **decision maker´s, technology owner´s or solution implementer´s point of view**.

6.2.2 Timeframe

The sustainability of a technological solution can only be evaluated with regards to the future. As the main objects of interest in DESSIN are technological solutions tackling the challenges of water scarcity and water quality, the timeframe considered for SA should at least include the assumed **lifetime of the solution or technology** under study. Nevertheless, impacts may also change over time (e.g. seasonally or in a long-term perspective) or occur with a time lag after implementation. The framework will be tackling these issues by offering to **look at different points in time** in the future and comparing the effects that appeared until then in relation to the status quo. A fundamental understanding of the dynamics of impacts is therefore a very important factor for performing technology sustainability assessment. It is recommended to collect data for metrics/ indicator calculation on annual base, so to enable to calculate aggregated indicators, e.g. cost coverage over the complete lifetime of the solution (e.g. 25 years) and also to enable to analyse e.g. the development of a time series of important input data, or compare results at a specific point in time.

However, as the results of ESS evaluation and SA should be in line with each other, the issue of choosing an appropriate timeframe can only be dealt with in agreement with the ESS Evaluation Framework. For further information on dealing with spatial and temporal issues in relation to ESS evaluation, see also chapter 4 of DESSIN D11.1 “Internal state of the art report on ecosystem services evaluation”(Lago et al. 2014). According to this, the easiest way to deal with this issue is to calculate indicators in relation to standardized units (e. g. “benefit per year”) so that technologies and solutions with different and varying temporal scales of impact can be compared. While assessing and comparing possible scenarios of measures to be implemented in the future it might be necessary to estimate or upscale results from testing in pilot systems. This can be done via various indicator specific methods and tools. Independently of the final approximation method used, the level of uncertainty attached to it is an important factor to be considered and reported. Regarding the issue of uncertainty, please make use of the specifications made in Part IV of the cookbook .

6.2.3 Spatial Scale

Same as for ESS benefits, the observed effects of a technology´s or solution´s implementation will vary with the spatial scale chosen for the assessment. In general, there are several spatial scales where impacts and benefits of the implementation can be observed: local, regional or global.

As the SA is to be performed from a decision maker´s, technology owner´s or solution implementer´s point of view, the spatial scale should be closely aligned with their domain of interest. Thus, choosing an appropriate spatial scale is quite **case specific** and requires detailed knowledge of the system and solution under study. Some solutions may affect only a smaller or much localized area, while others have impacts on a broader spatial scale. Basically, there may not even be only one appropriate spatial scale for assessing a technology´s or solution´s impacts. **Generic guidelines on choosing the right spatial scale are therefore difficult to provide**. Like the ESS Evaluation Framework, the SA is therefore flexible in use, enabling the user to modify the assessment to suit the given context ("cross- and multi-scale approach") (Lago et al, 2014). Indicators should preferably be defined in relation to standardized units (e. g. "benefit per m²" or "area affected/total area of domain") so that different technologies and solutions with varying spatial scales of impact can be compared.

For further information on dealing with spatial and temporal issues in relation to ESS evaluation, see also chapter 4 of D11.1 "Internal state of the art report on ecosystem services evaluation" (Lago et al, 2014).

6.2.4 Structure of the DESSIN SA Framework

The DESSIN sustainability assessment framework includes a set of 20 sustainability criteria, according to 7 sustainability objectives, within 5 sustainability dimensions (Table 10). For each criterion the DESSIN sustainability assessment framework proposes a list of corresponding metrics (cfr. last spreadsheet of the DESSIN Supplementary Material File).

Table 10: Objectives and criteria of the DESSIN sustainability dimensions.

Dimension	Objectives		Criteria	
Social (S)	S1	Quality of life enhancement	S11	Health and Safety
			S12	Economic impact creation
			S13	Job creation
			S14	Equity
			S15	Enhance cultural services
Environmental (En)	En1	Efficient use of water, energy and materials	En11	Efficiency in the use of water
			En12	Efficiency in the use of energy
			En13	Efficiency in the use of materials
	En2	Environmental efficiency	En21	Life cycle emissions to water, air and soil
Financial (F)	F1	Affordability (Ensure liquidity/solvency of the company)	F11	Cost coverage
Governance (G)	G1	Compliance	G11	Compliance with relevant regulations
			G12	Stakeholder involvement
			G13	Transparency
Assets (A)	A1	Technology/Solution reliability, adequacy and resilience	A11	Technology reliability
			A12	Adequate capacity of the technology/solution
			A13	Adaptability to changes
			A13	Safety and Health of operator/supplier
			A15	Efficiency
	A2	External effects of solution	A21	Disturbance impact of the technology/solution
			A22	Start up time (time from installation to effectiveness)
			A23	Alignment with existing knowledge

Dimensions

"Dimensions" describe the value-components within the concept of sustainability (de Groot et al., 2010). The SA in DESSIN adopts five dimensions as in TRUST. In order to align with the terminology in the DESSIN ESS Evaluation Framework, the dimensions are named as: Social, Environmental, Financial (in TRUST: Economic), Governance and Assets. As the "economic" dimension in DESSIN only includes financial aspects of sustainability, the dimension was renamed in order to better differentiate it from the social dimension that includes some economic aspects in social terms.

Objectives

The DESSIN SA includes a set of 7 sustainability objectives based on the five dimensions of the sustainability framework as follows: Social sustainability (1; S1), Environmental sustainability, (2; En1-En2), Financial sustainability (1; F1), Governance sustainability (1; G1) and Asset sustainability (2; A1-A2).

The objectives deal with the aim that the decision maker wants to achieve or improve by selecting a given technology. The weight attributed to each objective may vary between stakeholders and between decision-makers in different cases, but to achieve a holistic assessment all 7 objectives should be addressed.

Criteria

When performing a SA for a solution or technology, the use of the DESSIN framework shown in Table 10 entails the identification and selection of one or more assessment criteria for each of the 7 objectives. 20 performance criteria associated with the sustainability framework are proposed. 5 out the 20 defined criteria are directly related to the Social objective of "quality of life enhancement"; 3 relate to the environmental objective of "efficient use of water, energy and materials" and 1 to the environmental objective of "environmental efficiency"; 1 to the financial objective "affordability (ensure liquidity/solvency of the company)"; 3 criteria are defined for the Governance objective "compliance". The 2 Asset objectives "technology/solution reliability, adequacy, resilience, and safety" and " Minimize negative installation effects" include, respectively, 5 and 3 criteria.

Assessment criteria are points of view that allow for assessment of the objectives. For each criterion, metrics must be selected in order for clear targets to be set, and for further monitoring of the results.

Metrics

For each criterion, one or more measurable (quantitatively or qualitatively) metrics must be identified. The SA can be applied in a flexible way according to what the actual objective of the assessment is and what the particular challenges of a given system/spatial domain are. This will influence the scope (spatial and temporal boundaries) of the assessment, the choice of sustainability objectives and performance indicators/metrics, and the choice of analytical models and methods. *The DESSIN SA proposes a list of metrics identified as suitable for technologies included in the project, but generally this list is guiding and does not necessarily fit all solutions and contexts of implementation. Where alternatives are needed, metrics should be created, following the rules here described and tailored to the aim and objective of analysis.*

The metrics that will allow to measure performance in each criterion can be formulated in the form of metrics, performance indicators, performance indices, and performance levels, as defined below.

Metrics are therefore the specific parameters or functions used to quantitatively or qualitatively assess criteria; metrics can be performance indicators, performance indices or performance levels (Brattebø, 2012).), as described below. To address future impacts, metrics covering the domains of Social, Environmental, Financial, Governance performance are best generated and reported as percentage change from a reference situation (status quo). The metrics reflecting the assets performance does not necessary have to be reported as a change in percentage.

Performance indicators are quantitative efficiency or effectiveness measures of the solution or of the technology. A performance indicator consists of a value expressed in specific units, and, possibly, a confidence grade which indicates the quality of the data represented by the indicator. Performance indicators are typically expressed as ratios between variables; these may be commensurate (e.g. %) or non-commensurate (e.g. $\$/m^3$). In the latter case, the denominator shall represent one specific dimension of the system/area/ESS (e.g. annual costs, square meters,...), to allow for comparisons. The use of denominators of variables which may vary substantially from one year to another, particularly if not under the control of the undertaking, should be avoided (e.g. annual consumption, that may be affected by weather or other external reasons), unless the numerator varies in the same proportion.

Performance indices are measures resulting from the combination of more disaggregated performance measures (e.g. weighted average of performance indicators), from analysis tools (e.g. simulation models, statistical tools, cost efficiency methods) or from scoring systems. In general, they aim at aggregating several perspectives into in a single metric. Compared to performance indicators, their main advantages are that they can be more aggregated measures and they can be used to assess future scenarios (e.g. using simulation results or statistical analyses). However, they have the disadvantages of being potentially more subjective and less auditable.

Performance levels are performance metrics of a qualitative nature, expressed in discrete categories (e.g. excellent, good, fair, poor). In general they are adopted when the use of quantitative metrics is not appropriate (e.g. evaluation of customer satisfaction by means of surveys). They can also be adopted where there is clear consensus among stakeholders that observed impacts are present or can be expected, without detailed quantitative data available.

Where qualitative assessment is included, it is recommended that performance levels are recorded consistently, using the same type of scale for all qualitative indicators. For the DESSIN SA, it is recommended that typical five-level Likert items are used. It is important to include equal numbers of positive and negative positions whose respective distances apart are bilaterally symmetric about a "neutral"/zero value. A limited number of positions helps ensure balance in that the distance between each candidate value is the same, thus allowing for ordinal ranking and comparison.

Targets

Targets are the actual values (defined by the user of the SA, decision maker, or technology owner or solution implementer) to be achieved for each metric within a given time frame (short, medium or long term).

6.3 DESSIN assessment dimensions, objectives, criteria and indicators

6.3.1 Introduction to the proposed DESSIN SA indicators

A comprehensive assessment of the long-term effects of a technological solution can be quite case specific. Thus a generic SA framework needs to cover a broad set of indicators for several assessment purposes. A key principle in the selection and definition of specific indicato rs for the DESSIN SA has been to cover as best as possible indicators that are suited to bringing out the expectable effects and characteristics of the different DESSIN technologies. Consequently, the indicators proposed for the five sustainability dimensi ons are not only based on previously established frameworks, e.g. TRUST and the IWA performance indicator lists for water supply and sanitation systems, but also on the results from other WPs, and on outcomes of workshops with the technology providers in DESSIN. These workshops identified specific strengths, weaknesses, opportunities and threats (SWOT analysis) for each DESSIN technology on a qualitative basis, and the results were transferred into the respective indicators for the SA.

Additionally it was usefull to link the SA to the indicators developed for the Response Evaluation (Part IV) of the overall ESS Evaluation framework. As outlined in chapter **Fehler! Verweisquelle konnte nicht gefunden werden.** to **Fehler! Verweisquelle konnte nicht gefunden werden.** above the endpoint of the ESS evaluation are monetarized impact II assessment results. These types of monetarized benefits will relate to either cultural, provisioning or regulating services. The monetarized cultural services do affect the wider society and are therefore relevant to be accounted with specific indicators in the social dimension of the sustainability assessment, as shown in the figure below. An example is enhanced recreational activities due to a technology improving a rivers water quality and the willingness to pay of inhabitants for the enjoyment, like swimming. Furthermore benefits from provisioning or regulating services do most likely affect the organization implementing the solution. An example for that case can be found in the DESSIN mature case site of Llobregat, where operational expenditures can be reduced due to less treatment costs with the MAR facility included in the drinking water treatment process compared to the status without the MAR facility included. So indicators representing the benefits from provisioning and regulating ESS are to be accounted in the financial dimension of the sustainability assessment.

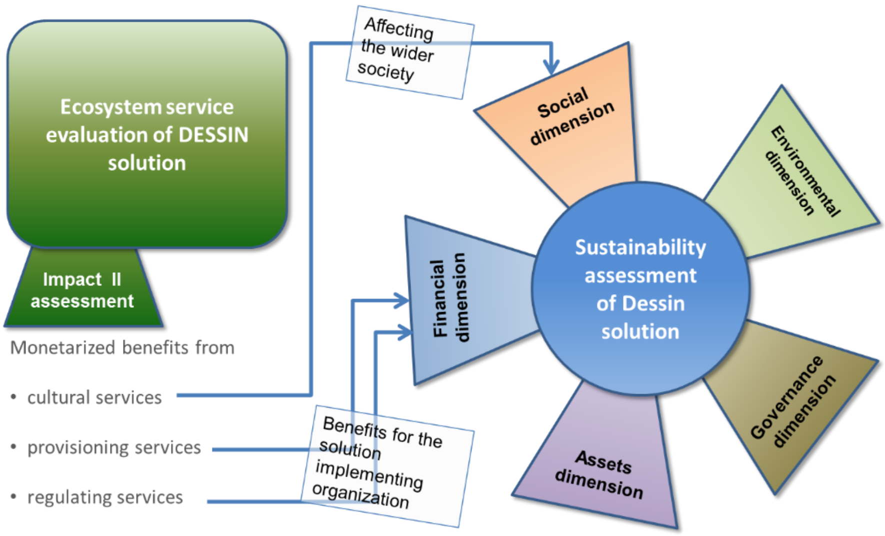
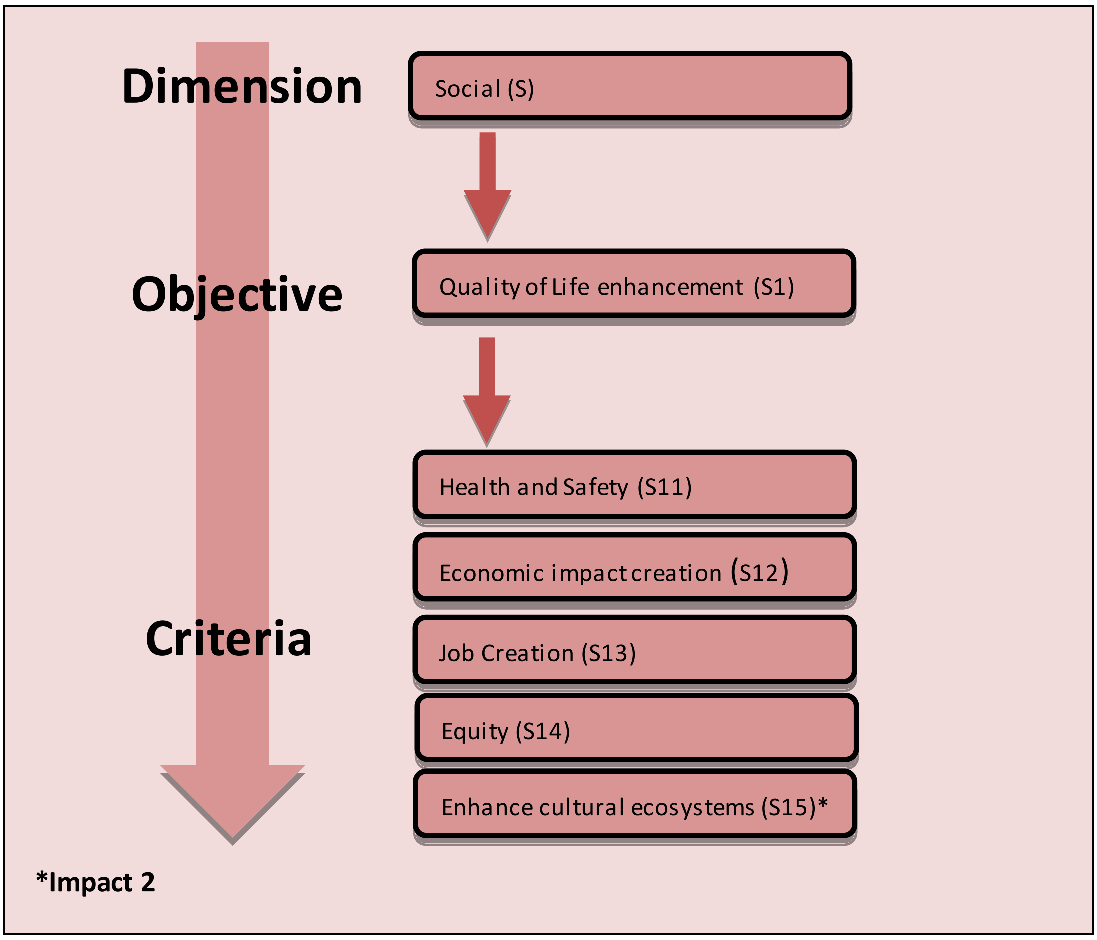


Figure 18: ESS evaluation and SA of a DESSIN solution

The full list of proposed indicators can be found in the last spreadsheet of the DESSIN Supplementary Material File. The underlying dimensions, objectives and criteria are described below.

6.3.2 Social Dimension



Definition

Generally, there is no authoritative approach to social sustainability assessment, but rather various interpretations regarding what issues should be addressed (Murphy 2012, Weingaertner and Moberg 2014). Most studies so far have focused on sustainability as a condition and measuring it with a series of indicators. A problem with this is that social process and variety in stakeholder perspectives are left out of scope. To invite a more open and dynamic approach, the following definition has been proposed; *"Social sustainability is: a life-enhancing condition within communities, and a process within communities that can achieve that condition,"* (McKenzie 2004).

The definition is accompanied by a non-exclusive list of key general aspects (*McKenzie* calls them indicators) of the condition, and steps towards their establishment and implementation are seen as inherent in the process. In a shortened form the key aspects can be listed as:

- Equity
- Diversity
- Interconnectedness
- Quality of life

- Governance, participation
- Social maturity, awareness

The centrality of these aspects is underscored in more recent overviews of research and policy concepts pertaining to social sustainability (Murphy 2012, Axelsson et al 2013, Weingaertner and Moberg 2014). In relation to quality of life, many studies consider employment as a key factor (Chan & Lee 2008, Hutchinson and Sutherland 2008, Cuthill 2009).

When it comes to UWCS sustainability, Van Leeuwen and Marques (2012) of TRUST, argue that the social dimension should include aspects related to the access to urban water services, the satisfaction of the users' needs and expectations, the public acceptance and the relevant role in the community of these services. This perspective is somewhat narrower, as governance is considered separately from other social aspects, but otherwise it resonates quite well with the other key aspects that are highlighted above. Still, for assessment of specific technologies, it will be more relevant to look into the wider social impacts that can be estimated to follow from implementation of the technology than to focus on user feedback and levels of service.

The social dimension is reflecting the performance of a given solution or technology in contributing to life-enhancing relations within the affected communities. The objective is enhancement of quality of life, in terms of health and safety, socioeconomic impact creation, employment, equitable distribution and realization of cultural values.

Objectives

S1 Quality of life enhancement

Quality of life (QOL) is the general well-being of individuals and societies.

Standard indicators of quality of life include not only wealth and employment but also the built environment, physical and mental health, education, recreation and leisure time, and social belonging. Material and immaterial cultural heritage are also increasingly addressed (Axelsson et al 2013) and would be included in our case, where cultural sustainability is not considered as a dimension on its own.

Criteria

S11 Health and safety

Degree to which the solution or technology contributes to conditions that protect or enhance the lives and health of the people affected.

S12 Economic impact creation

Socioeconomic impact creation, calculated on the basis of how implementation of the solution or technology generates activity and income through supplies and services from different business sectors. For large-scale interventions national input-output analysis can be employed. For more modest, local interventions it is possible to make adaptations of data to bring out the value chain behind the technology under assessment and use input-output analysis to calculate the impact at a regional, county or individual company level. The economic impact addressed here (incl. Indirect and induced impacts) shall be derived from initial spending for the solution itself.

S13 Job creation

Contribution of the implementation and/or operation of the solution or technology in terms of employment at the local, national or regional level, based on the value creation analysis for S12.

S14 Equity

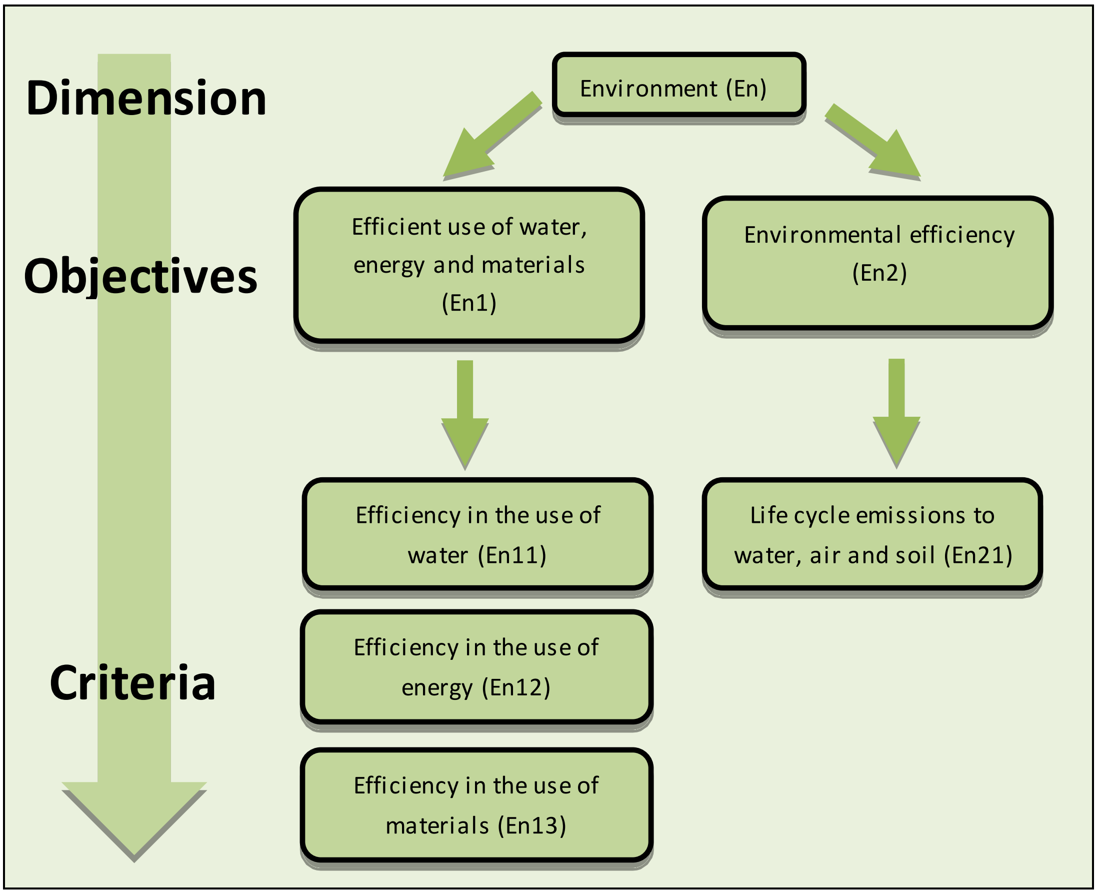
Degree to which the services or direct benefits associated with the technology or solution is fairly distributed or contributes to a more equitable distribution of benefits in the affected communities.

Equity refers to fair distribution of goods and benefits. It is also used more specifically to refer to equal life chances regardless of identity, to provide all citizens with a basic and equal minimum of income, goods, and services or to increase funds and commitment for redistribution.

S15 Enhance cultural services

This relates to social impact in terms of realization of market and non-market value linked to enhanced cultural services. Thus it includes economic impact via new or growing business from recreation/visiting activities (derived from Impact II assessments), as well as the degree to which the technology or solution contributes to knowledge-building and preservation of cultural heritage.

6.3.3 Environmental Dimension



Definition

The environmental dimension includes all direct impacts of technology or solution implementation on the environment. As the focus of this dimension is strongly on the technology or solution itself, ecological benefits to the ecosystem will not be considered here. The main objectives in the environmental dimension are to ensure an efficient use of resources and avoid undesirable environmental impacts. As the metrics proposed for the three criteria listed for the first objective are also relevant for performing an life cycle assessment (see En2), both objectives are supposed to be treated in a complementary way.

Objective(s)

En1 Efficient use of water, energy and materials

The aim of this objective is to assess the efficiency (and/or adequacy) of water, energy and other resources use for implementing and operating the technology as well as those of finale use. If two technologies are compared, the one with the best input-output-ratio of resources used compared to the service provided should be in favor.

In order to assess fulfilment of the objective the framework proposes 3 criteria and 11 metrics that may be relevant for evaluating the specific technologies & solutions in use in DESSIN. Metrics which are not suitable for a certain technology due to its special characteristics may be deleted or replaced by others that seem to be more adequate.

En2 Environmental efficiency

In contrast to the first objective proposed, environmental efficiency is supposed to focus not on input required for technology implementation but unfavorable outputs occurring with its implementation and operation. The approach that could be used for assessing these effects is commonly known in literature as life cycle assessment (LCA). As the objective is supposed to be assessed from a life cycle perspective, it has to include emissions occurring in the setup phase of the technology as well as those of the operating phase.

Hence, it is obvious that there might be some overlapping in criteria under En1 and En2. The framework therefore highlights that if a LCA is performed for assessing criteria En2, the criteria and metrics listed under objective En1 have to be carefully checked for redundancy (see comments below). If performing a LCA is not feasible to the user at all, En2 can be neglected and replaced by the indicators and metrics of objective En1 quite well.

Criteria

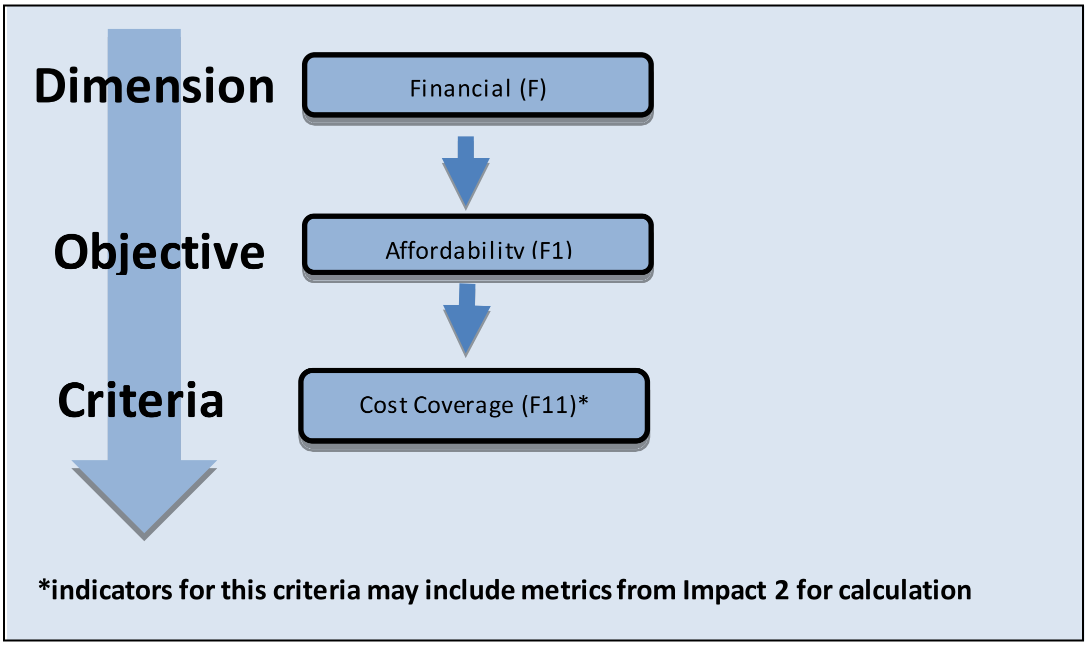
En11 Efficiency in the use of water (including final uses)
This criterion focuses on the efficient use of water contrasting the amount of water intake against losses (e. g. due to evapotranspiration or leakages), waste or reuse of water during the operation of the solution.

En12 Efficiency in the use of energy
In accordance with criteria En11 and En13, this criterion focuses on the efficient use of energy contrasting the total amount of energy consumed in the process chain against green energy usage and energy recovered during the operation of the solution.

En13 Efficiency in the use of materials
The extent to which scarce materials, chemicals and other consumables are consciously used in all phases of the solution´s life cycle and recycled.

En21 Life cycle emissions to water, air and soil
Environmental impact, including the process of the solution itself, all direct emissions into the environment (effluent water quality which is discharged or used in the environment, direct emissions to atmosphere), and all indirect processes required to build and operate the solution, that can be assessed following a life cycle assessment approach as defined in ISO14040 and 14044.

6.3.4 Financial Dimension



Definition

The financial dimension checks the affordability of a solution from the point of view of the organization implementing and operating the solution. Metrics necessary to calculate the degree to which cost coverage can be reached include costs associated to it (life cycle costing) and monetary benefits derived from the solution or other sources of financing receivable by the organization. The monetary benefits can also include benefits from enhanced ecosystem services that are due to the implemented solution (e.g. avoided costs in water treatment) as long as they are accountable for the organization.

Objective(s)

F1 Affordability

The aim is to check if a DESSIN solution is affordable or not by the organization in charge to implement and operate it.

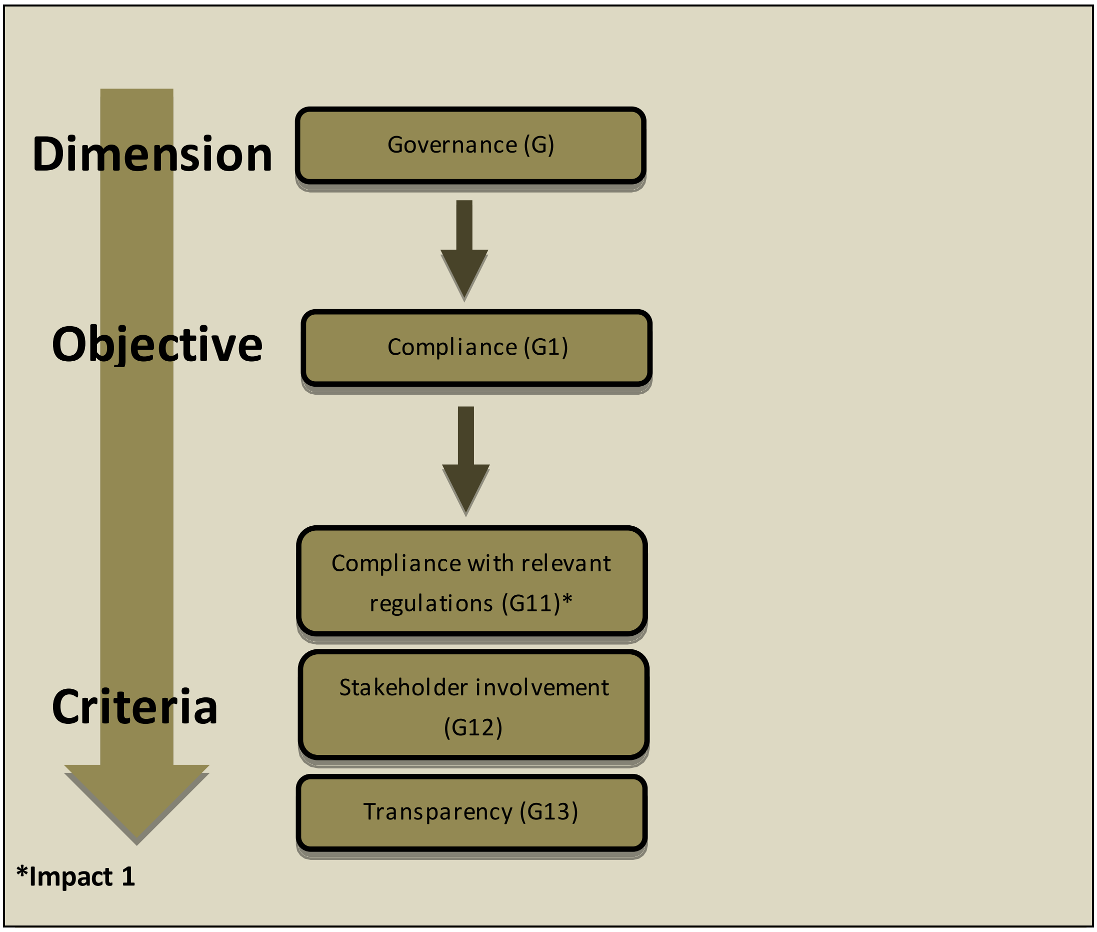
Criteria

F11 Cost coverage

The basic criterion is to check the solution for cost coverage. Therefore different metrics are relevant, in order to conduct a business case. The first two are the investment expenditures and the operational expenditures on an annual basis along the lifetime of the solution. On the other side sources to finance the solution must be quantified with metrics. Those are for instance additional income for the organization aligned to the solution. In comparison also benefits like cost reductions in relation to the status quo are imaginable and viable to be accounted for. Examples are for instance avoided costs of water procurement due to an increase of volume of water reuse (due to new sewer mining) or an increase of volume of water extractable from an aquifer (due to new aquifer storage and recovery). Those types of monetary benefits for the organization implementing and operating the solution shall be taken from the calculations of the ecosystem service evaluation, impact II, most likely from enhanced provisioning services improving human well-being. Others might arise from regulating services, if they can be expected to have a financial impact on the organization. This is for instance the case if the organization is responsible for flood protection and can expect to decrease damage costs from future flooding, which it would be charged for otherwise, via a DESSIN solution. All costs need to be calculated as present value (for the lifetime of the solution). Also all monetary benefits need to be calculated as present value (also for the lifetime of the solution).

A final indicator to sum everything up can be the percentage of cost coverage, expressed as following: (present value of monetary benefits / present value of costs) *100.

6.3.5 Governance Dimension



Definition

According to TRUST; "*Governance is related to the rules of the game, the respect for those rules by the stakeholders, the transparency, their participation in the decision-making process, particularly the customers, the effectiveness and efficiency of the measures taken and the quality of the accountability and adjustment mechanisms*" (Van Leeuven and Marques 2013:8).

The definition of governance applied in WP 12 of DESSIN is much broader; "*Governance is the combination of the relevant multiplicity of scales, actor-networks, goals, strategies, responsibilities and resources that forms a context that, to some degree, restricts and, to some degree, enables actions and interactions in the uptake of innovations in urban water management.*" However, the recommendations from WP 12 emphasize the importance of alignment, involvement and participation, and these aspects are consequently among those highlighted in the governance dimension of the SA.

Governance is the dimension reflecting the performance of a given solution or technology in contributing to good governance, by way of consistent management, cohesive policies and processes, as well as proper oversight and accountability in the water sector. The objectives are compliance with relevant regulations and standards, enhanced participation, and increased accountability in water management.

Objective(s)

G1 Compliance

The core meaning of compliance is 'being in accordance with regulations'. However, the concept is increasingly taken to include the state of being in compliance, plus the processes and structures required to become and remain compliant, and it is in this sense it is applied as an objective in the DESSIN SA.

Criteria

G11 Compliance with relevant regulations

Level of compliance with the relevant regulations and standards for good water governance in the EU (Water Framework Directive, Bathing Water Directive).

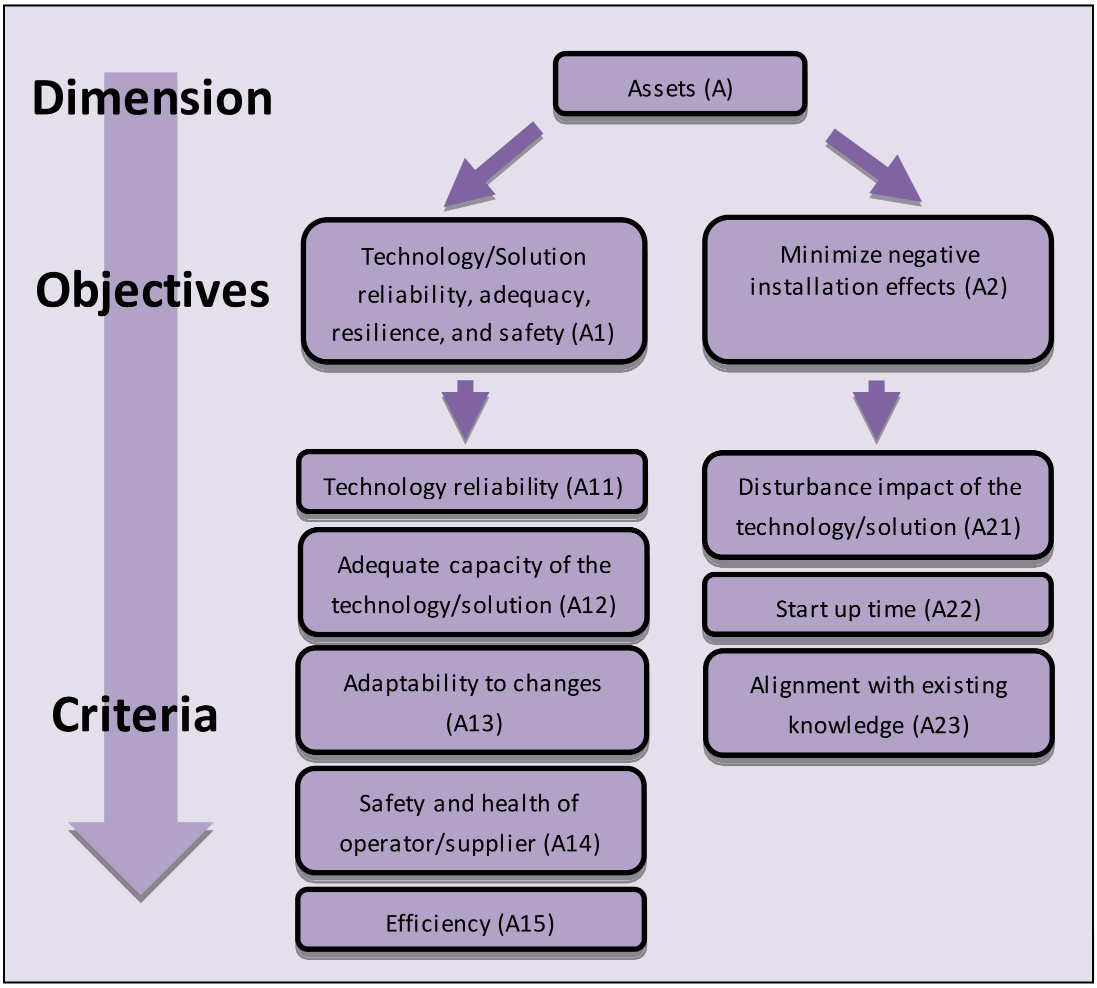
G12 Stakeholder involvement

The extent to which people who may be affected by the implementation of the technology are involved in and may contribute to or influence water management. Stakeholder engagement is a key part of corporate social responsibility (CSR) and achieving the triple bottom line.

G13 Transparency

The extent to which the utility/implementing institution's actions in water management are observable by outsiders. Transparency suggests this has three primary dimensions: information disclosure, clarity, and accuracy.

6.3.6 Assets Dimension



Definition

Assets is the dimension reflecting the level of performance of a given innovative solution or technology in providing an expected function. It includes two objectives: the first uses a list of four assessment criteria and a total of six proposed performance indicators in order to assess the level of reliability, robustness, efficiency and resilience of the technology per se; the second objective, plus 2 criteria and 2 metrics, is introduced in order to evaluate the impact of the technology in terms of disturbance to the surrounding environment and / or population and the start up time required before the solution is effective.

Objective(s)

A1 Technology / solution reliability, adequacy, resilience and safety

The aim of this objective is to assess the level of reliability, adequacy, resilience and safety of a given technology & solution, or to compare different technologies & solutions in reliability and safety terms. The overall goal is in choosing the technology that best strengthens security, reliability, resiliency, and recoverability.

To assess the distance from the objective the framework includes 5 criteria and 6 metrics proposed as options according to the specific technologies & solutions in use in DESSIN. The user can build other criteria and / or metrics more adequate for different applications.

A2 Technology/solution acceptability

This objective is proposed to take into account the disturbance the introduction (installation and operation) of the technology/solution can produce in the surrounding environment in terms of noise, smell, dust, view, and to take into account the time required by the solution to be effective.

To assess the distance from the objective the framework includes 2 criteria and 2 indicators proposed according to the specific technologies & solutions in use in DESSIN. The user can build other criteria and / or metrics more adequate for different applications.

Criteria

A11 Technology reliability

Ability of the technology to fulfill a required/expected function.

A12 Adequate capacity of the technology/solution

Sufficient capacity of the technology/solution to the expected use.

A13 Adaptability to changes

The ability of the technology to function at time t (availability at time t) for any given loads.

A14 Safety and Health of operator/supplier

The level of risk for the operator associated with the use of the technology of part of it.

A15 Efficiency

The extent to which input is well used for an intended task or function (output).

A21 Disturbance impact of the technology/solution

Disturbance created to the surrounding environment, measured in terms of complaints when the technology is in use (due to for instance noise, dust, aesthetics, landscape).

A22 Start up time (time from installation to effectiveness)

The time between the installation of the technology to when it starts to be effective.

A23 Alignment with existing knowledge

Measure of resources to be allocated to build competence to the staff operating the solution.

6.4 Interpretation of results

The interpretation of the results from the sustainability assessment can be performed by i) direct visualization of the estimated metrics depicted on a graphical solution before and after the implementation of a given measure or to compare alternative solutions in a given moment in time (Option A and B); ii) applying multicriteria decision analysis (MCDA) to evaluate the sustainability score of a given implemented solution or alternative ones (Option C); iii) a cost-benefit analysis (CBA) to aggregate the results including all costs and benefits for all stakeholders (Option D).

Option A: Bar charts

A bar chart is a chart that uses either horizontal or vertical bars to show comparisons among categories. One axis of the chart shows the specific categories being compared, and the other axis represents a discrete value.

The figure below presents an example of visualization using Bar charts adopted for comparing the performance indicator before and after the solution´s implementation.The example based on Aarhus mature case (cfr. Cookbook Step E – first bullet point)

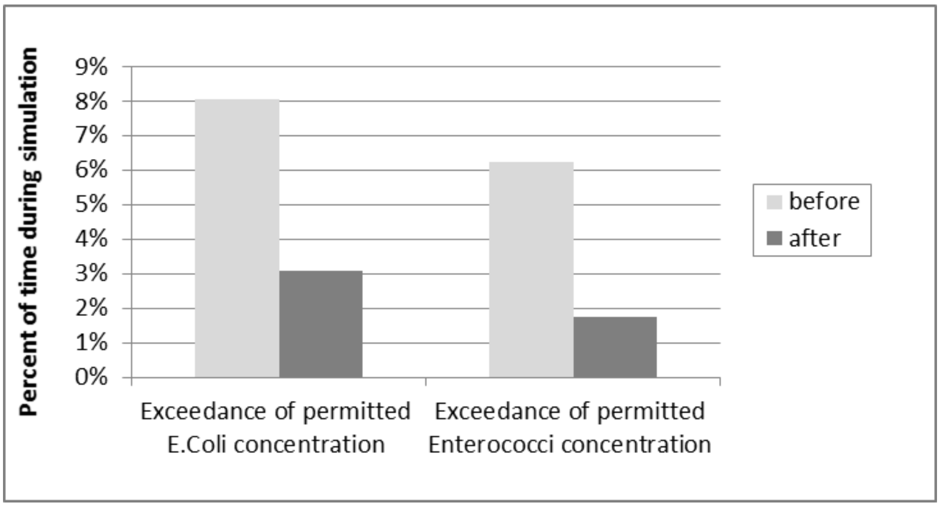


Figure 19 – Example of bar chart to compare estimated indicators, before and after implementation of measure, in Aarhus.

Option B: Spider graph

The Spider graph is a graphical method of displaying multivariate data in the form of a two-dimensional chart of three or more quantitative variables represented on axes starting from the same point. It can be used to compare performance per indicator before and after the solution´s implementation or to compare alternative measure at a given time.

When using this option, the metrics or performance indicators should be the result of a comparison (to a target value, previous values of the same indicator, or values of the same indicator from other undertakings) (ISO 24500 - standards as a support tool to manage assets). In particular, the SA DESSIN framework proposes to define the said variation in a way that an improvement always refers to a positive trend towards the achievement of a set goal if compared to a reference situation (on the other hand a decrease on the percentage variation, corresponds to an increase of distance from a set target if compared to a reference situation).

The figure below presents an example based on Aarhus mature case (cfr. Cookbook Step E – first bullet point)

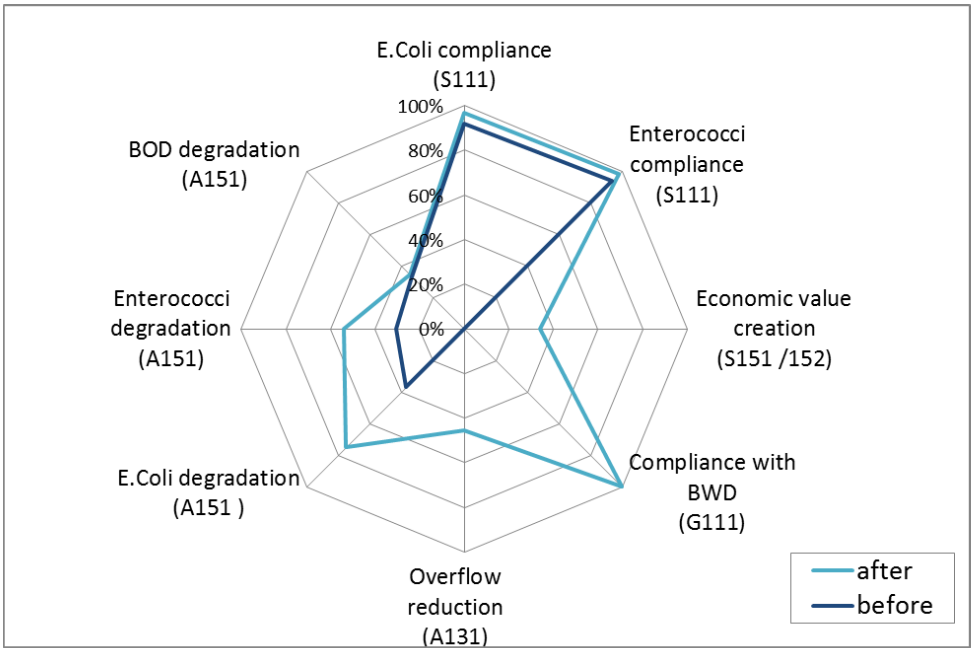


Figure 20 – Example of spider graph for the example of Aarhus

Option C: MCDA

A MCDA approach can be adopted to evaluate the sustainability of a given implemented solution or alternative ones. The MCDA should involve the consideration of sustainability attributes (and the respective metrics) for the five dimensions of sustainability. MCDA allows for aggregating the performances in all of those attributes by applying weighting techniques that reflect the legitimate stakeholders' preferences.

After the designation of the legitimate decision-maker (or decision-making group) who will provide his/her judgments regarding the relative contribution of scoring in each criterion for overall sustainability, a simple additive aggregation model can be used to calculate the sustainability score of each measure.

Option D: CBA

Subsequent cost-benefit analysis based on DESSIN SA results

The financial dimension in the SA is meant to represent financial sustainability from the point of view of the agency implementing the measure. However, a CBA could be a subsequent step aggregating SA assessment results from the social and the financial dimension in order the take the whole economic point of view (including all costs and benefits for all stakeholders). So even though there is a clear cut between financial implications (relevant for the agency/organization implementing the solution) and social-economic implications (relevant for all other stakeholders) in the DESSIN SA, results from both dimensions can be aggregated for a comprehensive CBA.

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