STRENGTH IN NUMBERS?

Lessons learned from a comparative analysis of green infrastructure valuations

Master Thesis

Strength in Numbers?

Lessons learned from a comparative analysis of green infrastructure valuations

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Preface

Growing up in a small village in rural Germany, I have been inevitably surrounded by nature throughout the first two decades of my life. During my study of urban planning, I sometimes came to experience binary mindsets about the 'urban' and the 'natural', often regarded as incompatible entities. However, I am more convinced than ever that a thriving urban society profits from learning from nature, especially on the background of the various challenges we are currently facing, of which climate change is arguably among the most prevalent ones.

The incorporation of nature into the urban context can take place in countless ways and it is hard to deny that economic aspects play a vital role in most of them. I have learned to encounter the powerful communication through numbers always with a healthy dose of suspicion and to scrutinize the procedure behind calculations. This led me to conducting projects about the quantification of intangible co-benefits of water management projects, intensive investigations of green infrastructure (GI) and their ecosystem services (ESS) during an internship at the *Institute of Ecological Economy Research* (IÖW) and eventually to writing this master thesis.

It should be noted that the initial motivation of this report developed during my internship at the IÖW where I worked with a tool which ascribes value to ESS in German cities and is currently under development. Originally, my plan was to conduct a cost-benefit analysis (CBA) of ESS in the newly initiated project *BlueGreenStreets* in Hamburg using this tool. However, because of the Corona pandemic this was not possible. Instead, I shifted the approach to the more theoretically grounded and comparative study it became. Therefore, the methodological approach of this thesis had to be limited to literature research.

I would like to express my deep gratitude to Susse Georg, my research supervisor, for her all positive encouragement and constructive critique, her patient guidance, the provision of highly inspirational literature and showing alternative pathways when a shift of perspective was advisable.

Abstract

Both the number and the severity of rainfall events is expected to rise due to climate change (IPCC, 2014). Already now, citizens and their assets are affected by the impacts of heavy rainfall events to a significant extent (Davis and Naumann, 2017). In cities, the vulnerability toward extreme rainfall events is exacerbated by land cover changes and especially surface sealing (Gill et al., 2007).

Conventional engineering approaches have been found to be not sufficient, not cost-effective and not sustainable for urban stormwater management (Fritz, 2017). Therefore, the perspective shifted toward GI, i.e. multifunctional natural areas designed to deliver a wide range of ESS in order to complement, augment or replace built infrastructures (European Commission, 2013). Due to the characterization of GI and their ESS as public services, their value cannot be determined directly through market-based methods. Hence, their positive influence is often overlooked, undervalued or not detected by the current economic system and consequently not or not adequately recognized in decision-making, which is primarily based on CBA (European Commission, 2013; Kumar and Wood, 2010). This is also the case in Germany, where the IÖW develops a tool for cities to valuate the ESS of green areas in order to promote their acknowledgment by decision-makers.

Based on the theoretical background of valuation studies and the performativity argument, this work explored five applications of an extended CBA, which make the value of GI and their ESS 'visible'. By comparing these approaches on the basis of different factors, their methodological and ideational similarities and differences became apparent and revealed how the benefits of ESS were rendered quantifiable. This information served as instructive set of recommendations for the IÖW-tool.

The findings show that the different authors use diverse methods to valuate ESS. These valuation methods express different interpretations of the authors about what counts in the valuation of ESS. The different interpretations became apparent in e.g. the level of detail of investigated ESS and are inevitably connected to a variety of factors, such as the understanding of CBA as a method, the quantification procedures and not least a set of necessary presumptions and estimates. Based on the findings, the IÖW-tool is recommended to integrate the ESS of water pollutant removal and maintain the possibility to quantify the value of those ESS, which are provided by the already existing green areas in a city. Further, the tool is urged to ensure transparency about the underlying procedures, which affect the valuation process and to accentuate the connection between the gain of monetary benefits and the related improvement of human well-being.

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List of Abbreviations

BCR	-	Benefit Cost Ratio
BMUB	-	German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety
CBA	-	Cost-Benefit Analysis
EBA	-	Ecosystem-based Adaptation
ESS	-	Ecosystem Service(s)
EU	-	European Union
GI	-	Green Infrastructure(s)
IPPC	-	Intergovernmental Panel on Climate Change
IÖW	-	Institute for Ecological Economy Research (**I**nstitut für **Ö**kologische **W**irtschaftsforschung)
IUCN	-	International Union for Conservation of Nature and Natural Resources
NBS	-	Nature-based Solution(s)
NPV	.	Net Present Value
RP	-	Revealed Preferences
SP	-	Stated Preferences
SUDS	-	Sustainable Urban Drainage System
TEEB	-	The Economics of Ecosystems and Biodiversity Initiative
WTA	-	Willingness to accept
WTP	-	Willingness to pay

INTRODUCTION

1. Introduction

The valuation of goods and services that matter for people is a central issue for decision-makers and particularly economists. It is the field of economy which often provides methods for decision-makers to resolve the hard and conflicting choices in order to increase the well-being of the society. When addressing the natural environment in the context of economic valuation, an interdisciplinary and methodological pluralism comes to the fore. This report addresses the valuation of GI and related ESS which are defined as those benefits that arise from the ecosystem structure and its processes that enhance various components of human well-being (Kumar and Wood, 2010). ESS can be classified into provisioning, regulating, supporting and cultural services (Millennium Ecosystem Assessment, 2005). While most of the provisioning and cultural ESS such as timber and recreation are services which have been addressed by the economics profession for a long time, it is the category of regulating ESS, such as climate, water and human disease regulation, which recently gained attention and presents much greater challenges. This is since these services cannot be valuated directly with market prices (Kumar and Wood, 2010).

ESS are a part of what Simpson (2010) calls the 'paradox of valuation'. This term builds on the notion that the things we like to place an economic value on are also the ones that are most difficult to estimate. This is since these goods are public which makes their benefits most widely dispersed, causing the valuation of ESS to become an extraordinarily difficult undertaking (Simpson, 2010).

1.1 Climate Change and Urbanization

Climate change consequences occur in multiple forms, such as an increasing overall global temperature, rising sea levels and the growth in number and severity of extreme weather events. Among these extreme weather events are e.g. droughts, storms and floods, some of which are more prevalent at certain locations. According to the fifth assessment report of the International Panel on Climate Change (IPCC), extreme weather events are classified as outcome of dangerous anthropogenic interference with the climate system and must therefore be regarded as key risks and treated as prioritized areas of interest (IPCC, 2014). In this report, projects which are concerned with precipitation-related extreme weather events - and here particularly heavy rainfall events - are in the fore.

Scientific forecasts on flood peaks predict an average doubling of severe flood peaks with a return period of 100 years within Europe by 2045. Due to the location of most European cities on floodplains or along the coast, flooding from both rising sea levels and extreme rainfall events will have a major impact on them. The reports point toward more annual mean precipitation in Northern Europe compared to Southern European countries where reduced rainfall amounts are estimated. There is also an expected change in seasonal rainfall in Northern Europe which manifests itself in a rising amount of winter precipitation falling as rain instead of snow (IPCC, 2014; Emilsson and Ode Sang, 2017). Although most fatalities in European countries are due to extreme temperatures, 50 % of the total population are affected by and 40 % of the occurring damages are the consequence of floods. From 2007-2017, more than 165 major flooding events evoked substantial economic damages across Europe, making flooding the most influential natural hazard in terms of economic loss (Davis and Naumann, 2017). The European Commission (2015) expects the annual damages in Europe from coastal flooding and fluvial flooding to exceed 17 billion € (currently 1.9 billion €) and 97 billion € (currently 5.5 billion €) respectively, unless significant prevention and adaptation measures are taken.

The vulnerability of urban areas toward climate change consequences is inextricably interwoven with its importance for humans as a place to live as well as its infrastructural properties in terms of telecommunication, transport, sanitation etc. Currently, around 73 % of Europe's population are city dwellers, making it one of the most urbanized regions globally already today, and the number of urban citizens is expected to exceed 82 % by 2050 and 90 % by 2100. However, it is noteworthy that urbanization processes in Europe in recent decades have taken place primarily in the form of spatial expansion rather than population growth. Land cover changes and particularly surface sealing are therefore the most influential concomitants of urbanization in Europe and exacerbate cities' vulnerability toward extreme rainfall events (European Commission, 2015; Kronenberg et al., 2013). Urbanization replaces vegetated surfaces with impervious built surfaces and disturbs multiple microclimatic processes. As the water regime for every area is influenced by a characteristic balance between surface runoff, evaporation, infiltration and ground-water formation, anthropogenic influences on the soil surface dramatically alter the water regime in urban areas in comparison to natural environments (Bavarian State Office for the Environment, 2005; Gill et al., 2007).

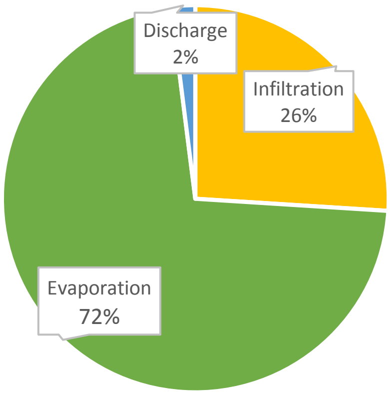


Figure 1: Water Regime in an undeveloped environment (Bavarian State Office for the Environment, 2005, p. 7)

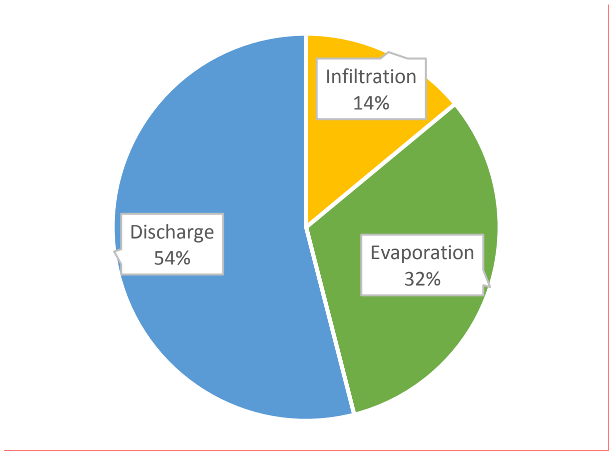


Figure 2: Water Regime in an urban environment (Bavarian State Office for the Environment, 2005, p. 7)

Increased surface sealing accelerates surface water runoff from precipitation, which otherwise could be intercepted by vegetation and absorbed and discharged by the underlying soil. According to the Bavarian State Office for the Environment, around 70 % of the rainwater evaporates in a non-urban, natural environment while the rest almost entirely infiltrates into the ground, causing the amount of discharged water to be negligibly small. As opposed to that, the amount of discharged water in urban environments exceeds 50 %. Here, only around 30 % of rainwater evaporates and around 15 % infiltrates into the ground. Figure 1 and Figure 2 underline the generally acknowledged problematic issue of surface sealing in urban areas by illustrating the water regime compositions exemplarily for the German state of Bavaria.

1.2 Traditional Approaches to Climate Change Adaptation

Generally, urban planners have focused on conventional engineering solutions toward climate change adaptation in terms of water management. These so-called gray infrastructures, referring to the built, engineered and physical structures usually made of concrete or other long-lasting materials, mediate between the human-made system and the variability of the climatic system and are still the frequent response to the exposure of communities to natural hazards. Among these traditional approaches are dikes, levees and breakwaters for riverine and coastal flood protection and drainage systems such as detention basins, storm sewers, pipes for stormwater management (Depietri and McPhearson, 2017; see Figure 3 and Figure 4).

Figure 3: Concrete breakwater elements, so-called dolosse in South Africa (Associated Press, 2015)

Figure 4: Stormwater detention pond in Texas (El Paso Herald-Post, 2017)

As opposed to GI, which entails multiple benefits within the context of climate adaptation, such as improving air quality or enhancing temperature regulation, those structures are designed with a single-objective oriented purpose (Davis and Naumann, 2017). Since they are typically designed to convey historical 'design storms', i.e. precipitation events with a comparably low recurrence interval, conventional urban drainage structures are often ineffective in the management of runoff during extreme weather events attributed to climate change (Maragno et al., 2018). Not least because of the related high costs in their construction, maintenance and repair, the European Commission regards the further investment in traditional, engineering solutions as "no longer possible in several cases" (European Commission, 2017, p. 29). Traditional approaches may have reduced damages from flooding events over the past two centuries but are no longer sufficient, often not cost-effective and not sustainable (Fritz, 2017). More specifically, they do not accommodate the uncertainty which is inherent of climate change. Whilst traditional engineering approaches are largely ignoring or supplanting the functions of biophysical systems, recent approaches have taken an alternative stance on this matter. These recent approaches are clearly pointing toward the increased utilization of ESS through nature-based solutions (NBS) in the form of GI (Depietri and McPhearson, 2017; Fritz, 2017).

1.3 Green is the new Gray

NBS make use of nature to tackle societal challenges such as climate change and disaster risk management. The European Commission has adopted the concept in its *Horizon 2020* research program to foster its uptake in urban areas. Its relationships with already existing concepts such as ecosystem-based adaptation (EBA), GI and ESS requires clarifying remarks. Of the mentioned concepts, NBS is the broadest and most recently introduced one which is why it is considered as umbrella term to the other concepts. The NBS concept has a distinct focus on the deployment of actions on the ground while EBA - as a subset of NBS - is particularly concerned with climate change adaptation by the use of nature. As a planning approach, GI targets the strategic guidance for the integration of NBS into the development of multifunctional networks of green spaces at various scales. Finally, the concept of ESS values the services ecosystems provide in the form of benefits which humans obtain, e.g. improved air quality. Through its proximity to the quantification and valuation of nature, ESS can support decision-makers in the prioritization of actions to maximize the benefits of NBS. In general, NBS can be regarded as powerful metaphor, which critically depends on GI and ESS for its systematic incorporation in urban areas (Pauleit et al., 2017).

All concepts have within the past two decades become part of the dominant discourse on the human-nature relationship in Western societies and emphasize the growing importance of the role of nature in policymaking. The concepts are motivated by the protection of nature and biodiversity in a world dominated by anthropogenic influences through leveraging nature as a way to complement, improve or even replace conventional engineering approaches. All four concepts are problem-focused, require inter- and transdisciplinary approaches and aim at the integration of nature conservation into the economy without fundamentally challenging the economic realm. The focus of the concepts is clearly on human interests and the enforcement of the environmental, social and economic benefits from nature (Pauleit et al., 2017).

According to the European Commission, GI is

> *"a strategically planned network of natural and semi-natural areas with other environmental features designed and managed to deliver a wide range of ecosystem services. It incorporates green spaces (or blue if aquatic ecosystems are concerned) and other physical features in terrestrial (including coastal) and marine areas. On land, green infrastructure is present in rural and urban settings."* (European Commission, 2013)

While the term 'infrastructure' refers to the stock of facilities and services that are needed for the functioning of a society, the term 'green' and/or 'blue' adds the notion that natural counterparts to built infrastructure can complement, augment or even replace built infrastructures. Due to the inclusion of aquatic ecosystems, GI is sometimes also referred to as blue-green infrastructure

(Cohen-Shacham et al., 2016). One of the key appeals of GI, as opposed to gray counterparts, is its multifunctionality, i.e. the incorporation of multiple functions and provision of several benefits in the same spatial area (European Commission, 2016). In an urban context, individual elements of GI, i.e. all types of vegetation and water-dominated areas, can form GI. Through unsealing, plantation with trees and vegetation, also developed spaces are characterized as part of GI (BMUB, 2018). The network of GI can not only improve environmental conditions and therefore have an immediate effect on citizen's health and quality of life but also creates job opportunities by supporting a green economy. This is since the interest in GI is expected to raise the demand for related job skills which are not only required for the installation and design but also for the operation and maintenance of GI practices (European Commission, 2019).

In GI implementation, common use is made of hybrid solutions which mix engineering approaches - referred to as gray infrastructure above - with ecosystem-based features (Cohen-Shacham et al., 2016; Depietri and McPhearson, 2017; European Commission, 2015; Foster, Lowe and Winkelmann, 2011). This report adapts the stance of most of the literature about GI which encompasses what has been introduced here as hybrid approaches. Examples for hybrid GI are green roofs, rain gardens, permeable pavements or trough-trench systems (see Figure 5 and Figure 6). In the sense of a compromising but promising middle course, hybrid solutions have been found particularly suitable in an urban context because the sole reliance on GI is often regarded as insufficient and urban planners have traditionally relied on built structures. Compared to gray infrastructure approaches, GI strategies comprise low-impact strategies. These apply for the level of protection but also for the level of risk in case they fail (ICLEI, 2019).

Figure 5: A trough-trench system (Bayerisches Landesamt für Umwelt, 2005, p. 35)

Figure 6: Permeable pavement on parking areas (Bayerisches Landesamt für Umwelt, 2005, p. 15)

Urban areas are characterized by limited space and city administrations are urged to manage climate change adaptation under the premise of cost-effectiveness. Therefore, hybrid solutions are suggested as the way forward in cities (Depietri and McPhearson, 2017). This claim was echoed in the latest report by the *World Bank* and *World Resources Institute* from 2019 which called for the 'next generation of infrastructure'. Furthermore, it was addressed in the UN's World Water Development report where the identification of the most appropriate, sustainable and cost-effective balance between gray infrastructure and GI has been urged instead of suggesting a replacement of gray infrastructure (ICLEI, 2019).

1.4 The (Non-) Valuation of ESS

Even if urban ESS delivered by GI only make up a fraction of the total ESS used in cities, the number of advantages compared to the relatively small space taken up by GI measures implies that the economic value of these locally provided services is surprisingly high (Gómez-Baggethun and Barton, 2013). If not implemented on private property, GI measures can be considered as public goods. However, mainstream or neoclassical economics sustains the widely held view that all public goods, e.g. urban green spaces or water bodies are outside of the economic domain because non-excludability and non-rivalry preclude the process of pricing them. Non-excludability means that it is highly impractical or impossible to prevent others from the good's consumption while non-rivalrous goods refer to the situation in which a person's consumption of the good does not keep somebody else from consuming it (Boardman et al., 2011). Since the value of public goods can therefore not be detected directly through market-based methods, both the loss of accompanied

ESS and their positive impacts are often not detected, overlooked or undervalued by the current economic system (Kumar and Wood, 2010; van Zoest and Hopman, 2014).

Although the recent emergence of publications about the economic potential of GI and ESS may have heightened decision-makers' awareness, GI and ESS have not been subject to many cost-benefit analyses (CBA) let alone extended CBAs (van Zoest and Hopman, 2014), which is an 'extension' of a conventional CBA beyond just considering the direct costs and benefits and includes analyses of the indirect cost and benefit components as well (German Federal Environment Agency, 2013). A CBA which incorporates the quantification and monetization of ESS, supports the economic perception of the related measures in multiple ways. First, it informs decision-makers through the explanation and quantification of ESS's economic contributions. Second, it lays the foundation for new modes of funding by assessing benefits and beneficiaries. And third, it initializes paths to the design and planning of green spaces in a way that enhances the economic benefits to the local society (van Zoest and Hopman, 2014). However, since the standard tool for decision-making are CBAs and these do not capture the (whole) value of GI and their ESS, public authorities are uninformed about the potential of GI and ESS and often still turn to solely gray infrastructure solutions, which are disadvantageous due to the stated reasons (European Commission, 2013; Gill et al., 2007). Especially in times of fiscal austerity, cost-effectiveness and therefore also the reliable scientific determination and incorporation of ESS into valuations has become critical (European Commission, 2015).

Supranational authorities like the European Commission, but also the research community, businesses, the civil society and policy initiatives have a growing interest in the valuation of ESS. This is due to the academic interest in the human-nature interrelation, economic opportunities for many companies, a vast amount of bottom-up movements concerned with the influence of nature on well-being and policy makers aiming to promote the conservation and sustainable use of the natural environment (European Commission, 2015; Gómez-Baggethun and Barton, 2013; Le Roux et al., 2016). Despite this growing interest, the wider deployment of GI in Europe has been prevented by a lack of robust evidence of the cost-effectiveness and longer-term economic benefits of these ESS-providing solutions (European Commission, 2017). Therefore, the European Commission is among the authorities, which are prompting science-based assessments of the delivery of ESS by NBS, with a focus on cost-benefit analyses of hybrid GI approaches (European Commission, 2015; Kabisch et al., 2017).

Also in Germany, cities are urged to address climate change related consequences such as heavy rainfall events with GI measures as they have been identified as approaches providing multiple benefits simultaneously, such as reducing flood risk, improving microclimatic conditions or minimizing noise (Menke, 2016). In the context of stormwater management, GI implementation efforts accompany a general paradigm shift from centralized toward decentralized water management. While the conventional maxim has been to remove rainwater completely and as quickly as possible through central water management facilities, the new approach emphasizes the benefits of local stormwater management measures which are found to react more flexible to changing water regimes (Minar, 2014). GI is identified as important part of water-sensitive urban development which assigns an important role to the vegetation and percolating soils and acknowledges that also the combination of gray and green infrastructures can provide a cost-efficient overall system for urban climate adaptation (Hansen et al., 2018). This notion is adopted by numerous German cities and their stormwater management strategies such as in Hamburg in their *RISA-project*, Bremen in their *KLAS-project* or Lübeck in their *RainAhead-project* (Deutscher Städtetag, 2015).

However, using the results of economic valuations of ESS in decision-making plays a small role in Germany. This is because the discussions are dominated by a strong scepticism, if not even rejection, of the economic assessments of environmental changes and the methods developed for assessing them. The underlying arguments are the low reliability of results, especially if they are based on survey-based studies, and the claim that the role and protection of nature is already largely regulated by law. Meyerhoff and Petschow (2014) counter these arguments by stating that they often rely on little knowledge of economic valuation methods and that economic valuation methods have been substantially refined in recent years. In view of the increasing EU emphasis, there is a dire necessity to support research on the importance of ESS and particularly on related valuation methods (Meyerhoff and Petschow, 2014). Research institutes such as the IÖW contribute to these current aspirations to quantify and monetize ESS. With their *Evaluation Tool for Economic Evaluation of Ecosystem Services of Urban Green*, the ESS of urban green spaces can be quantified and monetized (Klein, 2020).

This report will investigate recent valuations of GI and related ESS that use the extended CBA method, i.e. assessments that seek to incorporate indirect and often intangible benefits into their valuations. Since the costs for GI are determined more uniformly by the authors of the considered studies, they are of second priority while the focus of this report is on the quantification and monetization of benefits in the form of ESS. The quantification of benefits and their monetization building thereon, which can be conducted with a range of different techniques, will be investigated. Finally, and in keeping with my initial ambition, these findings will be reviewed with regard to if and how the IÖW-tool could be improved.

The research question for this report is therefore:

What counts in the valuation of ecosystem services, i.e. how do different cost-benefit analyses render the benefits of ecosystem services quantifiable?

This question is addressed through three sub-questions:

1. What are the methodological and ideational similarities and differences between valuations of ecosystem services and (how) can these be explained?
2. What are the motivations for and who are the beneficiaries of the valuations?
3. What can the tool from the IÖW learn from the findings of the valuation projects?

To answer these questions, different valuation approaches of ESS, which make use of extended cost-benefit analyses and have a primary focus on urban stormwater management, will be investigated. The aim is to provide an overview of current valuation approaches of ESS and analyze their underlying assumptions, institutional prerequisites, calculation methods etc. This will be done against the theoretical background of valuation studies which is closely related to the so-called performativity approach. The performativity argument stresses that the economic methods and calculations carried out to assess and analyze phenomena, reshape the phenomena themselves and thus how they are looked upon.

The title of this master thesis, 'Strength in Numbers', is a phrase commonly used to express that a group of people has more power than a single person. In the context of this report, it is, however, understood in a slightly different sense: First, it is used to direct attention to the extent to which there are 'strong' foundations - in the form of numerical valuations - for determining the benefits of ESS, and how 'solid' these valuations are constructed; consequently addressing the 'strength in numbers'. And secondly, at a superjacent level, the expression questions the 'strength' of decision-making based on those valuations, i.e. the extent to which decisions relating to non-market-based goods and services should be relying on economic information, consequently also questioning the 'strength of numbers'.

This report does not want to generally attend to the sociological character of valuations since this point has been stressed by a multitude of authors already, see e.g. the work from Marion Fourcade, Michele Lamont, Fabian Muniesa and Donald MacKenzie. Rather, the aim is to explore in more detail the techniques of extensive CBAs applied in the projects analyzed in this report. This is done to examine what methodological insights can be gleaned from these studies. Furthermore, it should be addressed in which ways a tool, which is currently under development, can potentially capitalize on detailed insights of valuations from similar project contexts. The structure of the report is as follows. After the performativity argument and the domain of valuation studies will be presented in the second chapter, the third chapter will present the methodological steps taken. After this, the current state of the art of the research field will be provided, including the four concepts NBS, EBA, GI and ESS. The analysis chapter following thereon will form the backbone of the report before its results are critically examined in the discussion and eventually summarized concludingly.

THEORETICAL BACKGROUND

2. Theoretical Background

The research topic of valuation in general and CBA more specifically takes its departure in the theoretical background of performativity in the context of economics. The 'performativity thesis' is the claim "that economics produces a body of formal models and transportable techniques that, when carried out into the world by its professionals and popularizers, reformats and reorganizes the phenomena the models purport to describe" (Healy, 2015, p. 177). This approach is closely related to the concept of valuation studies, sometimes also called sociology of valuation. This is an emerging study area which focuses on the tools, models, politics, processes, cultural differences and other inputs and outcomes of valuation. It is being developed in a variety of disciplines such as cultural geography, economic sociology, management and organisation studies and many more. There is at least a partial overlap with work from science and technology studies and the sociology of knowledge which have a longstanding interest in values as well and are influenced by e.g. Latour (1999) and Callon (1998). This growing interest has resulted in a certain degree of institutionalization, e.g. in form of the academic journal *Valuation Studies*, published the first time in 2013 (Helgesson and Muniesa, 2013). Fourcade (2011) notes that the valuation of peculiar goods has been transformed from a 'custom and law' process into a highly rationalized and impersonal one which is handled by specialized technologies and intermediaries.

Attention will first be given to CBA and extended CBA, as understood in the field of neoclassical economics. This includes the procedural steps of a CBA, its application with regards to environmental goods and services and the application of different valuation methods, such as stated preference (SP) or revealed preference (RP) methods. Second, CBA valuation will be connected with the performativity argument and be considered as a particular form of valuation. Third, an example of a performative argumentation on the CBA of environmental services carried out by Marion Fourcade (2011) will be provided.

2.1 Cost-Benefit Analysis

Through CBA, a comparison between the socioeconomic costs and benefits of a project is possible. CBA is a tool based on the recommendation that decision-makers should favor public policies and projects only if the costs of these proposals are outweighed by the benefits (Atkinson, 2015). In this context, the societal welfare is defined as the total amount of utility among all citizens in the society where costs are defined as reductions and benefits as increases in human well-being (Boardman et al., 2011; OECD, 2018). CBA provides the economic justification for a project and can therefore be characterized as the normative construction of an ”elaborate policy formation tool that enables the quantification of costs and benefits to the fullest extent possible” (Atkinson, 2015, p. 144). On the other side, the scope of a CBA make it a vast endeavour with a high ambition level (Atkinson, 2015). A broader rationale is put forward by Randall (2002) who argues that there are many reasons why a policy action can be characterized as a good thing. Two of those reasons - namely the benefits and costs - relate to the assessment of these actions and the justification of their consequences in monetary terms. CBA is therefore not just the transfer of market logic but an instrument that conscientious decision-makers should be interested in if they pursue their decisions to have ’good’ consequences (Randall, 2002; Randall, 2007).

CBA is based on a model of rationality in the sense that it forces decision-makers to look at the losers and beneficiaries in both spatial and temporal dimensions regardless of the use of monetary measures of losses and gains. Consequently, it avoids ’lexical’ thiking, i.e. making decisions based on impacts on a single group of people or a single objective (OECD, 2018). This rationalistic approach demands the full explication of reasons for taking decisions, rather than the reliance on unreasoned convictions or implicitly derived conclusions. Though, this takes place at the risk of over-simplification (Sen, 2000). Furthermore, CBA is directly connected to the notion that any project must be seen as one possibility of a series of options. Unlike other approaches, which only decide between different alternatives of action, CBA offers a rule for a decision that no change of the status quo is a reasonable option as well. This makes setting out the options for the achievement of a chosen objective a fundamental prerequisite of CBA. CBA accounts for time in a comprehensible way through the process of discounting which enables a comparison of costs and benefits over time. Although this is a contentiously and highly political discussed topic, because it is inevitably connected to normative judgements about the worth of future generations, it is impossible not to decide how impacts in the near and very distant future must be treated compared to immediate impacts. Additionally it is argued that CBA accentuates democracy because it is explicit in counting individuals’ preferences by directly looking and/or asking people what they want. Critics remark that this characteristic is rather a weakness than a strength since it includes people’s preferences regardless of how badly informed they might be (OECD, 2018).

Whereas the practical details may vary, the basic structure of a CBA has always an identical form. This structure involves the summation of the net benefits’ - benefits minus costs - monetary value over the lifetime of the project of concern. The crucial point is linked to the fact that costs and benefits appear differently for different times within the project lifetime. Therefore, the stream of net benefits is discounted, i.e. the values of net benefits in each period are treated differently depending on their occurrence in time instead of just being added together. Commonly, less weight is given to both costs and benefits the further their impacts are in the future. The then discounted net benefits are summed to determine the net present value (NPV). If the NPV is above zero, the decision rule is to favor the project while it should be rejected if the value is below zero. If mutually exclusive projects are considered, the project with the greatest net benefits is recommended by the CBA (Atkinson, 2015). The OECD (2018) recommends to take a variety of factors into consideration which should justify and accompany the calculations carried out. The fundamentally most important and first in every practical CBA is what question is being asked and what motivates the valuation. This is related to the considered options and the point of time when to commence the project. Furthermore, it should be addressed whether the action(s) should be undertaken at all. In a next step, it is important to raise the issue of who counts in the CBA, i.e. what are the boundaries set for the sum of individuals which the project is affecting. When getting to the core of the CBA, i.e. valuing the costs and benefits, a numerical basis for their comparison - most commonly money values - needs to be established. Building upon that, the discounting rate needs to be determined. It is inevitable part of a CBA that the costs and benefits will not be known with certainty. With regards to the implications of costs and benefits, the OECD (2018) differentiates between 'risk', i.e. costs and/or benefits are not known with certainty, but a probability distribution is known, and 'uncertainty', i.e. information about the end points of costs and/or benefits may be available but no probability distribution is known and even pure uncertainty about costs and benefits is possible. If a situation of uncertainty occurs, the CBA at the very least requires the performance of a sensitivity analysis. A sensitivity analysis addresses different values of the parameters about which there is uncertainty and requires assumptions about likely maxima and minima. The first possible outcome of a sensivity analysis is that the net benefits remain unaffected by the alternatives, making the analysis 'robust' with regards to the assumptions. The other outcome is that the changing assumptions will change the CBA result which necessitates a judgement about the reasonableness of the values chosen. The final decision based on a CBA needs to favour the project(s) with a positive NPV and rank projects by their NPVs. If budget constraints are existing, the criteria become more complex. Here, the benefit-cost ratio (BCR) ranking procedure can be applied in the case of single-period budget constraints, i.e. ranking projects according to their BCR and recommend them in that order until the capital contraint binds. This makes the BCR less recommended as a decision-making rule for project selection (OECD, 2018).

2.2 Cost-Benefit Analysis and the Environment

There have been vivid discussions with partially contrasting viewpoints about the monetary and non-monetary valuation of the environment for decades. However, there seems to be agreement upon the claim that, despite some flaws in monetary valuation approaches regarding biodiversity, there is a clear need of valuation tools in the context of sustainable development initiatives (Le Roux et al., 2016). Understanding the economic value of ESS is important because of the perceived persuasiveness of economic language. To convey the services that the natural world provides us with in monetary terms, is a powerful instrument for communicating its importance to a wider - perhaps previously unreceptive - audience. Furthermore, placing a value on nature aims to redress the fundamental imbalance whereby this value has been and is often still misjudged, undervalued or ignored completely in decision-making (Kumar and Wood, 2010; OECD, 2018).

The current interest for CBA is rooted in a variety of motivations, one of which is certainly the growing apparent ability of practitioners to assign monetary values on intangible impacts, mostly seen in environmental applications of the method, then called environmental CBA (Atkinson, 2015). Environmental CBA is

> *"the application of CBA to projects or policies that have the deliberate aim of environmental improvement or actions that affect, in some way, the natural environment as an indirect consequence"* (OECD, 2018, p. 19).

The valuation of ESS through environmental CBA relies on standard economic theory but is underpinned by the natural sciences. The concept of ESS in the context of valuation studies is based on the financial idea that an object's value is related to the services it provides. Hence, nature is presented as 'natural capital' which has a worth due to its returns for people (Chiapello, 2015). One remarkable characteristic of projects within the sustainability context is certainly that often substantial one-off costs are incurred on the one hand and a flow of benefits over a sometimes-undefinable long time period is generated on the other hand. This requires greater attention to the expanded time scale of benefit occurrence than in projects with temporarily predetermined beneficial effects (Naumann et al., 2011). Environmental CBA faces the inherent challenge to perform within the context of non-market-based goods and services which do not have a market price. So-called positive externalities are characteristic for public goods which have the two distinct features of non-excludability and non-rivalry (Boardman et al., 2011).

Callon (1998) provides a critique of the term ’externalities’ and instead proposes the notions of framing and overflow. Framing means the establishment of a boundary demarcating the actions which are happening independently from their surrounding context (Callon, 1998). Building upon the understanding that any economic assessment can only incorporate a limited amount of entities and researchers are never able to fully entail all relevant factors when performing calculations, an overflow is the equivalent to what Boardman et al. (2011) refer to as externalities. In the given context, a conventional CBA can be regarded as one attempt at valuation while an extended CBA represents another framing which seeks to be more ’complete’ through the incorporation of ’overflows’. In either way, CBA is a sociotechnical device which is assemblaged of people, knowledge and material things and turns the complex, messy world into a calculative order, which can be used productively (Hirschman and Berman, 2014).

2.2.1 Valuation Methods

There is a variety of methods for the determination of the economic value of ESS, which can be applied independently but are often integrated into a CBA. These methods can be divided into four groups, namely SP methods, RP methods, the market price-based method and cost-based methods. SP methods are based on intended behaviour and further classified into contingent valuation and choice experiments while RP methods are based on actual behaviour and entail the travel cost method and the hedonic pricing method. Whereas the market price-based method stands for itself, cost-based methods are subdivided into the damage cost method, the avoidance cost method and the substitution cost method (Dehnhardt, 2015; Pascual and Muradian, 2010). Additionally, a complementary approach to a CBA’s general objective - generating primary data on the total economic value which is placed by the public on environmental changes caused by a project proposal - exists. This approach is called benefit transfer, builds upon the accumulated findings of already conducted valuation studies and consequently applies existing monetary values to new project contexts (Atkinson and Mourato, 2008; Marre, 2014). As the ’add-ons’ to a conventional CBA, these different approaches are reflecting the extension possibilities since they incorporate indirect cost and benefit components.

2.2.1.1 Stated Preference Methods

SP methods can be understood as an umbrella term including a range of survey-based methods which use hypothetical markets to evoke preferences for specified projects. The most widely applied technique within the SP context is the contingent valuation method which is rooted in the economic theory of individual choice. The contingent valuation technique has been applied in developed and developing countries alike and gained attention primarily through its application following the Exxon Valdez oil spill in 1989 in Alaska (Atkinson and Mourato, 2008; Fourcade, 2011). It circumvents the absence of a market by presenting consumers a hypothetical market in which they have the opportunity to sell or buy the services in question, e.g. an improvement in air quality or a flood risk reduction (Fourcade, 2011). The respondents are then asked to state their maxmimum willingness to pay (WTP) or minimum willingness to accept (WTA) for a hypothetical change in the provision's level of the good or service which gives the practitioners information about all benefits associated with that change. The evoked WTP and WTA values are therefore monetary measures of the respondents' preferences and express the change in well-being enjoyed by an individual. In case of an expected environmental deterioration, the WTP is the determinant to avoid that outcome and the WTA determines the compensation to tolerate it (Atkinson and Mourato, 2008). Consequently, the value of a service or object is not defined according to a universal notion or ethical standard but as aggregation of individual preferences. Due to its reliance on surveys, the contingent valuation method is comparably resource intensive (Fourcade, 2011). Interestingly, SP methods do not align with the claim of many economists who often distinguish their discipline by basing their analyses on what people actually do rather than on what people say their subjective motivations for their actions are (Simpson, 2010).

A recent development in the domain of SP methods are so-called choice experiments. Choice experiments address the modelling of preferences for bundles of characteristics of goods and services and aim to isolate the monetary value of individual product or service characteristics which are typically supplied in combination with others. If for example a project, which is planned to improve the quality of a river, should be evaluated, potential attributes might be the improvement of the river's ecology, the decreased health risk for people exposed to the water, and the increased visual amenity. Choice experiments then characterize each alternative choice by a number of such attributes and are able to indirectly infer the WTP from the choices made. Choice experiments are therefore well-equipped to deal with situations where changes are multidimensional and the trade-offs between these dimensions are of specific interest (Atkinson and Mourato, 2008).

2.2.1.2 Revealed Preference Methods

RP methods focus on so-called 'surrogate markets', i.e. analyze preferences for non market-based goods implied by the past behaviour in an associated market. Instead of being based on intended behaviour such as SP methods, RP methods build upon actual behaviour. The two main techniques of this method are the travel cost method and the hedonic pricing method (Atkinson and Mourato, 2008).

The travel cost method addresses the valuation of spatial non market-based goods and services by taking the cost of travelling to a location as estimate for its economic value. It has been used primarily for outdoor locations and their recreational amenities, e.g. national parks, beaches or lakes. The travel cost method acknowledges that the recreational area is typically an unpriced good but emphasizes the factors which command prices and enable people to produce recreational experiences. Among these factors are the travel to and from the area, the recreational area itself and if the case, staying overnight at the location (Atkinson and Mourato, 2008). Although the travel cost method is usually applied for larger areas, Brauer Christiansen et al. (2019) have shown that the method can be useful for the dense urban context if appropriate alterations are taken beforehand.

The hedonic price method originates from the notion that the price of the majority of market goods and services is a function of a compound of characteristics. For example, the price of a car is likely reflecting its reliability, safety, fuel efficiency etc. The method uses statistical techniques to isolate the implicit price of the single characteristics. Property and labour markets are of particular interest for the method since the former gives information about the change of housing prices through e.g. road traffic, air pollution or the proximity to a landfill and the latter enables to draw conclusions about the value of avoiding the risks of injury or death by looking at different wages in jobs with exposure to physical risk (Atkinson and Mourato, 2008).

2.2.1.3 Market Price-Based Method

Market price-based methods are applied for goods that are traded in markets and therefore often used for provisioning ESS such as fibre and food. These prices are then interpreted as accurate information about the value of the environmental good or service in question according to the principle of welfare economics. It is assumed that the good or service is sold on a perfectly competitive market, i.e. full information is available, no subsidies or taxes exist and identical products are being sold (Pascual and Muradian, 2010).

2.2.1.4 Cost-Based Methods

One of the cost-based methods is the damage cost method which is connected to the valuation of the actual damages incurred on the environment or the saved potential costs which can be avoided through the ESS. For example, the value of a flood control measure can be assessed by estimating the damage costs in case of a flooding incident (Pascual and Muradian, 2010). The economic valuation of different damage types such as damage to materials or environmental diseases is carried out through the estimation of certain cost categories which can be interpreted as indicators of the loss of benefits experienced. In order to prevent duplication and interpret the results appropriately, it is important to define the costs with the support of different categories and to clearly distinguish them (Dehnhardt, 2015; German Federal Environment Agency, 2012).

The avoidance cost method - as opposed to the damage costs - is not directly related to the environmental damage. Instead, it addresses the costs which are associated with avoiding or reducing the activity which causes the environmental damage, e.g. emission avoidance costs. Avoidance costs are therefore the costs arising from measures to avoid a specific environmental impact, e.g. the reduction of pollutant emissions and are hence directly connected to the relevant activity adversely affecting the environment. In general, the application of the avoidance cost method is regarded as meaningful if the expected damages on the environment are higher than the costs of avoiding the source of the impact. In this sense, they can be characterized as the lower limit of the assumed damage costs (Dehnhardt, 2015; German Federal Environment Agency, 2012).

The substitution cost approach utilizes costs for an alternative solution as a measure for environmental costs and, like the avoidance cost method, is also not directly related to the environmental damage. Substitution costs examine how much people have to or would pay to realize the ESS through a technical substitute. For example, the value of groundwater recharge can be measured by the costs of obtaining water from an alternative source and the value of GI for flood control can be measured by the costs of retaining the water in an alternative structure, e.g. a rainwater retention basin (Pascual and Muradian, 2010).

2.2.1.5 Benefit Transfer

Despite the fact that there have been significant advances in methods that pursue the generation of primary data on the value of environmental goods and services, valuations will arguably still rely on the utilization of secondary data to some extent. The procedure of applying the results of existing studies to new but related project settings is called benefit or value transfer. This comprises taking a non market-based good’s or service’s unit value estimated in a primary study and using this estimate - maybe after some adjusting steps - for the valuation of benefits arising when a new project is planned to be implemented. If applied in appropriate situations, the benefit transfer method has the potential to reduce the need for time-consuming and cost-intensive original studies (Atkinson and Mourato, 2008). Since research and funding for valuation projects have been outpaced by the demand for environmental valuation information and the costs for the conduction of novel valuation research are high, many authorities compensate the lack of data by using benefit transfer (Fisher, Bateman and Turner, 2010; Nordman et al., 2018).

2.3 Valuation in the Light of Performativity

With the spread of market fundamentalism and neoliberalism, governments pursue the use of tools which ensure greater efficacy, causing quantitative measures of performance and benchmarking to diffuse rapidly and to have substantial effects on domains of human activity (Lamont, 2012). It has been found that quantified assessments are increasing, among which specifically economic assessments are on the rise (Chiapello, 2015). The main concerns circulate around the monetary valuation of goods and services about which there is a considerable uncertainty, like ESS. Since valuations are highly contingent upon the social context which they are embedded in, every valuation is not happening inside the mind of an individual but in experiences and practices (Fourcade, 2011; Lamont, 2012). Building upon this notion, there is a general agreement that values are social constructions. This social construction of a value can be described as the "process of social work and the result of a wide range of activities (from production and combination to circulation and assessment) that aim at making things valuable" (Helgesson and Muniesa, 2013, p. 6). Valuation is based on the idea that a value is not intrinsic to an object but produced in the relationship between the object and a person who regards it as valuable and therefore through practical valuation activities. As a process, valuation entails the identification and choice of objects and hence the decision about which objects escape and get attention, whereas this may or may not be a conscious procedure. Eventually, valuation leads to the qualification of what is valuable and estimating values within the chosen framework. The latter can itself be connected to a technical apparatus with varying sophistication and often produces the quantification of value in monetary terms. In that context, valuation, i.e. the process of worth attribution, is analytically to be distinguished from evaluation, i.e. the involvement of a second level of judgement, for example through a comparison of the value with a predetermined objective. However, the two processes are often impossible to separate on the empirical level. The process stages of valuation are inextricably interwoven with the viewpoints from which things are assessed and therefore the assumptions related to what counts in the given situation. These viewpoints are bound up with the people who perform the valuation and the people for whom it is performed, the purpose of the valuation as well as with the calculation methods used (Chiapello, 2015; Helgesson and Muniesa, 2013; Lamont, 2012).

The above-mentioned notions can be applied on CBA, itself being based on an economic welfare theory that aims to increase human well-being in the society. CBA is the technical apparatus producing the economic value of the costs and benefits of GI and can be characterized as the mean "by which experts come to know what they do (...), the device with which they work" (Voß and Freeman, 2016, p. 2). CBA is identified as instrument of performative knowledge production because it manifests a creation of reality that it describes (Voß and Freeman, 2016).

Arguably, the procedure of applying a CBA follows the same principles as to what Bruno Latour (1999) refers to as circulating reference in his eponymous paper about the observation of pedological fieldwork in the Amazon rain forest. He characterizes circulating reference as the transformation series that entities - in this case the CBA - are undergoing when they are handled by scientists. In his example, this entails the creation of a measuring grid, taking soil and plant samples, the illustration of findings in a graph etc. while the process of CBA analogously comprises the identification of a relevant project area, translating bioclimatic processes into numerical units and eventually monetary values and comparing of the outcomes with other relatable options. When going through a series of transformations, there is always a "trade-off between what is gained (amplification) and what is lost (reduction) at each information-producing step" (Latour, 1999, p. 71). It is argued that CBA is a tool contributing to the production of knowledge which is never resembling an external world "but rather a real interior world, the coherence and continuity of which it helps to ensure" (Latour, 1999, p. 58). The CBA within the context of economic performativity is interpreted from a different perspective than the conventional economic approach. This conventional approach is referred to by Healy (2015) who states that the economist, unlike the physicist or biologist, is not required to contrive instruments that represent the studied phenomenon in a quantitative form. It is argued, that a CBA of ESS, if seen from a performative stance, necessitates this very quantification techniques that translate the benefits of nature into measurable units.

CBA is a common example of what Espeland and Stevens (1998) refer to as technologically elaborated commensuration because it creates relations between different entities through the establishment of a common metric. Commensuration in general is defined as "the transformation of different qualities into a common metric" (Espeland and Stevens, 1998, p. 314) which in the case of CBA, is money. It is a crucial concept to describe how we make sense of the world and categorize entities. Commensuration is not a neutral or merely technical but a social process since it builds upon a set of assumptions which inform its use. Commensuration can be a response to exclusion and is therefore especially embraced by economists who grapple with the problem of externalities. By offering ways to constructing proxies for elusive and uncertain qualities, such as ESS, it simplifies and reduces disparate information into numerical units than can be compared more easily. In this way, commensuration resembles Latour's amplification through reduction. Often, commensuration is taken for granted which leaves the required work and the taken assumptions for its existence overlooked. Because it changes the terms of how valuation objects are treated, how these objects are valued in the first place and due to its inherently interpretive and deeply political character, it is too important to not be acknowledged in the field of sociological valuation (Espeland and Stevens, 1998).

As the research question reveals, this report is particularly interested to examine the entities which are getting amplified by a CBA, more specifically by the different valuation methods which are applied to valuate GI and ESS. The practice of CBA is embedded in an understanding of economy which is not merely concerned with the management of resources but rather a product of socio-technical practices. As Mitchell (2006, p. 1116) points out, "economic knowledge does not represent the economy from some place outside (...) but rather participates in making sites where its facts can survive". This ties in well with the notions from Voß and Freeman (2016), Latour (1999) and Espeland and Stevens (1998) presented above and underlines the fact that responsible authorities participate in the construction of a knowledge world which is bound up in historical, cultural and political conditions in a particular way when performing a CBA.

2.4 An Example for Performativity within Environmental Valuation

Marion Fourcade (2011) provides a vivid example about the performative construction of valuations in her paper 'Cents and Sensibility: Economic Valuation and Nature of "Nature"' where she approaches the general reasons, techniques and implications of the attribution of monetary values to intangible things. Her investigation is concerned with two major oil spills in France and the United States of America and examines the questions how people in these different sociocultural contexts framed the need for monetary compensation for the polluted landscape and loss of biodiversity and how the eventual economic measure of nature varied so much - and reversely to the amount of oil spilled - across the two cases. Her underlying approaches are therefore the examination of valuation methods put into place, their constructions, outcomes and implications. It is noteworthy that for Fourcade, the question is not so much whether nature should be monetized or not but rather how people came to "collapse different economies of worth applying to nature" (Fourcade, 2011, p. 1726) with not only a focus on both absolute money amounts but also the specific techniques to generate these amounts (Fourcade, 2011).

For the two case studies, the influence of institutions and public administration, the court system, and the cultural meaning of intangible goods are among the factors investigated and analyzed within the context of economic valuation. As Fourcade found, the understanding of some of the key concepts of valuation, such as the perception of nature, money and CBA itself caused the eventual large discrepancies in monetary compensation. Whereas nature in the USA has been perceived as wild and untouched area with intrinsic value, the French population framed nature as object of political-cultural reality existing adjacently to places which have been populated by humans for centuries. A more trustful relationship between politicians and bureaucrats in France compared to the contrary situation in the USA made CBA a practice which did not penetrate the existing decision-making processes to a large extent in the French context whereas the method has gained much more importance in the USA. As though the kind of impact of the disaster has been the same for the environment in both countries, their focus has been on different aspects of it and results in the usage of diverging valuation methods within the CBA. Since the US American case has been concerned with the individuals' subjective value of the environment, a contingent valuation approach was used which determined the WTP of every person within a selected group of people and extrapolated this value on the entire population of the country. In contrast with that, French scientists focused on determining the value of losses to the affected ecosystems and consequently applied market prices of tradeable goods such as fish. Although the contingent valuation approach has been applied there likewise, it very much focused only on the local affected citizens. Concludingly, the pricelessness of natural resources in the US American context was seen in the highest price possible while the pricelessness in the French context has been seen in the absence of price (Table 1; Fourcade, 2011).

Table 1: Key findings of Fourcade's investigated valuation of nature (Fourcade, 2011)

factor	USA	France
case	30,000-ton oil spill in Alaska, 1989	227,000-ton oil spill in France, 1978
understanding of money	money as agent for social equalization ('From dishwasher to millionaire'-mentality)	absence of socially equalizing power of money due to aristocratic setup of society
role of money	money as compensatory mean for punitive damages	money as compensatory mean for the sole economic prejudice due to the non-existence of punitive damages
understanding of nature	nature as wilderness and open, 'natural' reality	nature as part of the lived in, political-cultural reality
understanding of CBA	CBA as mobilization of expertise and only way to lift professional bureaucracies above the distrusted political domain	CBA as less far-reaching practice due to the powerful administrative tradition, a high status of technocracy, little scrutiny toward the political domain and hence a large retainment of authority in decision-making processes
valuation object	valuation of the subjective value of the environment to individuals	valuation of the actual price of the biomass destroyed in the oil spill and the putative restoration of the environment
valuation method	contingent valuation, i.e. usage of a WTP survey scheme and extrapolation to the national scale	market price of ecological losses and contingent valuation of economic losses with surveys among the population on the local scale
understanding of value	inherent value of nature	value of nature for humans

With her findings, Fourcade argues against the notion of economists describing their methods and interventions as morally neutral and instead shows that economic valuation methods are performative of political histories and commitments, legal rules, ecological theories, moral positions and social arrangements (Fourcade, 2011).

The production of values in particular ways, i.e. how other authors have used CBA and the related valuation methods to produce values of GI and ESS, is relevant for this report and should therefore be analyzed by examining how different aspects are rendered visible and countable by these different valuation methods. The 'framing' of valuations is put into place by a variety of factors, e.g. scale of the researched area, motivation of the calculations, addressees of the valuation outcomes etc., which limit a mere transfer of results from one place to another. These factors have been investigated by Fourcade and will analogously - adjusted to the scientific articles of interest for this report - come to the fore in the analysis. This 'framing' makes economic valuation so revealing because it is more than a process of monetary commensuration and rather a powerful process of a social construction which incorporates all sorts of assumptions about imaginaries about worth.

METHODOLOGY

3. Methodology

To gain insights into the emergence of interest for GI and related concepts as approaches of climate change adaptation and to map the current situation of the quantification of these concepts, a meta-review of already existing literature reviews has been conducted. For the first section of the upcoming state of the art chapter, which elaborates on the conceptual emergence and relations of the four above-mentioned terms, the report from Cohen-Shacham et al. (2016) and the book chapter from Pauleit et al. (2017) have been the most influential sources (see Chapter 4.1 and Chapter 4.2). Cohen-Shacham et al.'s report is an effort of the *International Union for the Conservation of Nature* to define its position on NBS and is an influential source whose findings have been acknowledged by e.g. the European Commission. Pauleit et al.'s book chapter, which provides a very recent review of key literature in the context of NBS and climate change, is receiving much attention by the research field and much cited. Thereafter, the current situation of the concepts with regards to quantification is presented. This part is supported by literature reviews from Haase et al., (2014), Ruangpan et al. (2020) and Jayasooriya and Ng (2014) (see Chapter 4.3). Haase et al. (2014) conducted a quantitative review of urban ESS assessments and therefore contributed to this report by concretizing research about the most commonly investigated ESS within an urban context. Ruangpan et al. (2020) analyzed the current research arena regarding NBS for hydro-meteorological risk reduction and provided meaningful insights into e.g. the techniques and tools for planning, selecting, valuating and implementing NBS as well as knowledge gaps and potential future research prospects. Finally, Jayasooriya and Ng (2014) examined different tools for determining stormwater management and economics of GI practices, serving as valuable background source about the currently existing techniques to quantify and monetize GI within a stormwater management context, their benefits and disadvantages.

From the review of these sources, it became apparent that the two concepts of GI and ESS are the most widely used terms within the environmental valuation context in urban areas. Therefore, these two key terms have been examined more systematically and became the foundation of my analysis of different valuation methods. The literature review, which is the main source of empirical material in this report, made use of the online search engines of *Google Scholar* and the *Peer-Reviewed Instructional Materials Online Database* (PRIMO) at *Aalborg University*, and looked for sources in both the English and German language. To identify relevant articles, the search was done by typing in the combinations of research words shown in Table 2. The most relevant papers have eventually been considered for a more detailed investigation.

Table 2: Research words for literature review

Research words (English)				
First concept (valuation)	Connection	Second concept (environmental benefit)	Connection	Third concept (water management)
"valuation" OR "cost-benefit analysis" OR "CBA"	AND	"green infrastructure" OR	AND	"water management" OR
	AND	"ecosystem services" OR	AND	"water retention"
	AND	"urban green infrastructure" OR		
	AND	"urban ecosystem services"		
Recherchewort (German)				
"Bewertung" OR "Kosten-Nutzen Analyse" OR "KNA"	AND	"grüne Infrastruktur" OR	AND	"Wassermanagement" OR
	AND	"Ökosystemleistung" OR	AND	"Wasserrückhalt"
	AND	"urban grüne Infrastruktur" OR		
	AND	"urban Ökosystemleistung"		

Respectively, the first 50 entries for each research word combination in both search engines have been taken into consideration to cover a manageable number of articles that are most cited. This amounts a total number of around 2,400 publications for each database, but there was a high degree of overlap between the two used databases. It should be noted that articles including the key terms come from a broad range of scientific fields, such as ecological economics, hydrology, urban studies, and ecology to name just a few. Title and abstract of the found papers have been scanned for the wider context in which the predetermined key words are used in, resulting in the exclusion of articles - e.g. because they made use of complex hydrodynamic modelling - and the further examination of other sources.

It became clear that most articles are of descriptive instead of analytical nature when addressing the valuation of GI and ESS, i.e. they rather point toward the motivation on research about GI and ESS valuation than actually conduct valuations. Those which perform valuations, do so to a lesser extent in urban contexts and if, concentrate on provisioning and recreational rather than regulating ESS. Among those which perform quantifications with emphasis on urban stormwater management, the monetary aspect is widely neglected. This continuous process of narrowing down the material, supported by the literature reviews elaborated on in Chapter 4.3, eventually allowed the selection of four relevant articles and the documentation of the procedure of the tool being developed by the IÖW, all addressing the quantification and monetization of ESS delivered by GI with a CBA approach and a primary focus on urban stormwater management. The related documents are concerned with:

1) A sustainable urban drainage system (SUDS) on the neighborhood scale in Berlin (Johnson and Geisendorf, 2019)
2) GI practices for stormwater management in Michigan (Nordman et al., 2018)
3) GI on community stormwater management in Beijing (Liu et al., 2016)
4) A SUDS in London (Ossa-Moreno, Smith and Mijic, 2017)
5) A tool to valuate the ESS of green urban spaces in German cities developed by the IÖW (Klein, 2020).

The literature review showed that there is only a small number of scientific articles corresponding with the developed criteria which made the final selection of papers easier. Furthermore, to enable an investigation of CBA within different geographical contexts, projects are selected with diverse implementation locations, with one project located in Germany, one project in the USA, one project in China and one project in the United Kingdom. It should be noted that the documentation of the procedure of the IÖW-tool has a slightly different standing than the other four articles. This is because the primary purpose of the document is to provide information about the tool's procedure and not to present the valuation of a case, like the other four publications. The paper is therefore used in two ways. First, their performance of an extended CBA, which is conducted exemplarily for the three German cities of Karlsruhe, Leipzig and Nuremberg in the document, is analyzed analogously to the other four publications. Second, the tool is regarded as my reference point to what can be learned from the findings of the other four articles. Against the background of valuation studies and the performativity argument, the articles will be analyzed by a guiding list of a total of 30 factors/guiding questions, shown in Table 3, which impact the quantification of benefits within the CBA of the related project. It should be noted that, although the performativity argument provides a valuable perspective for the examination conducted in this report, the author is somewhat limited in the 'active' performative approach. This is since neither empirical data in the form of self-performed calculations is available nor is it possible for the author to fully retrace the performative actions which have played into the valuation procedures of the considered projects. The analysis will therefore be predominantly carried out through the lense of the valuation studies approach.

The factors are informed by the stages of executing a CBA as recommended by OECD (2018) and inspired by the study conducted by Fourcade (2011). They can be divided into four sub-categories: necessary background information about the project, factors related to the investigated GI measures and ESS, factors related to the quantification of ESS, and factors related to the monetization of ESS with particular focus on the applied valuation methods. In the first stage, general information regarding the different projects will be summarized in brief project reviews which entail e.g. the motivation for the valuation, the size of the project and the addressees. In the second stage, the valued GI measures and their related benefits in form of ESS will come to the fore. Here, the interpretations of the concepts, the number and types of investigated ESS will be analyzed. In the third stage, the applied quantification methods will come to the fore to lead up to the fourth stage which is of prime interest. In the fourth stage, the applied valuation methods will be analyzed more detailed by elaborating on e.g. the reasons for their application, their outcomes and presentation, the incorporation of stakeholders and the authors' reflections on the valuations (Table 3).

Table 3: Set of Factors for the Analysis

Background Information				
Background of the Authors	Journal of Appearance	Motivation of Project	Country/Region of Project	Temporal Scale of Project
Has the approach been implemented?	Size of Project	Options under consideration	Addressees	Considered Vulnerability (-ies)
Investigated GI measures and ESS				
Considered Concept(s)	Investigated GI measures	Understanding of GI	Stormwater-related investigated ESS	Further investigated ESS
Number of investigated ESS	Number of investigated ESS related to stormwater management	Understanding of ESS		
Quantification Factors				
Intensity of considered rain event(s)	Applied quantification method(s)			
Valuation Factors				
Applied valuation (i.e. monetization) methods	Reasons for usage of valuation method(s)	Stakeholder involvement	Understanding of valued benefits	Beneficiaries of the Valuation
GI measure with highest assigned value	ESS with highest assigned monetary benefit	Understanding of CBA	Execution of Sensitivity Analysis	Critical stance toward valuation methods by authors

It should be noted that literature reviews also have disadvantages, particularly through the limited and predetermined key terms they are based on. A finite selection of keyworks is necessary to keep the report within the range of a feasible time period but introduces gaps in the list of articles to be reviewed. Additionally, the authors of literature reviews are always biased to some degree, i.e. the way she or he regards key terms as valid or not invalid. This causes her or him to include certain research words in the review and exclude others. Especially in the field of environmental valuation, the interchangeable use of key terms such as NBS, EBA, GI, SUDS or 'hybrid solution for stormwater management' etc. presents a problematic issue if not all terms can be reviewed. Lastly, poorly written abstracts may also be a cause for the exclusion of articles from the review (Grand and Booth, 2009).

DIFFERENT SHADES OF GREEN

4. Different Shades of Green

There is a variety of concepts for solving precipitation-related challenges by using natural processes and ecosystems. These concepts are often used interchangeably and play a vital role when environmental valuations are planned to be carried out (Ruangpan et al., 2020; Pauleit et al., 2017). Among the multitude of induced terms are e.g. low-impact development, water-sensitive urban design, SUDS and ecosystem-based disaster risk reduction (Li et al., 2019; Ruangpan et al., 2020). However, the four concepts of NBS, EBA, (urban) GI and ESS are found to be the most widely used which is why they are elaborated on in this chapter (Pauleit et al., 2017).

NBS, EBA, urban GI and ESS have received attention not only in the academic discourse but are addressed in current policymaking as well. The four concepts are partly overlapping, partly complementing each other and closely interrelated. The NBS concept has been found the broadest and most recent of the concepts which is why it is considered as an umbrella term to the other concepts. With EBA and GI classified as subcategories of NBS, EBA focuses on climate change adaptation via the use of nature and GI - as the related planning approach - provides strategic guidance for integrating NBS into the development of multifunctional networks of green spaces at various scales. Finally, ESS can be regarded as connector between the other concepts since they pursue the support of policymaking for prioritizing actions to maximize the advantages of NBS. This is done by measuring and valuing the benefits which humans derive from urban nature. The concept ESS has a higher degree of abstraction and a strong focus on valuation while the other concepts are more practical and solution oriented (Pauleit et al., 2017).

The first part of the following chapter will elaborate on each of the four concepts separately. This is done by illuminating the brief historic background and presenting a definition for each concept, highlighting their conceptual construction and relation to each other and providing examples. This chronological order only deviates in the subchapter for ESS where the listing of examples is pulled forward in the text. Thereafter, the current tendencies regarding the concepts within the related field of environmental valuation are highlighted.

4.1 Nature-Based Solutions

The term of NBS has been put on the agenda by practitioners in the late 2000s, namely the IUCN in a position paper for the *UN Framework Convention of Climate Change 2009*. The initial motivation has been to find new solutions that can simultaneously tackle climate change while protecting biodiversity and improving sustainable livelihoods. Accordingly, the term has been taken up by the

European Commission and supplemented with the notion that NBS are an innovative concept to generate growth and jobs as part of a green economy (Eggermont et al., 2015). Through the implementation of successive research programs, the European Union committed substantial resources to raise awareness to the notion that nature provides viable solutions for tackling modern societal challenges (ICLEI, 2019). NBS exceed the traditional biodiversity management principles by steering the discourse toward the inclusion of humans and fostering the integration of societal factors such as human well-being and socio-economic development. The concept, as opposed to the simple, replicable and predictable management of climate change challenges through solely technological strategies, presents an alternative approach which acknowledges the complexity of socio-ecological systems and their dynamic, self-organizing and inherently mutable properties (Eggermont et al., 2015).

Building upon the work of the IUCN, the European Commission has developed their own definition of NBS which shares the overall notion of addressing major societal challenges through effectively using the ecosystem and ESS. However, the European Commission defines NBS somewhat broader since not only the use of nature but also solutions inspired and supported by nature are identified as NBS (Cohen-Shacham et al., 2016). This report therefore follows the current definition of the European Commission which defines NBS as

> "*solutions that are inspired and supported by nature, which are cost-effective, simultaneously provide environmental, social and economic benefits and help build resilience. Such solutions bring more, and more diverse, nature and natural features and processes into cities, landscapes and seascapes, through locally adapted, resource-efficient and systemic interventions."* (European Commission, 2020)

This definition follows a preliminary definition from 2015 for the final report of the *Horizon 2020 expert group on Nature-Based Solutions and Re-Naturing Cities*, as part of the EU research and innovation policy agenda which aims to position the EU as leader in innovative natural solutions for more sustainable societies (European Commission, 2020). The *Horizon 2020* report makes clear that NBS, which have been identified as priority area for investment by the EU, are broad in definition and scope. Firstly, the concept is rooted in climate change adaptation and mitigation but understood as overarching term for simultaneously addressing multiple policy objectives, among which are biodiversity conservation, disaster risk reduction, the promotion of a green economy and poverty issues. Secondly, the concept has a broad understanding of nature which can be drawn from the expert group's list of more than 300 actions as examples of NBS, reaching from the expansion of forest areas over the implementation of green roofs to the planting of wind breaks. Thirdly, the concept is action oriented as *Horizon 2020* expects demonstration projects as reference points to upscale NBS not least across Europe (Pauleit et al., 2017). The United Nations Organization refers to NBS as a fundamental part of action for climate and essential to reach the goals of the *Paris Agreement on Climate Change* because they recognize the harmony between people and nature and are equipped to provide a holistic, effective, long-term, cost-effective and globally scalable response to climate change (UN, 2019). The above-stated working definition from the European Commission but especially the latter mentioned conception by the UN underline the anthropocentric-utilitarian nature of the NBS concept. In its ontological dimension, it refers clearly to societal challenges, in its epistemic dimension to problems defined by humans and in its practical dimension to the sustainable use of nature (Eggermont et al., 2015).

NBS is a concept that recognizes the dependence of human societies on natural systems (Wamsler et al., 2019). NBS have been identified as cost-effective alternatives to gray infrastructure in order to tackle challenges induced by rapid urbanization, climate change and more frequent natural disasters (European Commission, 2015). Especially in the context of stormwater management, NBS have gained prominence, partly because they are able to tackle multiple precipitation-related climate change challenges simultaneously. As more intense and frequent rainfall events are expected, these will produce run-off quantities which exceed the urban sewage systems' capacities. The increased urban run-off poses a threat for water quality as it is loaded with a significant amount of pollutants adversely affecting the water quality. Through mimicking the natural processes of infiltration and evaporation as well as providing storage space to some extent, NBS can help to address both problems. Furthermore, NBS may produce additional co-benefits such as improving air quality and the urban microclimate, providing carbon sequestration, increasing urban biodiversity, enhancing the living conditions with benefits for human well-being and quality of life or reducing pressure of e.g. wastewater treatment on peripheral natural areas (European Commission, 2015; Raymond et al., 2017). The advantages of NBS compared to gray infrastructure are reduced initial capital expenses as well as on-going operational expenses. This has been demonstrated e.g. in the city of Philadelphia/USA. It was shown that the NPV of GI for storm-water control over a 40-year period is between 1.94 billion USD and 4.45 billion USD, while benefits from conventional infrastructure ranged from only 0.06 billion USD to 0.14 billion USD (Stratus Consulting, 2009).

4.1.1 Ecosystem-based Adaptation

EBA first gained attention in 2008 during the *United Nations Framework Convention for Climate Change*. In the aftermath, it was mainly applied with a geographical focus on the global South but has been used in the global North later. As of today, the concept is found to be valid for developing and developed countries to the same extent and is widely used internationally. This can be seen e.g. in the encouragement of its use by the *European Climate Change Adaptation Strategy*. The concept has so far been applied primarily in the sectors of forestry and agriculture but is rising in interest for urban areas due to its cost-effective, comprehensive and multifunctional approach (Pauleit et al., 2017). According to the Secretariat of the Convention on Biological Diversity, EBA is defined as

> *"the use of biodiversity and ecosystem services as part of an overall adaptation strategy to help people to adapt to the adverse impacts of climate change."* (Secretariat of the Convention on Biological Diversity, 2009, p. 31)

EBA includes the design and improvement of GI and - similar to the NBS concept - is applied at different scales, from the micro scale at the building or small garden level to the macro scale at the city level. Its primary focus is on the sustainable management, restoration and conservation of ecosystems with the secondary objective to provide services which may support humans' adaptation to climate change. It is accordingly embedded in the concepts of climate change adaptation and ESS and therefore more limited in scope than the concept of NBS (Pauleit et al., 2017).

4.1.2 Green Infrastructure

The GI concept has its roots in the 1850s when first references to urban open-space networks in the USA and greenbelts in the UK have been made (Cohen-Shacham et al., 2016). The first example of a systematic incorporation of biodiversity in urban planning dates back to Berlin in the 1970s where researchers extensively investigated the city's plants, animals and related habitats and utilized that data in the urban planning of the city. It is probably due to the long-lasting expansion in combination with altering the natural environment, particularly through surface sealing and land consumption, that Europe was the first location where the recognition of nature's adaptation to the urban realm became evident (Kronenberg et al., 2013). The reemergence of the term then occurred between the 1980s and1990s when a growing concern about the uncontrolled urban sprawl in the USA became apparent. Instead of taking a reactionary role in form of dealing with space left after building or finished infrastructure development, practitioners proposed GI as instrument to proactively influence urban planning by identifying ecologically valuable land (Pauleit et al., 2017).

In the context of stormwater management, GI concepts have been proposed as best management practices for a more holistic treatment of runoff volume reduction, aquifer recharge and erosion prevention already in the mid-1980s (Schueler, 1987). As stated in Chapter 1, this report defines GI as

> *"a strategically planned network of natural and semi-natural areas with other environmental features designed and managed to deliver a wide range of ecosystem services. It incorporates green spaces (or blue if aquatic ecosystems are concerned) and other physical features in terrestrial (including coastal) and marine areas. On land, green infrastructure is present in rural and urban settings."* (European Commission, 2013, p. 3)

Out of the four concepts - NBS, GI, EBA and ESS - only GI has had a clear connection to the urban context from the beginning whereby all concepts found their way into the urban realm up to this point. It is imparted as contributing to similar if not the same policy aims as NBS but has a less narrow focus on climate change adaptation than EBA. Its suitability for the urban domain is underlined by the conceptual inclusion of a spatial layer and several principles which can be applied in urban planning, e.g. connectivity and multifunctionality. Like NBS and EBA, GI is meant to promote ESS and deliver multiple benefits to humans (Pauleit et al., 2017). Whereas GI is used in the spheres of practice, policy and scientific research likewise, the research applications are primarily related to urban settings (Cohen-Shacham et al., 2016).

Against the background of climate protection in general and stormwater management in particular, the ground is a central element of GI. Depending on its constitution and thickness, it has important functions for water storage, air cooling and reducing extremes of the urban climate and is often an inspiration for hybrid GI solutions. While unsealed ground, by infiltration and evaporation of water, has a protecting effect from climate change consequences on the built environment, artificially created hybrid solutions have a positive supplementary impact next to natural retention areas (BMUB, 2018). The overarching goal of GI practices is to ensure that the post-development hydrology of a site is close to the natural conditions which have been present before the occurrence of development (Li et al., 2019). Permeable pavements have been identified as effective GI strategy and are often implemented on urban alleys which are usually public spaces adjacent to private properties enabling public access for vehicles. Alleys are traditionally surfaced with impervious materials such as concrete or asphalt since they aim at a rapid storm-water runoff into the sewage system. The forecasted increased frequency and intensity of rainfall events is likely to overstrain the current system and leads to localized flooding. By utilizing a number of GI practices such as raingardens, rain-barrels, tree planting, green roofs, through-trench systems, cisterns or permeable pavements, green alleys are expected to enhance their performance in terms of stormwater management (Center for Neighborhood Technology, 2010; Foster, Lowe and Winkelmann, 2011; Wise, 2008; see Figure 7 and Figure 8).

Figure 7: A Raingarden in inner Sydney (City of Sydney, 2019)

Figure 8: A green roof in central Johannesburg (Fitchett, 2019)

Permeable pavement is designed out of materials which aim to produce similar runoff characteristics in cityscapes like those in a forest or a meadow. It allows water to infiltrate into the ground rather than running over it. Studies have shown that permeable pavement can reduce the runoff volume by 70 % to 90 % and can manage a 10-year rain event within a 24-hour period. Additionally, permeable pavement can have other benefits to urban areas, including noise reduction or the reduction of necessary road salt application on streets in the winter. In general, green alleys are expected to be three to six times more effective in storm-water management per invested 1000 USD than their conventional counterparts. For example Portland in Oregon/USA invested eight million USD in GI which saved them 250 million USD in gray infrastructure costs. Only one GI sewer rehabilitation project was able to save the city administration 63 million USD, and this does not include co-benefits such as groundwater recharge benefits or cleaner air (Foster, Lowe and Winkelmann, 2011).

4.2 Ecosystem Services

The term of ESS emerged in the late 1970s when ecosystem functions, that were beneficial to humans, have been labelled as 'services' to raise public awareness for biodiversity conservation. After scientists have broached the issue of ESS implicitly for decades, the *Millennium Ecosystem Assessment* in the early 2000s as first ever global assessment of ESS to policy makers has been a milestone in the popularization of the concept (Cohen-Shacham et al., 2016; Millennium Ecosystem Assessment, 2005; Pauleit et al., 2017). Since ESS have been applied in the urban context more and more at the the end of the 1990s, specialized urban research has resulted in a quick rise in publications (Pauleit et al., 2017). ESS are defined as:

> *"the beneficial outcomes to humans or the natural environment that result from ecosystem functions. In order for an ecosystem to provide services to humans there needs to be some interaction with, or at least some appreciation by, humans."* (European Commission, 2012, p. 13)

The concept aims to capture the complex relationships between societies and nature by categorizing a broad range of benefits that people obtain from ecosystems. ESS are interesting for this report particularly for urban areas. Urban ecosystems are referred to as "those in which people live at high densities, or where the built infrastructure covers a large proportion of the land surface." (Pickett et al., 2001, p. 129). The concept was developed from the growing concern that the benefits that humans derive from nature are not, or not sufficiently, taken into account in conventional economics. It can therefore be understood as an attempt to restore this balance by systematically assessing the demands for and supply of all types of services provided by ecosystems (Pauleit et al., 2017).

One of the main contributing authorities - the *Millennium Ecosystem Assessment* - proposed the classification of ESS into four categories which has been adapted by e.g. the *European Commission* and *The Economics of Ecosystems and Biodiversity Initiative* (TEEB). These categories are provisioning ESS, such as the supply of clean air, regulating ESS, such as climate and water regulation, supporting ESS such as photosynthesis and cultural ESS, such as recreational opportunities (Millennium Ecosystem Assessment, 2005; Table 4).

Table 4: An incomplete list of ESS (TEEB DE, 2015)

Provisioning ESS	**Regulating ESS**	**Supporting ESS**	**Cultural ESS**
• clean air • food • water • primary production of biomass (e.g. timber, fiber, fuel)	• climate regulation • flood control • disease regulation • waste treatment • water purification	• photosynthesis • nutrient cycling • water cycling • soil formation • oxygen production	• recreational aspects • aesthetic aspects • spiritual aspects • educational aspects

While this classification into four different categories might be useful for the taxonomical understanding of ESS, it has been identified as not useful within the valuation context by Fisher, Bateman and Turner (2010). Instead, the distinction between intermediate services, final services and benefits has been found as more constructive approach (Table 5). This is because it is important for the valuation exercises to value the endpoints which have a direct effect on human welfare, termed as 'benefits' in the economic field. While both intermediate and final services are ecological phenomena, intermediate services combine in complex ways to provide final services that have a direct effect in human well-being. The term is similar to what the *Millennium Ecosystem Assessment* refers to as supporting services. For example benefits such as food, wood and recreation are different from the services which provide them. Looking e.g. at clean drinking water for consumption, this is the benefit of the final service of water provision. This water provision itself is a function of intermediate services such as soil retention and nutrient cycling. The end benefit finally requires some built capital most of the time which might be an urban distribution system for the given example. Is is argued that this scheme, as opposed to the classification introduced by the *Millennium Ecosystem Assessment*, avoids or at least curbs the flaw of double counting. Based on the classification of four categories (Table 4), recreation would be regarded as cultural service, nutrient cycling as supporting service and water flow regulation as regulating service. If a decision-maker would be confronted with the valuation of a wetland conversion, a CBA including these three services would have the error of double counting because water flow regulation and nutrient cycling both support the provision of the same service under consideration, namely the provision of usable water. The recreational service is merely a human benefit of this water provision. Nevertheless, this argument does not mean that intermediary services do not have any value themselves since their deficit would result in a mal- or disfunction of ecosystems which are then not able to deliver the final services and benefits that they are capable of. For regulating services this would mean a decreased capacity to respond to environmental stresses such as natural hazards (Fisher, Bateman and Turner, 2010).

Table 5: Alternative Conceptualization of ESS (Bateman, Turner and Fisher, 2010)

Intermediate services	Final services	Benefits
pollination primary productivity	water regulation →	drinking water; domestic-use water; water for irrigation
structure and process	water purification →	recreational swimming; fishing; drinking water
soil formation	climate regulation →	reduced energy demand; crop production stability

The application of economic valuation techniques to the natural environment's complexities raises some challenges, the most fundamental of which is that there must be a sound foundation of natural science for such applications, according to the OECD (2018). The ESS concept provides the conceptual framework for this requirement of interdisciplinarity. Although it originated from the natural sciences, the concept is highly compatible with economic analyses since it emphasizes the role of ESS which contribute directly to human well-being (OECD, 2018). ESS demarcate from the so-called ecosystem functions, i.e. all physical, chemical and biological processes and interactions that occur in different ecosystems, by their anthropocentric perspective, i.e. the direct link between humans and the benefits of ecosystems. ESS are addressing all services and goods that serve people direct or indirect economic, material, health or psychological benefits (TEEB DE, 2012).

To strengthen the role of nature in decision-making, the concept of ESS is the most widely used of the four described - NBS, EBA, GI and ESS. Since there seems to be a tension between studying the values of ESS and the communication of those on the one hand and the utilization of the concept in practical planning on the other hand, GI is an important bridging concepts to incorporate ESS in the urban development domain (Pauleit et al., 2017). After the emergence of the concept, the NBS approach marked a subtly yet important shift in perspective. This shift is best described in the changed perception from people being the passive beneficiaries of nature's benefits to the proactive role of humans to protect, manage and/or restore natural ecosystems as a significant and purposeful contribution to addressing societal challenges (Cohen-Shacham et al., 2016).

4.3 Present Situation of Ecosystem Service Valuation

Many of the contributing papers to the literature of GI and ESS - by emphasizing their importance for human well-being and demanding their consideration within decision-making processes - entail the motivation of research about valuation rather than actually documenting findings of such research. While there seem to be many statements of the hypothesis that ecosystems deliver valuable services, there are fewer pieces which carefully test that hypothesis (Simpson, 2010). Most articles are of descriptive nature, in which the versatility of GI with regards to addressing climate change by providing ESS is acknowledged but no related measures are analyzed (see e.g. de Groot, Wilson and Boumans, 2002; Ghofrani, Sposito and Faggian, 2017; Hansen et al., 2019 and Li and Bergen Jensen, 2018). Others such as Young, Jones and Symons (2015) aim to frame GI and ESS within an economic framework but do not pursue further efforts to quantify those. Instead, authors are most commonly restricted to only list potential valuation methods without exemplarily applying them.

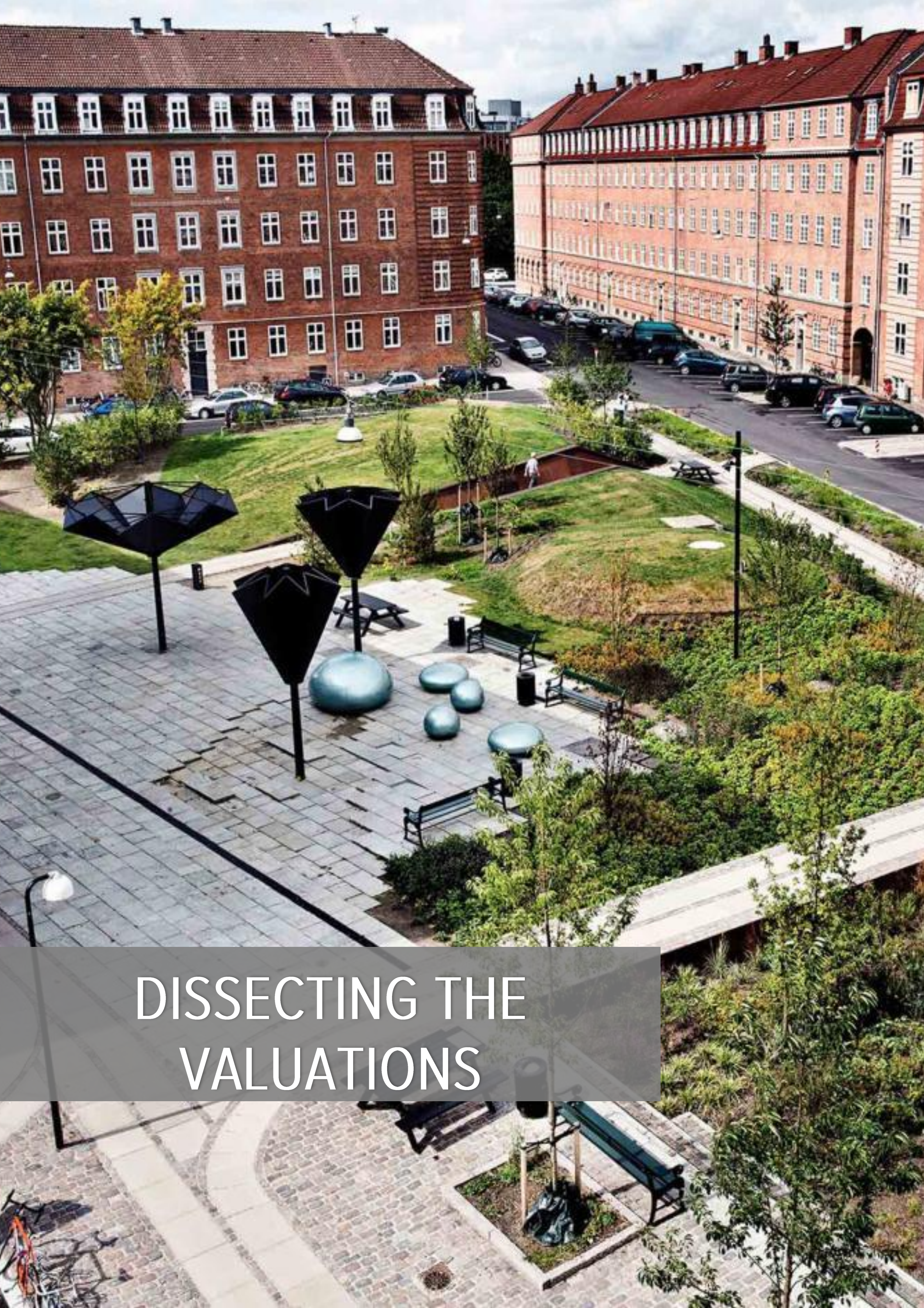
Because the valuation of regulating ESS is still an evolving domain of ecological economics, there are not many studies which address this topic in an urban context and even less with a focus on stormwater management and under consideration of monetary measures (Haase et al., 2014; Kumar and Wood, 2010). For GI measures and their delivery of ESS, where quantitative data has been made available, services such as carbon sequestration and storage, recreational services and provisioning services are more frequently quantified than others (Naumann et al., 2011; Haase et al., 2014). Within the investigated articles, green roofs have been found the most popular investigated GI structures (see e.g. Langemeyer et al., 2020; Nurmi et al., 2013 and Silva, Cruz and Teotónio, 2019). This is reflected in Li et al. (2019) who have found that among the five GI categories 'green roof', 'bioretention', 'bioswale', 'permeable pavement' and 'rainwater harvesting system', the study of green roofs represented the largest proportion, with bioretention and permeable pavement following (Li et al., 2019).

Where valuations have been conducted with regards to stormwater management, they are focusing on bio-physical processes and are mostly carried out by analyzing, simulating and modelling hydrology, hydraulics and water balance processes with support of software-based programs (Ruangpan et al., 2020). Exemplary investigations comprise e.g. the computational modelling of water depths in different points of the drainage system and have been carried out by Alves et al. (2019), Loc et al., (2017), Zellner et al. (2016) and Zhou et al. (2013). Software-based tools pose challenges for this report for multiple reasons. A major limitation is their design which makes the majority of them - contrary to CBA - only applicable within the specific country or region they were developed in. Furthermore, they are often connected to a relatively large amount of data input which makes their application more expensive and not free from outcome uncertainties. Many of the tools lack the incorporation of updated GI practices and are ill-equipped to model the current state of the art implementations accordingly (Jayasooriya and Ng, 2014). The specific problematic of software-based modeling tools for this report is that they 'hide' multiple information-producing steps within the model setup and therefore do not allow for an investigation in the context of the performativity approach which relies on the visibility of these assumptions.

Even when GI practices with relation to stormwater management are valuated without the use of rather complex modeling techniques, the monetary aspect of a quantificaton is missing (see e.g. Farrugia, Hudson and McCulloch, 2013; Logsdon and Chaubey, 2013 and Maragno et al., 2018). This aligns with the findings of Haase et al., (2014), who found that over two thirds of the investigated articles applied exclusively non-monetary indicators while only one third incorporated both non-monetary and monetary methods. Therefore, most assessments of benefits from GI rely on benefit transfer from other studies. In this context, Naumann et al. (2011) found that the availability of usable value estimates is as much a barrier to valuation as the difficulty of measurement of ESS delivery. This is because valuations are highly context-dependent and their results should be transferred across projects only with great caution (Naumann et al., 2011). While scientific articles about the general performance of different GI measures, such as rain gardens (see e.g. Chapman and Horner, 2010 and Hunt et al., 2006) and foremostly green roofs (see e.g. Locatelli et al., 2014; Stovin, Vesuviano and Kasmin, 2012 and Susca, Gaffin and Dell'Osso, 2011) in the context of water management are abundant, the monetization of effects, let alone CBAs are rarely subject of scientific research.

Overall it can therefore be concluded that there is a multitude of descriptive scientific articles about GI and their ESS delivery. Among those that carry out valuations, the domain of stormwater management is widely neglected and if valuations with this focus are conducted, they are mostly connected to hydrodynamic modelling tools which pose challenges due to the mentioned reasons. Furthermore, the valuations of stormwater related GI rarely include monetary quantifications and if so, these are carried out with methods other than CBA. Finally, the scientific studies which address the quantification and monetization of ESS delivered by GI with a CBA approach, have been further selected for the upcoming analysis.

DISSECTING THE VALUATIONS



5. Dissecting the Valuations

As mentioned in Chapter 3, the analysis is concerned with four recently published articles and the documentation of the IÖW-tool's procedure. The five documents focus on assessing the extended costs and benefits of SUDS in Berlin/Germany (Johnson and Geisendorf, 2019), stormwater GI practices in Grand Rapids/USA (Nordman et al., 2018), GI and community stormwater reduction in Beijing/China (Liu et al., 2016), SUDS in London/United Kingdom (Ossa-Moreno, Smith and Mijic, 2017) and green urban spaces in German cities (Klein, 2020). SUDS is understood as form of GI which replicates an area's natural drainage processes by using vegetation-based interventions such as swales or water gardens that increase local infiltration, attenuation and detention of stormwater (Johnson and Geisendorf, 2019; Ossa-Moreno, Smith and Mijic, 2017). The analysis is based on the factors listed in Table 3 and divided into four sections which are concerned with:

1. necessary background information related to the examined articles,
2. factors related to the investigated GI measures and ESS and their interpretation by the authors,
3. factors related to the quantification of the ESS and
4. factors related to the valuation, i.e. monetization of ESS.

In what follows, all findings from the analysis of the different factors will be presented. For reasons of clarity, only selected factors will be illustrated in smaller tables and figures whereas the complete listing in the form of an extensive Excel-sheet can be found in Appendix A. While the first part of the analysis in 5.1 will present the mapping of the project's background information with support of brief reviews, 5.2, 5.3 and 5.4 will analyze the authors' interpretations of benefits, their quantification and especially the application of the different valuation methods.

5.1 Background Information

To introduce the analyzed publications and provide information about their general approach, the following paragraphs will describe each article/project with regard to background factors such as the professional affiliation of the authors, the journal of appearance, the spatial and temporal scale of the projects, the identified vulnerabilities which necessitate a valuation of GI measures as well as the motivations and addressees of the articles. The findings are summarized in Table 6 at the end of the subchapter.

5.1.1 SUDS in Berlin

Johnson and Geisendorf, the authors of the first paper, research within the field of environmental economics and published their study about the neighborhood SUDS in Berlin the journal of *Ecological Economics*. While their valuation is conducted ex-ante, the article does not provide information about the current state of project implementation. The area of interest is a 1,170,000 m² neighborhood in the district Pankow northern of Berlin's city center, which is inhabited by around 19,000 people. In their valuation, Johnson and Geisendorf (2019) assess three different SUDS scenarios including e.g. extensive green roofs, tree drains, swale-trench systems and permeable pavements. The authors stress the focus on a predetermined combination of those features for each scenario instead of valuating single GI measures. Their project is grounded on the problem of increased runoff due to surface sealing which causes both quantitative and qualitative problems for the receiving water bodies. Because the project site does not lay within a flooding zone, the problem of higher water quantities is of second priority for the authors. Instead, their emphasis is on the water pollution through stormwater runoff.

The motivation of their publication is to demonstrate the economic feasibility of SUDS in order to inform decision-makers about the 'proper' assessment of planned stormwater projects. Consequently, the local administration is the main addressee of their valuation and the related results (Table 6).

5.1.2 GI in Grand Rapids

Nordman and the contributing authors of the paper stem from the domains of biology, economics and hydrology and published their article about the stormwater GI practices in Grand Rapids in the *Journal of Cleaner Production.* Whereas one of the authors is affiliated with the field of economics, the other three contributors work within fields dominated by natural science. Like the project in Berlin, the valuation is carried out ex-ante and no information is stated about when the project is to be realized. With a project size of over 117,000,000 m² and 200,000 considered inhabitants, it is the largest project among the reviewed articles both in terms of size and number of citizens. In their valuation, Nordman et al. (2018) compare six different single GI measures, including e.g. infiltrating bioretention basins, green roofs and rain gardens. Urban flooding, erosion and pollution are identified as the key issues whereas downstream communities are regarded as particularly vulnerable toward these adverse consequences.

The motivation of their study is to help academic researchers and particularly local stormwater managers to understand the benefits and costs of stormwater GI to foster the realization of cost-effective practices. They address their recommendations to the local administration which expends significant resources every year to manage stormwater. To a lesser extent, they also consider private landowners an important target group because they are currently not encouraged to install onsite stormwater management measures (Table 6).

5.1.3 GI in Beijing

Liu and his co-authors, who work within the fields of urban and regional ecology as well as ecohydrology with a focus on eco-environmental science and technology in China, valuate GI on community stormwater reduction and utilization in Beijing. Their article was published in the journal of *Environmental Management*. Like in the abovementioned projects, an ex-ante assessment has been conducted and information about the implementation status is not available. The project in Beijing has with around 55,000 m^2 by far the smallest project size. Similar to the project in Berlin, the Beijing project is planned to be implemented on a neighborhood scale and covers 54,783 m^2. In their study, the authors consider four different scenarios in the form of three different GI measures - green space depression, permeable pavement, storage pond - and their integrated application. The authors regard urban flooding, water shortage and surface water pollution as the vulnerabilities of interest, with the rapid urbanization process in China being the underlying reason.

Liu et al. (2016) concentrate specifically on the promotion of GI in China as example for a developing country and underline the competition of GI with gray infrastructures in decision-making. Unlike the previously mentioned projects, Liu et al. (2016) do not focus on the local administration as the primary addressee but target foremostly the local community with their valuations. Particularly residential builders and owners are encouraged to implement GI facilities because they are identified as forerunners for investors, who then use GI measures as profitable business investments. This motivation is based on the current lack of funding possibilities for GI measures which curbs their uptake by the local population (Table 6).

5.1.4 SUDS in London

Ossa-Moreno, Smith and Mijic's scientific background is civil and environmental engineering which makes their professional affiliation the most technically oriented among all projects. Their publication about SUDS in London appeared in the *Sustainable Cities and Society* journal. Again, the valuation is performed ex-ante, with no information provided about the implementation time of the project. The considered project area is ca. 2,500,000 m² large, with a related population of around 16,000 people. Just like Johnson and Geisendorf (2019), their focus is on a set of measures rather than single GI features. Overall, the authors compare amongst a set of five different scenarios of SUDS combinations. It should be noted that these scenarios entail certain features, particularly rainwater tanks and rainwater harvesting cisterns, which can be regarded as rather technical compared to the more 'natural' usage of GI in the other projects. This can presumably be connected to the more technical background of the authors. The scenarios are valuated regarding their performance to tackle the challenge of urban flooding.

Ossa-Moreno and his colleagues stress the relevance of incorporating 'wider benefits', i.e. benefits not immediately related to stormwater management, into the assessment and pursue a notable change in the valuation of proposed SUDS to increase their global uptake in cities. Like the project of Liu et al. (2016), this project primarily targets the local community. More specifically, they argue for an incorporation of wider benefits as leverage to convince decision-makers of the economic benefits of GI measures in order to eventually subsidize property owners (Table 6).

5.1.5 IÖW-Tool

Klein, who is the author of the documentation paper supporting the IÖW-tool, works within the field of ecological economy research. Because the tool is currently under development, the documentation paper has not been published yet. The project size for the IÖW-tool can be chosen dependent on the desired spatial context and is assumed to have a large to medium-sized German city scale by default. In the documentation of the tool's procedure, the urban green spaces in the three German cities Karlsruhe, Leipzig and Nuremberg are valuated. The general objective is to provide a tool for cities to quantify and monetize the ESS of urban green spaces. The IÖW-tool is, similar to the abovementioned studies, concerned with ex-ante valuations, i.e. determining whether something that has not been done yet should be done. Connected to this kind of valuation is usually the question whether something should be done at all (OECD, 2018). Unlike the other projects, the valuation made possible with the IÖW-tool is the only one that acknowledges the alternative of not taking action as possible option and Klein (2020) therefore the only author who incorporates this main characteristic of CBA into the valuation process. This is done by giving cities the opportunity to calculate the status quo ESS performance of their current green areas. Starting from this status quo, a greening or even de-greening scenario can be envisioned. This scenario results from the increase or reduction of the proportion of green spaces, green bicycle and pedestrian paths, green roofs and the number of street trees. The magnitude of increase or reduction can be chosen at will of the user. The effects of the scenario are first quantified and then monetized based on the ESS of water retention, temperature regulation, carbon regulation, air pollution reduction and amenity increase. For this report, the ESS of water retention is the key part. Ultimately, the positive or negative annual benefits arising from a given scenario can be compared to the status quo. Given the opportunities to individually adapt the input parameters, i.e. the spatial scale, the considered rainfall events, and different greening scenarios, the IÖW-tool appears to provide a significantly higher flexibility than the other projects. However, this flexibility is associated with the more generic characteristic of a tool as opposed to the other four publications, which describe the assessment of planned implementations.

The IÖW-tool, like Johnson and Geisendorf (2019), identifies surface sealing as cause for increased surface runoff which then causes the sewage system's overstraining. In contrast to Johnson Geisendorf (2019), the tool focuses on the increased amount of runoff instead of the worsened water quality.

Klein (2020) aims to provide a tool for cities to quantify and monetize ESS of urban green spaces in Germany, which makes the local administration the target of her valuation results. This is because the local administration is the user and the addressee of the valuation at the same time. Although some of the input parameters for the quantification of ESS and particularly the valuation technique can eventually be chosen by the local administration, the documenting paper of the tool recommends input parameters, quantification technique and valuation method. The following sub-chapters will therefore take their point of departure in these recommendations (Table 6).

Table 6: Selected Factors for introductory information

Factor	SUDS in Berlin	GI in Grand Rapids	GI in Beijing	SUDS in London	IÖW-Tool
Source	Johnson and Geisendorf, 2019	Nordman et al., 2018	Liu et al., 2016	Ossa-Moreno, Smith and Mijic, 2017	Klein, 2020
Size of Project	'neighborhood scale': 1,170,000 m²; 19,000 inhabitants	117,400,000 m²; 200,000 inhabitants	'neighborhood scale': 54,783 m²	2,500,000 m²; 16,000 inhabitants	dependent on selected area; city scale by default
Options under consideration	3 different forms of SUDS	6 different GI measures	3 different GI measures and their integration	5 different forms of SUDS	status quo; free choice of future scenarios
Motivation of Project	Better assessment of planned stormwater management projects by demonstrating economic feasibility of SUDS	Foster the implementation of cost-effective practices by understanding relative benefits of stormwater GI	Promotion of GI in China by showcasing their economic advantages compared to gray infrastructure	Change in the valuation of proposed SUDS to increase their uptake in cities worldwide by showing the relevance of wider benefits	Provision of a tool for cities to quantify and monetize ESS of urban green spaces in Germany
Addressees	local administration	local administration, private landowners	local community, investors	local community	local administration

Overall, it can be noted that the disparities occurring between the different projects are mainly inevitable project characteristics connected to the specific local contexts, such as the spatial scale, the considered number of affected populations and the different scientific backgrounds of the authors. Whereas the publications appear in different scientific journals, all these journals are of transdisciplinary nature and focus on application-related topics rather than the development of theoretical approaches. The general motivation for the valuations in the form of reducing stormwater runoff is shared by all authors and only nuances, e.g. the concentration on water quality instead of water quantity (Johnson and Geisendorf, 2019) or the particular acknowledgement of the vulnerability of downstream communities (Nordman et al., 2018), are apparent. The emphasis of Liu et al. (2016) and Ossa-Moreno, Smith and Mijic (2017) on the current lack of funding for GI measures are concretizing remarks regarding the addressees of the valuation, which do not interfere with the generally shared objective of all authors to elaborate on the monetary valuation of GI benefits and the tools which put them into place.

While a tool generally has a more generic character than already conducted valuations, the IÖW-tool has a unique characteristic by addressing the status quo situation which allows the comparison before and after the change. All the other valuations compare different kinds of ‘doing something’. Hence it can be assumed that these valuations are presuming the economic advantages of GI compared to gray infrastructure. This does not necessarily imply that these economic advantages are doubted by the authors of the IÖW-tool but rather that they take a more cautious stance. This ties in well with the skepticism toward economic valuations in Germany found by Meyerhoff and Petschow (2014) (see also Chapter 1). It seems that users of the IÖW-tool, i.e. city administrations, at least want to have the possibility to comprehend the magnitude of economic advantages and relate them to the original situation.

5.2 Investigated GI and ESS

All articles acknowledge the concept of GI, whereas the projects in Berlin and London specifically focus on SUDS as one form of GI. These projects valuate complete SUDS, i.e. the combination of multiple features, rather than single SUDS measures, understanding SUDS as set of measures that replicate the natural water cycle through evapotranspiration, infiltration and detention with additional benefits such as mitigating the heat island effect, improving air quality and providing recreational sites. SUDS arguably add a more technical aspect to the term of GI which is evident particularly in the English project. Here, features such as roof disconnection through water cisterns and large rainwater tanks are among the valuated measures next to more natural measures such as infiltration strips and urban wetlands. Although the project in Berlin addresses SUDS as well, the emphasis is on more natural features such as swale-trench-beds, ponds, tree drains and swales.

The projects in the USA and China do not particularly focus on SUDS, thus they valuate GI measures such as porous asphalt, rain gardens, bioretention basins and conservation of natural areas in the USA and green space depression and storage ponds in China. In the American context, GI is understood as an integrated approach to mimic natural hydrology and link ecological and economic sustainability. By viewing stormwater as a resource, the focus is on the onsite effects of GI as opposed to gray infrastructure which follows the maxim to move water offsite as quickly as possible and therefore imposes detrimental effects on downstream communities. In the Chinese context, GI refers to a broader view and a coordinated effort to employ soils, vegetation and natural processes for water management in order to create healthier urban environments.

The German IÖW-tool understands GI based on the rather broad definition by the *German Federal Ministry of the Environment, Nature and Conservation, Construction and Reactor Safety* which regards GI as all forms of green open spaces and green buildings, including e.g. nature conservation areas, allotment gardens, cemeteries, parks, woodland, facade and roof greenery (German Federal Ministry of the Environment, Nature and Conservation, Construction and Reactor Safety, 2015). The IÖW concretizes this definition by putting the main focus on surface cover types according to the *Urban Atlas* of the *Copernicus Land Monitoring Service*. This document enables the classification of land cover types 'green urban areas', 'forests', 'herbaceous vegetation associations' and 'sports and leisure facilities' which are, besides the additional categories of 'near-natural green spaces', 'greened bike and pedestrian paths', 'green roofs' and 'street trees' the key land cover types for the IÖW. Hence, GI is here directly connected to the surface cover type and its characteristics for the ESS which are of interest for the valuation (see Appendix A).

Considering how ESS are addressed, it becomes evident that two projects and the IÖW-tool do not incorporate ESS definitions as such but provide alternatives. In the article from Liu et al. (2016), ESS are understood as benefits of GI while Ossa-Moreno, Smith and Mijic (2017) define ESS as the wider benefits of SUDS, the primary benefit being the replication of the natural drainage processes of the area. The document from the IÖW refrains from defining ESS since its characterization as supporting documentation of the tool concentrates on the procedural steps of the valuation and builds upon a predetermined understanding of ESS as the benefits which humans obtain from the natural environment. A similar definition is shared by Johnson and Geisendorf (2019) as well as Nordman et al. (2018), who regard ESS as the benefits humans enjoy through ecosystems which are present in urban contexts and the direct and indirect benefits people obtain from ecological systems (see Appendix A).

The different studies investigate different numbers of ESS, both in terms of ESS related to water management and other ESS (Figure 9). With nine ESS, Johnson and Geisendorf (2019) consider the most ESS in total whereas three of them are related to water management. Nordman et al. (2018) valuate eight ESS in total, with an equal distribution among those which are concerned with water management and those concerned with other environmental benefits. Only the study by Liu et al. (2016) concentrates completely on water management-related benefits. Ossa-Moreno, Smith and Mijic (2017) valuate a total number of seven benefits while four of them are directly connected to water management. The IÖW-tool by Klein (2020) valuates both the smallest amount of overall ESS and water management-related ESS with five and one, respectively.

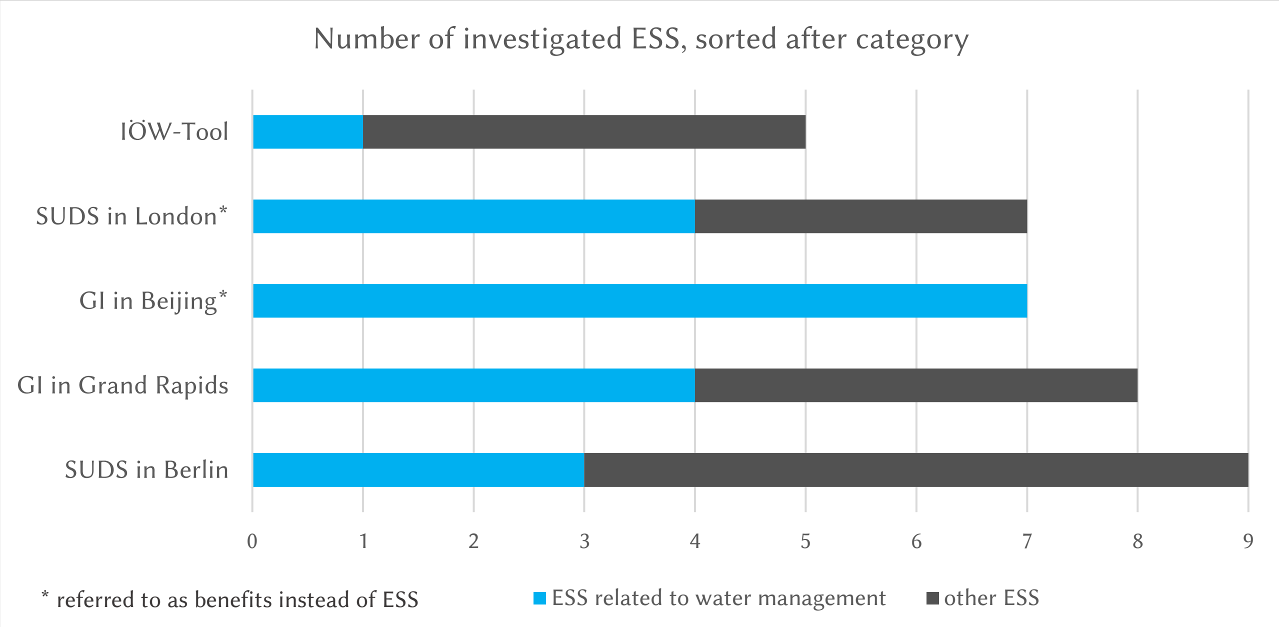


Figure 9: Number of investigated ESS, sorted after category

Not only the number but also the type of valuated ESS vary amongst the projects. Table 7 summarizes the different types of ESS valuated by the projects to provide a project-wide overview and concretize Figure 9 which only entails the numerical distribution of ESS.

Table 7: Type of valuated ESS after categories

Study	ESS related to Water Management	Other ESS
SUDS in Berlin **(Johnson and Geisendorf, 2019)**	- runoff reduction - groundwater recharge - drinking water saved	- air quality regulation - CO_2 storage and sequestration - energy savings - increased building longevity - habitat creation - aesthetic improvements
GI in Grand Rapids **(Nordman et al., 2018)**	- runoff reduction - phosphorus removal - total suspended solids removal - flood risk reduction	- public amenity - energy savings - air quality regulation - CO_2 storage
GI in Beijing **(Liu et al., 2016)**	- benefit from substituting tap water	

	- benefit from saving green space irrigation - groundwater recharge - water quality improvement - benefits from flood protection expense exemption - benefit from saving the operational costs of drainage facilities - benefit from saving the sewage treatment fees	
SUDS in London (Ossa-Moreno, Smith and Mijic, 2017)	- runoff reduction - groundwater recharge - rainwater harvesting - benefit from saving wastewater and surface water treatment fees	- air quality regulation - biodiversity and ecology - amenity value (only valuated for basins)
IÖW-Tool (Klein, 2020)	- runoff reduction	- temperature regulation - CO_2 regulation - air quality regulation - amenity value

This overview shows that the only ESS related to water management, which is valuated within all project contexts, is runoff reduction. Liu et al. (2016) break down this benefit into multiple other benefits such as the benefit from saving the operational costs of drainage facilities or the benefit from saving the sewage treatment fees. The ESS of groundwater recharge is valuated for the projects in Berlin, Beijing and London while water quality improvement is addressed at least by the projects in Beijing and Grand Rapids, here broken down into phosphorus and total suspended solids removal. Another benefit valuated within two project contexts is the benefit from saving the sewage treatment fees, occurring in the projects in Beijing and London. All remaining ESS related to water management are valuated exclusively within the respective project context and therefore very site-specific, e.g. drinking water saved for SUDS in Berlin, rainwater harvesting for London or the benefit from saving green space irrigation in Beijing. Among the ESS, which are not related to water management, air quality regulation and the amenity value are the ESS most commonly valuated in the projects. Carbon dioxide regulation, i.e. storage and/or sequestration is addressed by three of the projects, namely the one in Berlin, the one in Grand Rapids and the IÖW-tool. ESS in the form of energy savings are addressed within the project contexts in Berlin and Grand Rapids whereas the remaining ESS, i.e. increased building longevity, habitat creation, biodiversity and ecology and temperature regulation are valuated in only one of the projects, respectively (Table 7).

Overall, it can be concluded that addressing the concern of increasing stormwater runoff takes place with GI measures that are highly diverse among the different projects. Relating to the number of investigated ESS, certainly a special role can be assigned to the project in Beijing since it is the only project that solely concentrates on water management related benefits. Therefore, the benefits are described in a greater level of detail than in other projects and do not include any benefits outside the water management domain. It is noteworthy that the IÖW-tool is limited to only one ESS related to water management, namely runoff reduction. This can be explained by the fact that the sole focus of the tool is not just on stormwater management, as it is designed to provide a more holistic assessment of urban GI and their ESS. Moreover, the findings about the number of investigated ESS must generally be treated with caution because they do not reveal any information about the monetary value of their benefits.

Elaborating on the different types of valuated ESS, the ESS of runoff reduction is the only common denominator amongst all projects. Overall, the valuation of ESS in relation to water management is a very heterogeneous field, as also is the case with the other ESS. To elaborate on the issue of what exactly is valued, i.e. rendered visible, in the different projects, a look back to the different conceptual understandings by the *Millennium Ecosystem Assessment* and Fisher, Bateman and Turner (see Table 4 and Table 5 in Chapter 4.2) is useful. As Fisher, Bateman and Turner (2010) argue, the decision on what should be valued - the ecosystem processes, ESS or benefits - is a highly contentious issue within the valuation of regulating ESS. In their opinion, the distinction between intermediate ESS, final ESS and the resulting benefits provides a more meaningful categorization of ESS than the *Millennium Ecosystem* Assessment, which distinguishes 'only' the type of ESS, i.e. provisioning, regulating, supporting and cultural ESS. Since benefits are the end element of the ecosystem process-service-benefit-chain, only these benefits enter the domain of well-being, which is likely to be the most interesting for the decision-making discourse. For example, the ESS of runoff reduction does not reveal information about the 'direct' effect of the ESS on human welfare while the benefit from flood protection expense exemption links the ESS of runoff reduction to the benefit of improving human well-being. Whereas four of the projects - SUDS in Berlin, GI in Grand Rapids, SUDS in London, the IÖW-tool - adapt the conceptual understanding of the *Millennium Ecosystem Assessment* and categorize ESS as regulating services next to the other three categories of provisioning, supporting and cultural ESS, the project about GI in Beijing builds upon the notion by Fisher, Bateman and Turner (2010). In that way, Liu et al. (2016) concentrate more closely on the benefits immediately affecting people, such as saving money for the irrigation of green space, instead of the final ESS provided. This is because Liu et al. (2016) do not define ESS per se but interpret them purely as benefits of GI, and because their sole focus on water management related ESS arguably allows them more depth in their study.

Consequently, there seem to be different opinions as to what should be rendered visible, i.e. counted in the valuation of ESS. It can only be speculated at this point which underlying trajectories cause the authors to choose some ESS over others, concretize some of them and widely neglect others. What can be said is that the selection of ESS aims at making each valuation as strong as possible and that evidently this 'strength in numbers' is interpreted differently by the different authors.

5.3 Quantifying ESS

The valuation of ESS, i.e. assigning monetary values to the ESS, is preceded by quantification procedures, which build upon the intensity of considered precipitation events. For the intensity of considered precipitation events, the notion of the recurrence period is important because it reveals information about the power of their impact. The recurrence period is a term to describe the return interval of precipitation events based on both the magnitude and the duration of the event and is therefore regarded as a widely acknowledged proxy for the severity of rainwater events. For example, a 20-year rain event of a given strength and duration has a 5 % occurrence chance in any given year and a 500-year rain event has a 0.2 % occurrence chance in any given year. The term is based on statistical calculations of historical rainfall amounts which have to date back at least ten years (United States Geological Survey, 2019). As can be seen in the following paragraphs, the severity of considered rainfall events varies widely across the projects, from an 'everyday rain' until a rainfall event with a statistical return time of 1000 years.

Johnson and Geisendorf's (2019) input data adopted the approach of an already conducted project named *KURAS* which addressed concepts for urban wastewater systems and rainwater management in Berlin and evaluated already existing rainwater management measures (Matzinger et al., 2017). Therefore, rainfall data was based on the year 1990 because this year has been identified as representative example for the average rainfall amount and distribution for the examined area. This shows that the emphasis of this project is not on extreme flooding events but usual rainfall amounts. Nordman et al. (2018) use a 19.6 mm as lower and a 25.4 mm rain event as upper limit. Given the fact that a 90th percentile 24-hour rain event is taken as design criterion for GI measures, it can be assumed that only moderate rainfall events were taken into consideration. Liu et al. (2016) took a set of four different rainfall scenarios into account. These reach from a rain event with a statistical recurrence period of one year with 24 hour duration and a resulting rainfall amount of 45.6 mm over rain events with recurrence periods of two and five years, 24 hour durations and 72 mm and 115.2 mm respectively to a rain event with a 10 year recurrence period, a 24 hour duration and a resulting amount of 158.3 mm. Ossa-Moreno, Smith and Mijic (2017) based their quantifications on three different rainfall events with a 30 year, a 100 year and even a 1000-year recurrence period while they did not provide information about the duration and amount of the rainfall events. Although the recurrence period is only one indicator for the strength of the rainfall event since the duration and rainfall amount are other important determinants, it can be assumed that the 1000-year rain event is the most extreme rainfall event among all projects given the similar rainfall patterns between London and e.g. Beijing. The IÖW-tool did not presume a certain rain event by default. Rather, different scenarios can and should be applied within the CBA dependent on the user's preferences for scenarios and the local rainfall patterns (see Appendix A).

All projects relied on external support for the quantification of ESS. While Johnson and Geisendorf (2019) utilize modeling of experimental data from the *KURAS* project, Nordman et al. (2018) use the Excel-based *Construction Stormwater Toolbox* developed by the *New York City Department*. In that way, they used a so-called 'benefit function transfer' since they did not transfer the outcomes of other studies to their project - as done in the benefit transfer method - but adapted the calculation concept originally developed for a different study site, including different incomes and preferences of the populations and differences in the environmental attributes being valued. Furthermore, the authors used the *Rainwater Rewards Calculator*, a web-based stormwater value calculator accessible for citizens, landowners and policy makers, which estimates the reduced runoff quantity through the implementation of GI measures (West Michigan Environmental Action Council, 2020). Liu et al. (2016) relied on a quantification method developed by Liu et al. (2014), which calculates urban stormwater runoff with a scheme entailing precipitation, evaporation, canopy interception, among others (Liu et al., 2014). In this way, it is similar to the IÖW-tool which calculates the amount of retained stormwater with the so-called discharge coefficient method which takes the surface cover type and related discharge coefficient, the area of GI measure implementation and the chosen rain event into account (Klein, 2020). Ossa-Moreno, Smith and Mijic (2017) based their quantification on the *Adaptation Support Tool* developed within another project called *The Blue Green Dream project*, together with the *British Environment Agency's* updated flood maps for surface water and rainfall and evaporation patterns derived from the *British Geological Survey* (see Appendix A).

The reliance of the projects on external information has three implications. First, it accentuates the notion of Hirschman and Berman (2014) who identified the "enrolment of many different actors" (p. 797) as indispensable requirement for sociotechnical devices such as CBA. These actors play important roles at each information-producing step, e.g. through collecting information that go into the device and developing the procedures that produce the calculations and have therefore direct influence on what and what not becomes countable. Second, it leads to a difficult traceability of these underlying assumptions which eventually led to the determination of numerical inputs. And third, it can serve as a counterexample for the IÖW-tool which should ensure the transparency of underlying assumptions, calculations and estimates to the highest extent possible.

5.4 Valuating ESS

Through the application of different methods, the quantification results are 'translated' into monetary values and enable the valuation. Not only the valuation methods themselves, but also the related justifications, limitations, stakeholder involvement and beneficiaries are critically examined in this sub-chapter. Particularly the beneficiaries of the valuations are a revealing factor because they express the very core idea of CBA, namely the statement that monetary benefits reflect an increase in human well-being (OECD, 2018). Following this maxim, the determination of benefits raises the question 'Who are those humans whose well-being is increased, i.e. who profits from the implementation of GI measures and the ESS they provide?'. The beneficiaries of the valuation, if stated by the authors, can give an answer to this question and test the claim that most cost-benefit analyses do not acknowledge distributional consequences, i.e. do not state whose well-being is affected by monetary benefits to what extent (Hirschman and Berman, 2014).

Across all projects, a total number of 20 ESS has been valuated with five different valuation methods. The market price-based method was the most often used method and has been applied six times whereas four of these applications can be attributed to the project by Liu et al. (2016). The second most commonly used method was the substitution cost method with five applications while three of these applications have been made by Nordman et al. (2018). This is followed by the benefit transfer method with four applications. The damage cost method and the avoidance cost method have been applied twice (Figure 10). Without pre-empting the notions at the end of this sub-chapter, two things become apparent already. First, no usage has been made of SP methods and RP methods. Second, neither of the authors motivated their choice of the applied valuation methods.

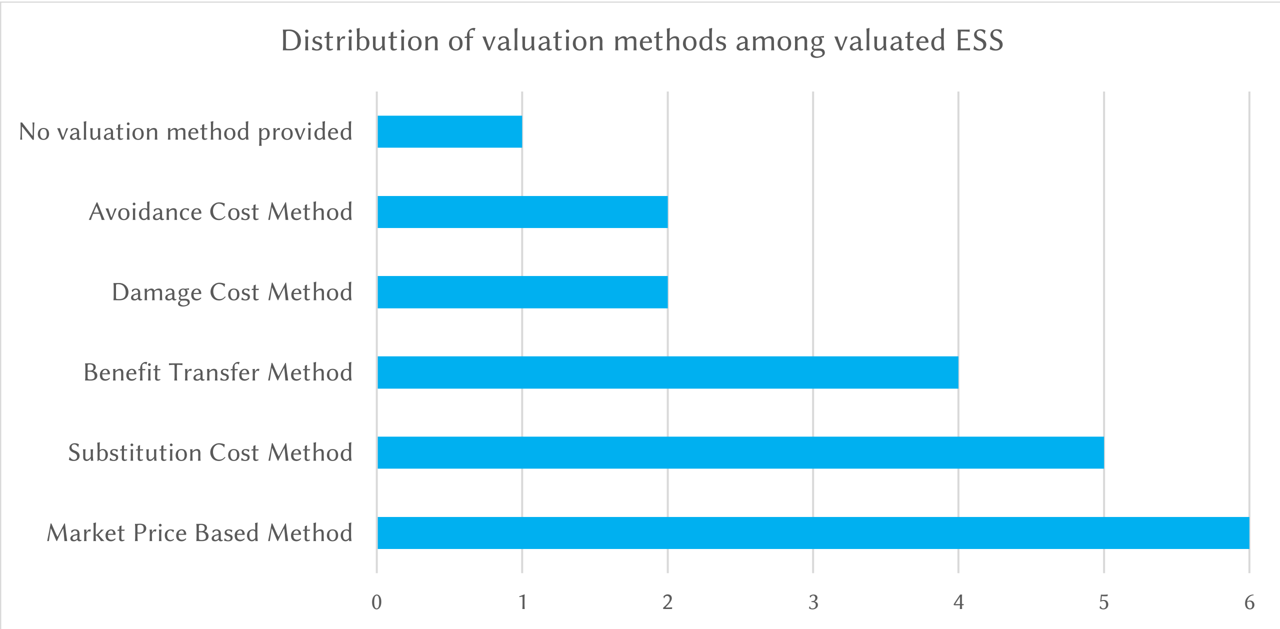


Figure 10: Distribution of valuation methods among valuated ESS

Initially, the analysis also aimed to investigate the numerical results of the projects in the form of monetary units - such as the GI measure(s) with the highest assigned value or the ESS assigned with the highest monetary benefit - to enable a direct comparison of values among projects. However, a comparison between these factors for all projects is problematic for different reasons. Firstly, GI measures and ESS can be hardly related to each other since the authors do not provide information about which ESS is delivered to which extent by which GI measure. This makes the relation of GI measure to ESS within a project already challenging. Moreover, some projects (see Johnson and Geisendorf, 2019; Ossa-Moreno, Smith and Mijic, 2017) do not even assess single GI measures but only combinations thereof. Secondly, the projects have been implemented at different times and therefore made use of different inflation rates. Aggravatingly, the projects have been conducted in different locations, applying the local currencies and using different costs for GI measures. Consequently, the variety of different investigated GI measures and valuated ESS, combined with different monetary currencies, dates of valuation, and local spatial contexts make a comparison of costs and benefits on a numerical basis not meaningful. Therefore, the following paragraphs will present the application of the valuation methods within each specific project context and elaborate on the details of the valuation execution, including the stated reasons, beneficiaries of the investigated GI measures and stakeholder involvement.

5.4.1 SUDS in Berlin

The water management related ESS investigated by Johnson and Geisendorf (2019) are runoff reduction, groundwater recharge and drinking water saved (Table 7). For their monetization, Johnson and Geisendorf (2019) use the market price-based method and the benefit transfer method (Table 8).

They distinguished the monetary benefits from ESS into ‘private’ and ‘social’ benefits whereas the former are valuated through market-based methods and the latter through non-market based methods since “they have no direct monetary value” (Johnson and Geisendorf, 2019, p. 195). As a consequence, they split the ESS of runoff reduction into the private benefit of the reduction of the rainwater fee and the social benefit of runoff reduction which is defined as the reduction of pollutants in the water and not as the reduction of runoff amount. This can be explained by the authors’ notion that the project area is not located within flooding zones. The private benefit of the reduction of rainwater fee was then valuated with the market price-based, i.e. applying the rainwater fee for property owners because a higher percentage of stormwater is retained onsite which results in reducing the surface runoff draining into the sewer system. The same method was applied for the ESS of groundwater recharge by applying the groundwater fee because the natural infiltration of GI measures such as tree drains and swales increases the amount of water which infiltrates into the groundwater. Interestingly, the benefit of the ESS ‘drinking water saved’ was incorporated into the overall valuation but no information was provided about how this ESS was valued, i.e. there is a lack of transparency about the technique used to assign the monetary value to the benefit. The most precarious valuated ESS was the public benefit of runoff reduction in the form of pollutant reduction, i.e. dust, heavy metal and organic substance reduction, in the water. For this ESS, a benefit transfer from another study was applied. This study has determined the ESS derived from a WTP estimation conducted for the improvement of the river Spree from a poor to moderate water quality status. The benefit transfer seems to be questionable insofar because the cultural importance of the Spree is significantly different from the cultural importance of the river Panke, which is assigned with the ESS in the project. According to the city of Berlin, no river is as closely connected to Berlin as the Spree since the city was created adjacent to the river and is shaped by it. Originally primarily dominated by industrial development, the river has increasingly gained importance for urban development, recreational and ecological aspects over time (City of

Berlin, 2020). Consequently, it is questionable whether people attribute the same cultural importance to the Panke and therefore assign as high monetary values to a related water quality improvement as they do in the case of the Spree. The usage of the benefit transfer method in this context becomes even more contentious because this ESS has been assigned with the highest monetary benefit of all social benefits within the study, making it the strongest argument for GI implementation on a CBA basis (Johnson and Geisendorf, 2019; see Appendix A).

Table 8: Valuation Methods applied by Johnson and Geisendorf, 2019

SUDS in Berlin (Johnson and Geisendorf, 2019)	
Valuation Method	**Ecosystem Service**
Market Price-Based Method	runoff reduction (private benefit: reduction of rainwater fee)
	groundwater recharge
Benefit Transfer Method	runoff reduction (social benefit: reduction of pollutants)
No valuation method provided	drinking water saved

Johnson and Geisendorf (2019) justified their selection of valuation methods by stating that quantifiable values for Berlin or Germany have been used where possible and benefit transfers were applied when no method could be directly adopted. By involving stakeholders such as administrators of the city district, estate managers, and other public interest groups, a sensitization toward local preferences for GI measures is apparent. Together, these stakeholders prioritized relevant GI measures prior to their valuation based on local requirements. The separation of benefits into private and social benefits emphasizes the motivation of the authors to specify different beneficiaries of GI measures, i.e. to provide a higher level of precision of 'what counts for whom'. This distinction of benefits helped to identify property owners (see benefit of reduction of rainwater fee) and citizens (see benefit of groundwater recharge, reduction of pollutants and drinking water saved) as beneficiaries of Gi implementation and can be interpreted as promising attempt to increase human well-being, complying with the general maxim of CBA. However, the costs and benefits of GI measures have eventually not been distributed among the stakeholders of property owners, the city, the water works company and private people since the aim of the study was to analyze the economic performance of GI measures as a whole (Johnson and Geisendorf, 2019; see Appendix A).

5.4.2 GI in Grand Rapids

In the project of Nordman et al. (2018), the water management relevant ESS are runoff reduction, phosphorus and total suspended solids removal and flood risk reduction (Table 7). While the substitution cost method was applied for runoff reduction and the pollution removal, the damage cost method was used for monetizing the flood risk reduction (Table 9).

Regarding the runoff reduction, the substitution cost method monetized by determining the avoided costs for the corrective and preventative maintenance of gray infrastructure, i.e. how much money was saved by not having to pay for the gray infrastructure that would alternatively have to handle the stormwater. Interestingly, the focus here was 'only' on the corrective and preventative maintenance of already existing infrastructures and not additionally on the investment costs of new infrastructures. It can therefore be assumed that the considered rainfall events were not expected to overstrain the current infrastructures. An analogous procedure was conducted for the pollution removal by determining the avoided costs for their treatment in a wastewater treatment plant. Since the ESS of flood risk reduction was concerned with damage to potentially affected downstream communities, the monetary value was determined by estimating the avoided costs for the damage compensations. The figures of damage compensation were derived from a recent flooding event in 2013 where around $ 450 million of damages have been caused in downtown Grand Rapids. However, this approach should be scrutinized because the rainfall events responsible for the 2013 flooding have been far more severe than the threshold chosen for the project (McMillin, 2013). It can therefore be doubted whether the data can be taken as representative indicator and therefore whether the applied monetary values for the damages and therefore also the value of the ESS is overestimated (Nordman et al., 2018, see Appendix A).

Table 9: Valuation Methods applied by Nordman et al., 2018

GI in Grand Rapids (Nordman et al., 2018)	
Valuation Method	**Ecosystem Service**
Substitution Cost Method	runoff reduction
	phosphorus removal
	total suspended solids removal
Damage Cost Method	flood risk reduction

Nordman et al. (2018) did not provide a thorough justification for their choice of valuation methods but only addressed that budget constraints and the lack of funding for valuation projects forced them to use the *Construction Stormwater Toolbox* developed by the *New York City Department* instead of developing their own technique. Whereas there is no direct stakeholder involvement related to either quantification or monetization of GI measures, it should be noted that the applied *Rainwater Rewards calculator* is a user-friendly online tool which enables everyone to calculate the monetary value for a great variety of GI measures. Identifying the beneficiaries of the valuation, certainly downstream communities profit from the ESS of flood risk reduction since less damages occur to their properties. Regarding the ESS of runoff reduction and pollutant removal though, the beneficiaries cannot not be clearly identified. It is to assume that the saved costs for treating runoff and polluted water affect the budgetary situation of the local administration positively. However, no further information was provided by the authors to what extent these saved costs are allocated to the citizenship (Nordman et al., 2018; see Appendix A).

5.4.3 GI in Beijing

Liu et al. (2016) focussed only on water management-related ESS in their project, namely the benefit from substituting tap water, the benefit from saving green space irrigation, the benefit from groundwater recharge by infiltration, the water quality improvement by pollutant elimination, the benefit from the flood protection expense exemption, the benefit from saving the operational costs of drainage facilities and the benefits of saving the sewage treatment fees (Table 7). The applied valuation methods for the different benefits are the market price-based method, the avoidance cost method and the substitution cost method (Table 10).

The market price-based method has been applied for the benefit from substituting tap water, the benefit from saving green space irrigation, the benefit from groundwater recharge and the benefit from the flood protection exemption by incorporating the prices for tap water, the prices for irrigation water, the groundwater price and the flood prevention charge, respectively. Particularly the benefit from the flood protection exemption raises questions because the flood protection expense must be paid by the developer before the community is constructed. Since the project location is an already existing community, the inclusion of this benefit seems rather inappropriate. The avoidance cost method was used to monetize the benefit from water quality improvement by pollutant removal through determining the opportunity costs of removing these pollutants in the surface runoff instead them being retained by GI measures. Lastly, the substitution cost method was applied to the benefit from saving the operational costs of drainage facilities by determining the operational costs of pipelines and to the benefit from saving sewage treatment fees by determining treatment costs in sewage treatment plants. It should be noted that the authors refrained from valuating benefits such as the improvement of air quality, recreation and restoring ecological habitat through GI because they only took into account benefits which are "easier to quantify and calculate (...) by simply methods" (Liu et al., 2016, p. 1022). By only using market price-based and cost-based valuation methods, the authors therefore arguably regarded methods related to actual and intended behavior as too difficult. This reveals that the perceived difficulty to determine ESS serves as justification for what to render visible and therefore countable within the valuation (Liu et al., 2016; see Appendix A).

Table 10: Valuation Methods applied by Liu et al., 2016

GI in Beijing (Liu et al., 2016)	
Valuation Method	**Ecosystem Service**
Market Price-Based Method	benefit from substituting tap water
	benefit from saving green space irrigation
	benefit from groundwater recharge
	benefit from flood protection expense exemption
Avoidance Cost Method	benefit from water quality improvement
Substitution Cost Method	benefit from saving the operational costs of drainage facilities
	benefit from saving sewage treatment fees

Liu et al. (2016) did not state reasons for their selection of valuation methods and did not involve stakeholders. Arguably, their understanding of benefits aligns the best with the CBA maxim of increasing human well-being among all projects since the investigated benefits are directly associated with the local population without exception. This can be seen through the distribution of benefits to e.g. saved expenses for flood protection or green space irrigation. The authors did not identify benefits primarily from avoiding the adverse environmental impact in the form of flooding but focused on the onsite utilization of 'surplus' water for everyday purposes. Furthermore, the benefits served as trigger for the local administration to implement subsidies for residential builders, owners and dwellers (Liu et al., 2016; see Appendix A).

5.4.4 SUDS in London

Ossa-Moreno, Smith and Mijic (2017) addressed the water management related benefits of runoff reduction, groundwater recharge, rainwater harvesting, and the reduction of charges for treating wastewater and surface water (Table 6). The authors applied the damage cost method and the benefit transfer method for the related monetization (Table 11).

The damage cost method is applied to the benefit of runoff reduction while a benefit transfer is carried out for the remaining benefits. Using the damage cost method for runoff reduction, first properties and infrastructures at risk for a determined rain event must be identified. By using the

‘Multi-Coloured Manual’, a document to provide guidance on appraising flood hazards in the UK, and flood maps, the expected losses due to flooding of properties and infrastructures were defined. However, further data needed to be obtained for the service disruptions to the London underground system. This has been done by analyzing information about the value of time of passengers and the number of passengers who would be affected. The latter was estimated as the number of people which enter or leave all stations that would be affected by a potential flood because “this methodology proved to be an accurate calculation when compared to TFL [= Traffic for London: the local government body responsible for the transport system] records” (Ossa-Moreno, Smith and Mijic, 2017, p. 415). This procedure should be looked upon critically because it firstly raises the question how an estimation of passenger quantities can be more accurate than official records in the first place and secondly how this is proved? Moreover, this point is a striking example of how far-reaching the implications of valuation methods can become since the accuracy of passenger quantity estimations and records suddenly is an important determinant for monetary benefits of GI measures that focus on stormwater management. This accentuates the importance of assumptions as inputs which influence the valuation procedure significantly. After the potential average annual damages of floods have been determined for at least three different rain events, the effects of the selected GI measures are defined by integrating their effects in the flood maps. By taking the difference between the average annual damages with and without the selected GI measures, the monetary benefit could eventually be determined. The benefit transfer method has been applied to the ESS groundwater recharge, rainwater harvesting, and the reduction of charges for treating wastewater and surface water. For this purpose, “information from other projects from the UK or similar countries (...) which used techniques such as WTP, WTA, hedonic pricing, among others” (Ossa-Moreno, Smith and Mijic, 2017, p. 413) has been used. This vague description of the benefit transfer method does neither provide any detailed information about which techniques have been used for the monetization of which ESS nor does it reveal the concrete values that have been derived. This is even more problematic given that the project specifically aims at the promotion of GI measures through the incorporation of wider benefits. Arguably, a strong argument for the inclusion of wider benefits into economic assessments of GI should not exclusively rely on secondary data for these benefits but rather generate primary (Ossa-Moreno, Smith and Mijic, 2017; see Appendix A).

Table 11: Valuation methods applied by Ossa-Moreno, Smith and Mijic, 2017

SUDS in London (Ossa-Moreno, Smith and Mijic, 2017)	
Valuation Method	**Ecosystem Service**
Damage Cost Method	runoff reduction
Benefit Transfer	groundwater recharge
	rainwater harvesting
	reduction of charges for treating wastewater and surface water

Ossa-Moreno, Smith and Mijic (2017) did not state a justification for applying the selected valuation methods. Stakeholder involvement has played an important role for the determination of suitable SUDS scenarios but was also emphasized thoroughly in the allocation of benefits. By breaking down the valuated benefits per affected stakeholder group, e.g. residential property owners, non-residential property owners, school infrastructure or road infrastructure, the project provided the only detailed allocation of monetary benefits specifically for different beneficiaries. This does not only enhance transparency but also provides each stakeholder group with important information about whether and which SUDS combination has the largest impact on them and their well-being. In that sense, the calculations made things visible (and knowable for people with high numerical affinity). Benefits were interpreted as instruments to raise awareness about the economic advantages of GI to eventually encourage the establishment of better economic, financial and planning regulations in England (Ossa-Moreno, Smith and Mijic, 2017; see Appendix A).

5.4.5 IÖW-Tool

Klein (2020) only valued the ESS of runoff reduction as water management related ESS (Table 7) and applied the substitution cost method in this context (Table 12).

This is done by taking the investment and maintenance costs of conventional rainwater retention basins and multiplicate them with the amount of retained rainwater by the selected GI measures. The relevant cost data can either be estimated through assumptions based on published information about the costs of rainwater retention basins but should ideally be derived from local water authorities familiar with the project area to increase accuracy. The opportunity costs of retaining the water in the conventional rainwater retention basin were regarded as benefits of the GI measure. As opposed to Nordman et al. (2018), who only took the maintenance and corrective measures of gray infrastructure as substitute, the focus of the monetization in the IÖW-tool is on additional relief and retention structures that support the stormwater runoff in the sewer system. This approach is connected to the presumption that the existing gray infrastructures are unable to cope with the increased amount of stormwater runoff (Klein, 2020; see Appendix A).

Table 12: Valuation methods applied by Klein, 2020

IÖW-Tool (Klein, 2020)	
Valuation Method	**Ecosystem Service**
Substitution Cost Method	Runoff Reduction

The justification of the substitution cost method is compared with another substitutive cost approach, namely the substitution costs for the improvement of the current sewage system. Klein (2020) states that the improvement of the current sewage system is both hard to realize and hard to measure, which is why the focus is on additional water retention infrastructures. A study regarding the application of this method for the local context of the German city Bremen has found that the substitution cost method in the latter form is criticized especially by the local authorities, because the city administration does not consider the construction of additional rainwater retention basins as realistic alternative for stormwater runoff reduction in the first place. Furthermore, its inclusion into valuations bears problems for the political communication of the valuation results to the public (Stell, 2020). Hence, it is questionable whether the decision in favor of additional rainwater retention structures can be validly justified by the difficulties connected to the alternative approach of focusing on the existing sewage system. A discussion about the appropriateness of other - potentially more accurate - valuation methods such as damage cost method or market price-based method is not provided.

Stakeholder involvement for the application of the method is limited to the procurement of information from the local water utility company and the city administration since this information is required for the preceding calculations, e.g. the relevant rainfall amounts and the prices for conventional rainwater retention basins. The city administration is also regarded as the only beneficiary of the valuated runoff reduction since saved costs fall within the city's household budget. There is currently no information about the possible allocation of the monetary benefits to e.g. the water discharge fee which would also benefit the local population. Therefore, the CBA maxim of increasing well-being for a preferably great amount of people is currently not met. However, it should be noted that the tool emphasizes the mere valuation of GI and leaves the decision about the potential allocation of related benefits to the city administrations in which the tool is applied (Klein, 2020; see Appendix A).

5.4.6 Summary of Results

Overall the analysis shows that, although the projects share the goal of addressing precipitation-related challenges in cities with the implementation of GI, the 'framing' of each valuation study is precarious. This is because the 'framing exercises', i.e. determining what to count and how to count it, are different in every project. The different approaches to valuations are inextricably interwoven with a multitude of assumptions. These take form in applying valuation results of a study that conducted information about the WTP for water quality improvements in a different spatial setting (Johnson and Geisendorf, 2019), incorporating damages of recent flooding events with devastating consequences (Nordman et al., 2018) or rely on estimates on average passenger numbers potentially affected by a flooding-induced infrastructure disruption (Ossa-Moreno, Smith and Mijic, 2017), to name the most debatable ones. These assumptions are regarded as the most debatable ones because in all three cases, the valuation could theoretically have been carried out under more reliable methodological circumstances, i.e. performing a WTP survey for water quality improvements at the original study site instead of relying on a benefit transfer (Johnson and Geisendorf, 2019), incorporating damages of flooding events averaged over a greater time span instead of relying on the figures of one of the most devastating flooding events in the younger history of the city (Nordman et al., 2018), and integrate official records of the local traffic administration about average passenger numbers instead of regarding estimates as more credible (Ossa-Moreno, Smith and Mijic, 2017). While the ESS of runoff reduction is at first sight the common denominator among all projects, the detailed inspections of each project reveal that this ESS is interpreted differently, and this depends on the local context and vulnerabilities. While e.g. Johnson and Geisendorf (2019) do not focus on the greater amount of runoff caused by heavy rainfall events but rather on the detrimental effects on the water quality, Liu et al. (2016) frame their study on the utilization and not primarily the discharge of stormwater.

Because valuation methods should be chosen dependent on how appropriate they are for the specific project context (Harrison et al., 2018), the nonexistent or unsatisfactory motivations for the choice of the applied valuation methods should be critically assessed. While the projects of Liu et al. (2016) and Ossa-Moreno and Smith (2017) completely lack reasons for the applied valuation methods, Nordman et al. (2018) blame budget constraints and the resulting lack of funding for the missing self-developed valuation approaches. Johnson and Geisendorf's (2019) and Klein's (2020) explanations are limited to reasons of simplicity which should be regarded as questionable justifications because they only reveal reasons for the discard of some but not the selection of other valuation methods. It is also apparent that neither of the projects used a SP or RP approach to valuate ESS, arguably because these techniques are associated with higher costs and require a greater amount of time (OECD, 2018). It should be acknowledged that the authors of all projects take a critical stance at least toward their valuation outcomes, by deliberately taking rather modest numerical assumptions (Johnson and Geisendorf, 2019), address the limitations of benefit transfers (Nordman et al., 2018), concentrate on market price-based benefits (Liu et al., 2016), admitting the reliance on simplified approaches and limited datasets (Ossa-Moreno, Smith and Mijic, 2017) and admitting the advantages of hydrological models for more accurate results (Klein, 2020). In the cases of Johnson and Geisendorf (2019) and Nordman et al. (2018), even sensitivity analyses have been carried out to address the identified uncertainties of the CBA, i.e. to what extent their studies are subject of 'overflows'. Although the different authors had different approaches to the valuation of GI measures and related ESS, they unanimously understand CBA as tool to inform current decision-makers about the economic advantages of GI and foster their uptake in the urban planning domain. Generally, all authors therefore focus on the need for numbers to distinguish and qualify different alternatives in order to enable a comparison and to be able to make a choice.

Finally, the authors express their (non)conformity with the CBA's maxim of increasing human well-being through the provision of monetary benefits by identifying different beneficiaries. In that context, it is argued that directing the valuation results toward the local population (see SUDS in Berlin, GI in Beijing, SUDS in London) represents a more direct because more immediately 'visible' endeavor to increase human well-being than focusing on the local administrative bodies. Identifying the local administration as main beneficiary does not interfere with the increase of human well-being per se but necessitates at least a detailed explanation about how individual people benefit from the saved monetary expenses. Such a detailed explanation is lacking.

Whereas the different assumptions, underlying procedures and project contexts show the high variety and complexity of ESS valuations, these differences offer a rich knowledge base and an initial point for the rather flexible IÖW-tool to recognize and potentially adopt factors which are not acknowledged yet. Firstly, the IÖW-tool should strive toward a greater transparency than the other four publications regarding the performative actions. This applies to the determination of input parameters for the quantification of ESS, the justification for selecting the preferred valuation method to monetize these ESS as well as to the communication of underlying assumptions and estimates. Ensuring transparency becomes even more important given the high flexibility of the IÖW-tool which allows for the individual adjustment of different rainfall scenarios, various GI measures and the spatial scale of their implementation. This flexibility enables the local customization of the tool but also provides a wide scope for political exertion of influence. Furthermore, the tool's adaptability should not be overstretched because a greater number of potential scenarios results in a greater variation in the valuation results. The application of the tool within the context of the city Bremen has shown that, if too many scenarios about the pursued GI measures, their spatial scales and the considered rainfall events are established, the final valuation results lose their argumentative power because they show a wide variance (Stell, 2020). Secondly, the IÖW-tool should keep the incorporation of the status quo because the "rule for deciding if anything at all should be chosen, unlike other approaches which can decide only between alternatives to do something" (OECD, p. 32), is a main characteristic of CBA. It is argued that - especially given the role of CBA as tool for showing the potential of ESS benefits - the comparison of the situation before and after the implementation shows the potential of GI measures. Thirdly, the IÖW-tool should incorporate water pollutant removal into the valuation of runoff reduction since this ESS has been identified as significant factor by the other projects and addresses the challenges for the quality of water that are connected to increased rainfall amounts. Lastly, a higher level of detail of the ESS of runoff reduction, i.e. breaking down the ESS into more detailed benefits for different stakeholder groups - as done by Liu et al. (2016) - seems advisable. This is connected to the recommendation of directing the valuation more toward the improvement of human well-being. In the current form, the revealed monetary values are merely considered as a cost saving factor for the public administration rather than benefits for individuals. Whether the demanded increased focus on benefits for individuals can be realized through the substitution cost method, is at least questionable. But if the practitioners do not want to change the valuation method itself, it would arguably be recommendable to offset the saved costs through allocating them to e.g. savings of the water discharge fee for households. To direct the valuation more toward individual well-being, the distinction of Fisher, Bateman and Turner (2010) could be used as supporting methodological step because the demarcation between final ESS and direct benefits is meaningful for both the valuation procedure itself and the allocation of benefits. Lastly, it is recommended to acknowledge the paradigm shift from centralized to decentralized stormwater management (see Chapter 1) in Germany by reflecting it in the used valuation method. This paradigm shift is currently not respected in the applied substitution cost method because the focus is on treating as much runoff as possible with one large retention structure instead of treating or even utilizing the water onsite.

DISCUSSION

6. Discussion

The discussion will put the findings into a wider context from two perspectives. First, an 'insider-perspective' will directly tie up on the different applied valuation methods and their suitability for the valuation of ESS. Second, an 'outsider-perspective' that takes a stance on the highly controversial debate about the appropriateness of environmental valuation in general and CBA in particular, is provided.

6.1 Critique of the Valuation Methods

In the analysis it became apparent that the applied valuation methods are limited to market price-based and cost-based approaches. Generally, the focus on market price-based and cost-based valuation methods, accompanied by the exclusion of SP and RP methods, has the advantage of using data from actual markets which thus reflect actual preferences or costs of individuals. The other advantage, which has presumably played a more important role for the authors of the publications, is the fact that data about quantities, prices and costs is relatively easy to obtain (Pascual and Muradian, 2010). In the following paragraphs, the limitations of the three most often applied valuation methods, shown in Figure 10 - the market price-based method, the substitution cost method, and the benefit transfer method - will be discussed.

While market price-based methods are primarily applied for provisioning ESS such as fuel or timber, which can be characterized as relatively well-defined, Johnson and Geisendorf (2019) as well as Liu et al. (2016) use this method for the regulating ESS of stormwater runoff reduction. Although the method reflects actual costs of e.g. groundwater in the projects, it assumes a perfectly competitive market, i.e. no barriers to entry and exit, perfect information about the price of the good, many sellers and buyers and undifferentiated products. Arguably these unflawed market conditions are unrealistic because e.g. often the local administration has a monopoly on selling water and the price is subject to variations, dependent on water scarcity. These flaws fail to suitably reflect the economic value of the good or service and consequently distort the value of the ESS (Pascual and Muradian, 2010).

The substitution cost method is contentious because it is related to two major assumptions related to its suitability. First, the user of the substitution cost method regards the substitute as appropriate surrogate for the 'original' ESS. For example, the substitutes for GI measures in terms of removing pollutants from the water are sewage treatment plants (see GI in Grand Rapids and GI in Beijing). These sewage treatment plants are therefore expected to remove pollutants precisely as good from the water as the considered GI measures. A better or worse performance by the sewage treatment plant would distort the amount of saved costs per amount of cleaned water and consequently lead to either an overestimation or underestimation of the monetary benefits of GI measures. Evidently, the analogousness of GI measures and technical substitutes in terms of their performance can never be guaranteed, which means that the accuracy of the surrogate is likely to be impaired. This shows that the substitution cost method is connected to a necessary number of assumptions which establish a more precarious valuation framework than e.g. the market price-based method. Another chain of performative actions is connected to the dissemination of the valuation results. This leads to the second major assumption, namely that the user of the substitution cost method regards it as appropriate tool to communicate the valuation of benefits. For a valuation, the mere production of numbers is not enough because the question remains what the implications of these numbers are. Personal experiences with the application of the substitution cost method for stormwater management within the IÖW-tool for the German city Bremen showed that the substitution cost method proved to not be well accepted among city administration officials. This is because the method suggested the substantial investment of public funds in technical rainwater retention basins which were regarded as the substitute for GI measures. This was a strategy the city administration did not pursue and - also in the spirit of an envisaged re-election - definitely did not want to communicate to the public because a strong opposition by the public was expected (Stell, 2020). This example illustrates that the performative implications for valuation methods go beyond the calculative frame of determining numerical values and enter the realm of political decision-making where the effects become more and more blurry.

Furthermore, the benefit transfer method, i.e. applying estimates derived from one setting to the valuation of ESS in another setting, is problematic per se because no approach, which aggregates the findings from other studies, can be more reliable than these original studies. Given the fact that the original study reaches its outcome already through a set of assumptions often unique to the local context, a benefit transfer always bears the risk of rendering the results into the direction of greater inaccuracy. In this way, benefit transfer is the counterexample for the original notion of ‘strength in numbers’ because it deteriorates the power, i.e. reliability of valuations, through the aggregation of more studies (Simpson, 2010).

While the authors have little to no influence on the flaws typical for each valuation method, they have the opportunity to choose the most appropriate method for their specific context. However, none of the authors sufficiently stated a sound justification for the selected valuation method(s). The reasons for this lack of justification are unclear. To provide guidance to researchers and practitioners in choosing the ESS valuation methods suitable for their context, Harrison et al. (2018) used the experience of 27 case studies which applied different assessment methods. Based on a survey, the case study teams revealed their underlying reasons for the selection of the valuation method(s). Harrison et al. (2018) grouped these reasons into methodology-oriented, research-oriented, stakeholder-oriented and decision-oriented reasons and developed linked decision trees to make the information available for future studies. These decision trees are the outcome of a multitude of factors relevant for practitioners when choosing a valuation method, such as the incorporation of local knowledge, spatial and temporal explicitness, transparency or the ability to address multiple ESS. They are found to be understood easily by people and useful in capturing the structuring of the decision process for method selection by the case study teams. Although the decision trees are trivializing the complexity of environmental valuation methods, particularly evident by their discrete and linear character of requiring a binary choice at each stage, they are capturing the individual 'framing' of ESS valuations by the local context (Harrison et al., 2018).

Therefore, they can be regarded as useful support device for practitioners in advance of a planned environmental valuation, e.g. for city administration officials who aim to use the IÖW-tool to valuate urban green spaces. Arguably, they would have helped the authors of the analyzed publications to motivate their selection of methods as well. Additionally, they increase comprehensibility for people outside of the valuation arena by unfolding transparency about their choice.

6.2 Critique on Environmental Valuation

In the broader context of the valuation of nature, the debate on anthropocentric and biocentric views has been at the heart of the discussions (Eggermont et al., 2015). While ecologists advocate for a biocentric perspective which is based on intrinsic ecological values, economists emphasize instrumental values in their anthropocentric perspective. There are different scientific camps with diverging opinions about the complementarity and substitutability of the two mentioned approaches. Some argue that the adoption of a utilitarian perspective induces societal changes that eventually cause the instrumental conception of the human-nature relationship to become increasingly reliant on cost-benefit rationales. Others regard the biocentric and anthropocentric approach to be complementary and do not see a conflict in their simultaneous use (Pascual and Muradian, 2010). It is important to acknowledge the critique toward the utilitarian perspective.

When monetizing nature in general and ESS in particular, the primary intention should not be to separate people and nature by simplifying the meaning of nature through commodification. Rather, economic valuation should pursue the goal of making visible and addressing the reluctance, inability and ideological intolerance toward the incorporation of the hidden values of nature and ESS into the current decision-making arena (Brondízio and Gatzweiler, 2010). Valuation therefore takes the importance of nature for humans as a premise and intends to help decision-makers in situations where there are alternate courses of action (Kumar and Wood, 2010). This can be understood as reaction to the often still prevailing error of treating nature as externality and ESS as limitless and free (van Zoest and Hopman, 2014).

James C. Scott's parable about the early European state and scientific forestry in his book *Seeing Like A State*, which bears resemblance to Latour's notion of circulating reference, may serve as a warning example: "By radically narrowing down his vision to commercial wood, the state forester had, with his tables, paradoxically achieved a synoptical view of the entire forest." (Scott, 1998). Transcribed into the context of this report, it is therefore to be avoided that 'by radically narrowing down his vision to the use of nature as commodity, the urban planner, with his economic valuations, paradoxically achieves a synoptical view of the entire nature in the city'.

This report as well as the IÖW-tool do not doubt the inherent value of ecosystems and therefore take the position of the above-mentioned complementarity perspective, i.e. the understanding that the inherent value of nature and its worth for humankind can coexist. Based on the performative practices carried out to connect both aspects, it is even argued that the anthropocentric and the biocentric must be complementary in order to enable the consideration of ESS in decision-making processes.

6.3 Critique on Environmental Valuation through CBA

While the previous sections discussed the valuation as of nature and particularly ESS as such, the following paragraphs will provide a critical appraisal toward the most widely used valuation method, namely CBA. Given, there is a plethora of articles dedicated only to the assets and drawbacks of CBA, only a small part of these critiques will be presented here.

In the words of Scott, CBAs can be regarded as state simplifications which produce standard units of measurement - monetary values - and represent a technique for grasping a large and complex reality. To make aspects of the ensemble comprehensible for officials, this complex reality has to be reduced to schematic categories - costs and benefits. The "only way to accomplish this is to reduce an infinite array of detail to a set of categories that will facilitate summary descriptions, comparisons, and aggregation" (Scott, 1998, p. 77). This quote underlines the discrepancy between the goal to assure accurate, reasonable valuation results and the performance of assumptions which are necessary to reach these results. "Tracing the construction of indicators - the statistics, conventions, groupings, and complex weighting choices involved in their production and circulations - provides insight into the largely hidden practices of classification and aggregation that support them (...)" (Mennicken and Espeland, 2019, p. 232). Dependent on the traceability and transparency of these assumptions, indicators and input parameters, there is a risk that the decision-maker is not aware or incapable of understanding the trajectories which are impacting the final results of a CBA. In the worst case, this can lead to decisions made on an invisible or blurry set of assumptions that the decision-maker does not comply with.

Another, no less precarious scenario is associated with the fact that CBA, like any calculative tool, is prone to political machinations, i.e. that the decision-maker is well aware of the underlying trajectories and can manipulate them in a way that leads to the desired result. It is not so much a question of how realistic the strategic (mis)use of CBA is, but much more crucial that it is within the realm of possibility. This is underlined by Hirschman and Berman (2014) who found that economics has a greater influence on policy-making when economists are able to define a policy question essentially technical. Arguably, CBA is a tool expressing this essential technicality and can consequently be used to affect the political exercise of power. Because the IÖW-tool's flexibility allows for the exertion of political influence in both the quantification and valuation stage, it is prone to these political machinations, which makes tracing the construction of indicators all the more important on the background of ensuring transparency.

A criticized determinant which is inextricably interwoven with CBA, is discounting, i.e. the mathematical procedure to adjust future costs and benefits of projects to present value. On the background of climate change, sustainability and interventions which often incur costs today to prevent harm in the more distant future, discounting becomes even more problematic (Atkinson and Mourato, 2008). This is because choosing a discount rate cannot be done on the base of purely economic factors but the responsibility to future generations is grounded in ethics, estimations about the well-being of people in years to come and the preservation of life opportunities (Gowdy, 2010). While it may be reasonable to say that individuals generally prefer to have something now than in the distant future, the use of a single precise number to value the effects of climate change decades or even centuries in the future is questionable. Discounting poses a dilemma for CBA valuations because it is an integral part of the methodological procedure but also a normative statement about the value of people's preferences (de Groot, 2010).

Based on the critique of CBA, some authors propose pluralistic multi-criteria approaches. These approaches have the potential to integrate and overcome the differences between technical and social approaches and differ from CBA by not necessarily monetizing all criteria. By taking different criteria into account and assign a score and a weighting to each criterion, a ranking of different measures of concern is produced. In the simplest multi-criteria approaches, the weighted average of the scores amounts the final outcome and the option with the highest weighted score is regarded as best alternative. However, multi-criteria approaches are also not uncontested, for example because they tend to work with experts' preferences and not or only partly include public preferences. They also qualify for the critique of the hidden practices of classification and aggregation which constitute the construction of indicators (Mennicken and Espeland, 2019). Furthermore, it is is often unclear how these approaches deal with issues of time discounting and are arguably not less susceptible to political machinations, especially because of the focus on expertise knowledge (OECD, 2018).

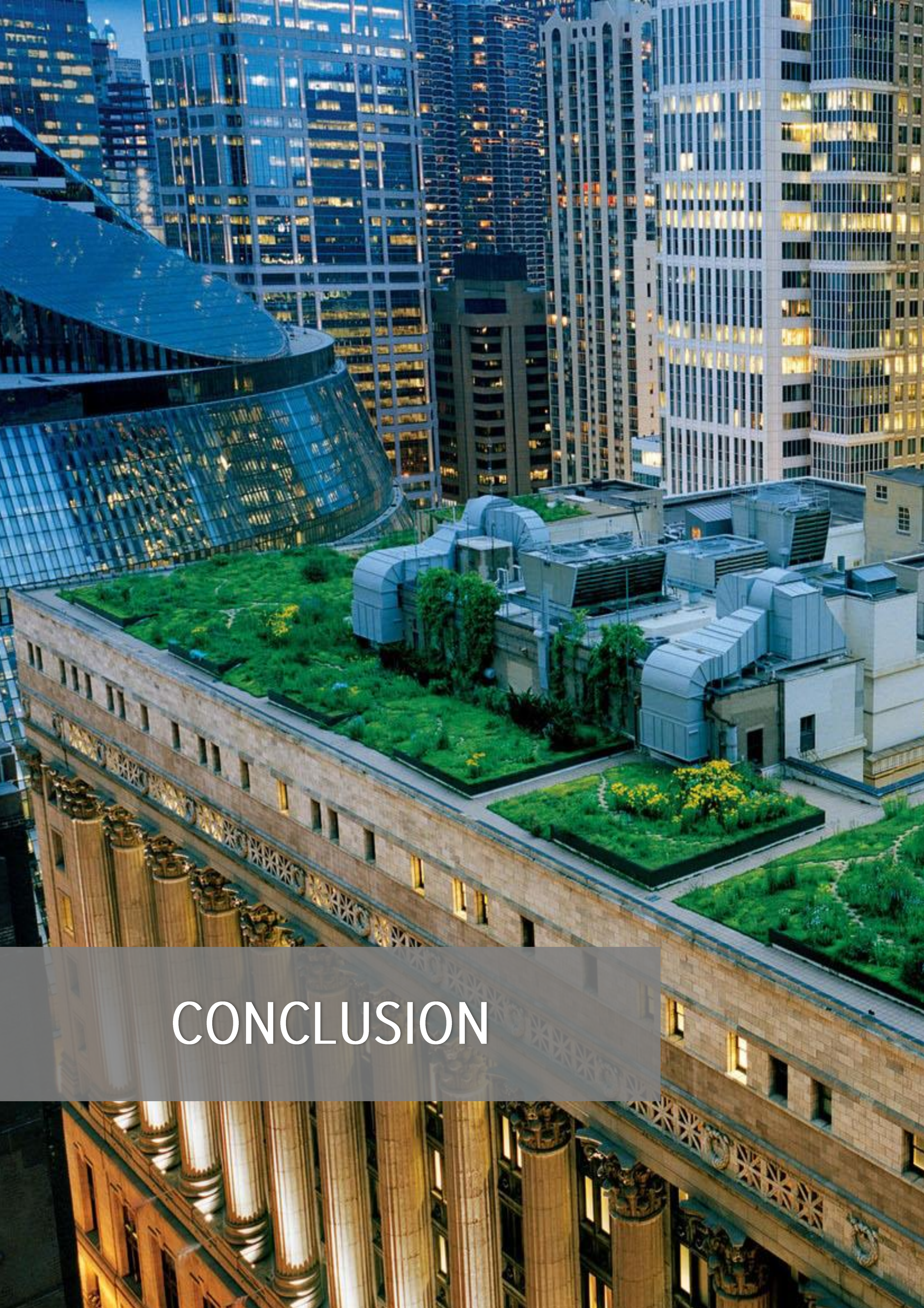
A concrete proposal which regards the incorporation of ESS into decision-making based only on monetary aspects as insufficient, is forwarded by Scholte, van Teeffelen and Verburg (2015). They propose a pluralistic approach to socio-cultural valuation, which incorporates both quantitative and qualitative methods to strengthen one another. This is because quantitative methods excel in integrating monetary values and qualitative methods better grasp how and why people value certain ESS (Scholte, van Teeffelen and Verburg, 2015). The underlying motivation for this claim builds upon the complex interplay between ESS and its contributions to human welfare and addresses the gap found between monetary benefits and their influence on well-being. This is a concern that has come to the fore for some of the analyzed projects in this report as well. According to Scholte, van Teeffelen and Verburg (2015), ESS research has become too dominated by a monetary interpretation of value and environmental valuation has been coined too monistic and economic which leaves little room for other social scientific methods. As a response, they identify three value domains associated with ESS values: ecological value, economic value and socio-cultural value. Ecological value captures the extent to which the ESS contributes to the health of the ecosystem and the economic and socio-cultural value reflect the relative importance of ESS to people. However, as opposed to economic value, socio-cultural value is not expressed in monetary terms. While the authors critizise the current focus on merely economic aspects in ESS valuation due to their insufficiency in capturing the 'true' value, they accentuate that the proposed pluralistic methods do not serve as alternative but complement to the current, monetary forms of ESS valuation (Scholte, van Teeffelen and Verburg, 2015).

It remains unclear whether the reduction of ESS to the common denominator of monetary values makes CBA a more or less accurate method than multi-criteria approaches or other kinds of valuation techniques. It therefore also remains unclear whether the application of CBA, like in the IÖW-tool, or multi-criteria approaches delivers the more accurate results for the projects analyzed in this report. However, it is argued that CBA is momentarily the most widespread and applied valuation method by decision-makers. It should thus be used carefully and attentively and complemented by other legitimate ethical or scientific reasoning where possible and necessary (Pascual and Muradian, 2010).

6.4. Critique on Performativity

It has been shown that CBA and the related valuation techniques are devices within a 'cognitive infrastructure', i.e. a mode through economics influence policy. Cognitive infrastructure is referred to as "the economic styles of reasoning (...) and the establishment of economic policy devices that produce knowledge and help make decisions" (Hirschman and Berman, 2014, p. 781). CBA is such a policy device through which economics can exercise influence and which is a sociotechnical assemblage of knowledge, people and the material world (Hirschman and Berman, 2014; see also Latour, 1999). Through the accumulation of these entities into monetary values, CBA turns the messy and complex world into a calculative and formal order which can be used productively (Hirschman and Berman, 2014). However, the performativity notion bears the vulnerability to be applied 'too extensively' in both a relativistic and deterministic sense. First, one should be careful to not use performativity in order to render decision-making overly relativistic, i.e. have the belief that everything is relative to differences in individual consideration and perception (Brisset, 2018). Second, one should be careful to not use the performativity notion in order to render the decision-making overly deterministic, i.e. have the belief that all events, including decisions, are determined by previously existing causes. The cognitive apparatus and associated tools may be influential in defining and framing things but do therefore not necessarily determine the policy process. Every CBA and every tool in general, which is utilized for the support of decision-making, has only a limited scope in which it produces information. Policy processes may or may not take the outcomes of these tools into consideration but are certainly influenced by various other aspects and therefore not solely determined by these tools.

Lastly, it should be emphasized that this report is a 'victim' of performativity itself. This means that I myself, by including some aspects and excluding others, by accentuating some arguments and only mentioning others, by making some projects the objects of my analysis and ruling out others beforehand, by concentrating on selected ESS and regarding others unimportant, affect the very way in which this report circulates information to the reader. Because these decisions are associated with my subjective standpoints about the appropriateness of information and assessments about the persuasive power of arguments, "there is nothing innocent to make the invisible visible" (Strathern, 2000, p. 309).



CONCLUSION

7. Conclusion

This report has analyzed the valuation of ESS of five different projects concerned with urban stormwater management, drawing on the theoretical background of the performativity approach. It has become clear that there are different approaches to what things should be highlighted to which extent in order to make a valuation strong and how dependent these valuation processes are on presumptions and estimates.

All authors shared the idea of rendering the 'invisible' benefits of ESS in the form of reducing stormwater runoff 'visible' through a CBA. For that purpose, all authors first quantified ESS and then valuated them, motivated by showing the advantages of GI in order to support its implementation. In that context, the valuation of ESS has been carried out in different ways by the authors through the application of certain valuation methods. The used valuation methods were the avoidance cost method, the damage cost method, the market price-based method, the substitution cost method and the benefit transfer method while the most frequently applied methods were the market price-based method, the substitution cost method and the benefit transfer method. It has become evident that each valuation method valuates ESS in a distinctive way and that the same valuation method is performed more or less differently dependent on the author of the investigated publications. In that way, every valuation method bears a different interpretation of the respective author about what counts in the valuation of ESS. These different interpretations are inevitable connected to a variety of factors, such as the local context, the availability of data and resources, the understanding of CBA as a method, the quantification procedures and not least a set of necessary presumptions and estimates. The different interpretations became particularly apparent in the selection of different GI measures, the number, type and level of detail of investigated ESS as well as in the determination of beneficiaries of the ascertained monetary benefits. It has been argued that addressing the local population instead of the local administration as beneficiary of monetary benefits, expresses the core idea of CBA - improving human well-being - to a higher degree and that this core idea is not expressed sufficiently by the majority of the authors.

The accuracy of the determined values, which cannot be more than estimates, is affected by these different interpretations about what should be counted in the valuation of ESS. In this way, they directly influence the 'strength in numbers', i.e. determine the precision of valuation outcomes. Here, the deceit of the notion 'accuracy' becomes obvious because there is nothing such a point of reference for when intangible goods or services are valuated accurate enough. Presumptions and estimates are therefore inevitable part of environmental valuations. However, this makes it even more important for practitioners to ensure accuracy to the greatest extent possible. For this, it is essential for practitioners to be aware of the shortcomings and limitations of their approaches and even more important to communicate these weaknesses. Certainly, it must be distinguished between presumptions made on a sound basis and without the possibility of using a more reliable alternative and such made simply for the sake of simplicity. If presumptions are made on an insufficient or unreasonable base though, the danger of diluting the validity of valuation results is a grist to the mill of those who are already skeptical about the credibility of economic valuations of ESS in the first place. Only if inaccuracies are avoided from the outset and openly explained, can the decisions based thereon be well-founded and thus reflect the 'strength of numbers'.

For the IÖW-tool, these findings result in the following recommendations. First of all, it should retain the feature that distinguishes it positively from the other publications. This feature is the integration of the status quo situation in the valuation because it showcases the meaningfulness of GI and related ESS for urban stormwater management by enabling a comparison with the alternative of not taking action. Furthermore, it is recommended to integrate into the tool those features that proved to be advantageous in the other projects. The tool is encouraged to incorporate the ESS of water pollutant removal into the valuation because it has been found that - besides the greater quantity of stormwater runoff caused by more and more severe rainfall events - the decreasing water quality through pollution poses a major challenge. Furthermore, the tool should ensure transparency about the 'hidden' procedures which affect the valuation process because the awareness and transparency about the necessary assumptions greatly influence the accuracy of its calculations and consequently the plausibility of its recommendations. In addition, the tool should accentuate the connection of gaining monetary benefits through ESS and the improvement of human well-being. This can be realized either through a modification of the substitution cost method toward the incorporation of distributional cost savings for individual citizens or the selection of a different valuation method. Arguably, a different valuation method would reflect the paradigm shift toward decentralized onsite treatment of stormwater runoff more adequately than the substitution cost method, which currently concentrates on large-scale offsite stormwater management.

Finally, the tool should not strive toward the 'quality' of being universally applicable, a goal often demanded by authors within the environmental valuation domain. On the background of this report's findings, such a universality is not possible due to the high dependencies on the local context and multiple project-specific circumstances. The IÖW's goal to develop a tool for the determination of ecosystem service benefits within Germany seems to be spatially reasonable because the cultural background, the legal framework and the understanding of environmental valuation are quite homogeneous. The tool therefore has the potential to help integrate sustainable solutions into urban planning and encourage that ecosystems "become more than just another state variable to the economist" (Carpenter and Turner, 2000, p. 1).

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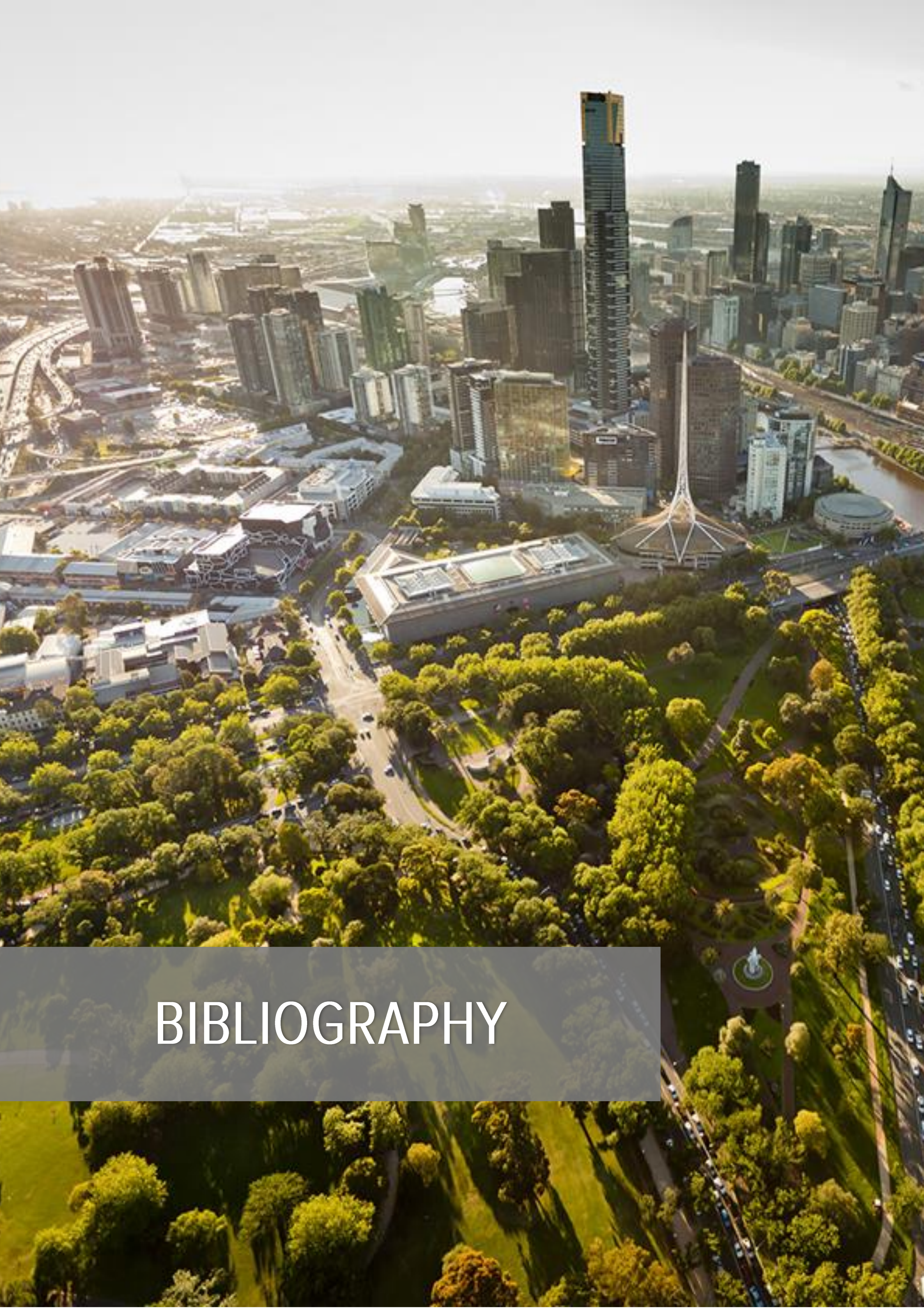

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9. Appendices

Appendix A: Excel-Table including the comparison of factors amongst the valuations