Nordic Council
of Ministers

Economic benefits of nature-based solutions

in relation to sea level rise, storm surges and extreme rain

Contents

This publication is also available online in a web-accessible version at:
https://pub.norden.org/temanord2025-516

Preface

This report has been commissioned by the Nordic Working Group on Environment and Economics (NME). The report has been prepared by a consortium led by Anthesis Group in cooperation with Menon Economics and the City of Copenhagen. Nature-based solutions can be regarded as actions that are inspired and supported by nature. Such solutions are cost-effective and simultaneously provide environmental, social and economic benefits.

This study shows that the inclusion of positive externalities from nature-based solutions in a cost-benefit analysis can contribute at such a magnitude that the effect should not be neglected. This finding is illustrated through a number of case studies. The main conclusion is that nature-based solutions is a good way to adapt to climate change. In order to include positive externalities into the cost benefit analyses more valuation studies would be needed according to the findings of the study.

Members of the Nordic Working Group for Environment and Economy have provided comments and inputs to the report during the work. The authors of the report are responsible for the content as well as the assessments and recommendations, which do not necessarily reflect the views and the positions of the governments in the Nordic countries.

December 2024

Magnus Cederlöf
Chair of the Nordic Working Group for Environment and Economics

Abstract

Nature based solutions (NBSs) can play a key role in adapting to climate changes, especially when it comes to sea level rise, storm surges, and extreme rainfall. To better understand the full effects of nature-based solutions, positive externalities such as public health, biodiversity, water purification, carbon sequestration and other ecosystem services (ESSs) can be included in the cost benefit analyses (CBAs) conducted to inform the decision upon what solution to use for the climate change adaption.

In the report we present six NBS case studies from the Nordic countries where the positive externalities are monetised and discuss how this affects the outcome of CBAs. Benefit transfer (or more general; value transfer) techniques are used to transfer estimates from previously published and peer-reviewed environmental valuation studies to our six case study sites.

Our results indicate that the inclusion of positive externalities in CBAs leads to a substantial increase in the social benefits of NBS, which could potentially change the outcome of CBAs from net costs to net benefits of the project. We end by discussing how CBAs can benefit from inclusion of positive externalities when CBAs are used to inform decisions makers on how to choose the most efficient measures to adapt to water-related climate change impacts.

Sammanfattning

Naturbaserade lösningar kan spela en viktig roll i anpassningen till klimatförändringarna, särskilt när det gäller stigande havsnivåer, stormfloder och extrem nederbörd. För att bättre förstå de fulla effekterna av naturbaserade lösningar kan positiva externa effekter som folkhälsa, biologisk mångfald, vattenrening, koldioxidbindning och andra ekosystemtjänster (ESS) inkluderas i de kostnads-nyttoanalyser som genomförs. I rapporten presenterar vi sex fallstudier av naturtillgångar från de nordiska länderna där de positiva externa effekterna monetariseras och diskuterar hur detta påverkar utfallet av kostnads-nyttoanalyser. Tekniker för nyttoöverföring (eller mer allmänt, värdeöverföring) används för att överföra uppskattningar från tidigare publicerade och expertgranskade miljövärderingsstudier till våra sex fallstudieplatser. Våra resultat indikerar att inkluderingen av positiva externa effekter i kostnads-nyttoanalyser leder till en betydande ökning av de sociala fördelarna med naturbaserade lösningar, vilket potentiellt kan förändra utfallet av kostnads-nyttoanalyser från nettokostnader till nettofördelar av projektet. Vi avslutar med att diskutera hur kostnads-nyttoanalyser kan dra nytta av att inkludera positiva externa effekter när kostnads-nyttoanalyser används för att informera beslutsfattare om hur de ska välja de mest effektiva åtgärderna för att anpassa sig till vattenrelaterade klimatförändringar.

Preamble

This report constitutes the final delivery on the project "Economic benefits of nature-based solutions in relation to sea level rise, storm surges and extreme rain" financed by the Nordic Council of Ministers' Working Group for Environment and Economy (NME). Contact person within NME has been Lotta Eklund. The project has been managed by Krister Mars at Anthesis Group, and other participators has been Sebastian Winther-Larsen from Menon Economics as well as Jan Rasmussen, Rosalina M Wenningsted-Torgard, and Per Andreasen from the Municipality of Copenhagen, and Bianca Nijhof from Anthesis Group. Useful input to the project has been given by members of the NME, as well as from Ståle Navrud at Menon Economics and Stefan Åström at Anthesis Group.

All conclusions, as well as errors, belongs to the authors.

1. Introduction

Climate change is increasing the risk of sea level rise, storm surges and extreme rainfall. This, combined with increased urbanisation and intensified land use, leads to significant socio-economic costs in terms of damages to infrastructure and houses, as well as severe public health risks. Implementing Nature Based Solutions (NBSs) to adapt to a changing climate rather than the standard "grey" solutions, can not only address the core problem, but also provide significant social benefits for public health, biodiversity, and Ecosystem Services (ES) such as carbon sequestration and water purification.

Upon deciding how to adapt to a specific threat occurring from sea-level rise, storm surges, and extreme rainfall, the social costs of all adaptive measures should be compared to their social benefits in a Cost Benefit Analysis (CBA) to identify measures which provide the highest net benefits. A CBA seeks to identify all positive and negative impacts of a measure (or project/ policy) to all stakeholders affected in a society (usually at the national level) and monetise these impacts to provide a comprehensive assessment of the social costs and benefits. While most of the cost components, as well as benefits in terms of avoided damage to infrastructure and buildings, can be valued by market prices; external effects on public health, biodiversity and ESSs lack market prices (or market prices reflect only parts of their value) and are often listed as non-priced impacts. However, for CBAs to be an effective decision-making tool the number of non-priced impacts should be minimized. In the evaluation of NBSs for climate adaptation, this means that the externalities should be monetised for a comprehensive monetary assessment also of that these measures provide. This project, funded by the Nordic Working Group for Environment and Economy (NME), explores how the inclusion of monetised values for impacts on identified ESSs can affect the CBA outcomes and thus influence the decisions regarding NBS implementation.

In the project we identify ESSs from six implemented NBS in the Nordic countries and apply a method for a benefit transfer method to monetise their benefits based on an extensive literature search on economic valuation studies on ESSs.

2. Background

Externalities

Side-effects caused by anthropogenic activities are often referred to as externalities. Examples of this can be pollution, eutrophication, and reduced biodiversity. However, externalities may also be something positive, such as bees from beehives pollinating nearby fruit trees. Third parties can be dependent on these externalities, as shown in Figure 1, and if the impact is negative this causes societal problems where the cost often lands on the third party, or at the society. This Impact – Dependency explanation is a part of the Natural Capital Protocol, where the importance of including the cost from adverse effects from human activities into decision makings is discussed (Natural Capital Coalition 2016). One guiding principle within the EU environmental policy is the "polluter pays principle" which says that the driver of the impact must either reduce their impact or compensate those suffering from the reduction in the natural capital.

Figure 1 Impact pathways as described by Natural Capital Protocol.

Economic benefits

Nature-based solutions (NBSs) offer multiple economic benefits, including direct protection against sea-level rise, storm surges, and rainfall damage. They also deliver broader sets of benefits such as enhanced public health benefits, biodiversity, and ESSs in terms of regulating ecosystem services like water purification (improved water quality) and, carbon sequestration, as well as cultural ecosystem services in terms of recreational, landscape aesthetical and educational benefits.

For the topic of societal benefits, the question who the beneficiaries are, and who should pay for these benefits arise. The EU line that the polluter should pay is clear, there may however be occasions where the driver is unknown, or for other reasons cannot be held responsible, and in such cases the society must address the problem. Actions to reduce adverse effects might also be taken by other agents, and in such cases these agents may be compensated by the society. An example of this is the scheme implemented by the Swedish Forestry Agency were forest owners gets financial compensation for letting out their land for restoring old wetlands (Gråd, Isaksson, and Eriksson 2024). Other examples related to this report is how to share costs for a reduction of nitrogen and phosphorous running out in the Baltics, where the beneficiaries clearly are all countries around the Baltic Sea.

Regardless of who address the negative externalities, to form well informed decisions with the purpose of maximising societal benefit, the improved natural capital should be monetised and included in the decision process.

We have identified several positive externalities from NBSs, and, in this chapter, we will briefly discuss some of them.

Carbon sequestration

Emissions of greenhouse gases is a global problem, with massive social costs. Reestablishing wetlands may be one part in sequestrate carbon back into the soil, especially on peat rich areas. For this project we estimate possible sequestration of CO_2 to be between 0.48 and 3.76 ton/ha/year giving a span of sequestrated CO_2e/ha/year from 1.76 ton until 13.80 ton (Lin 2020). We further follow the recommended social cost of carbon with marginal reduction in societal cost being in the range of 6.7 to €222/ton CO_2e (WGI 2021).

Water purification

Wetlands that capture runoff water originating from agricultural areas also capture excessive nutrients that would otherwise lead to eutrophication of lakes, rivers, and coastal areas. Under optimal conditions, wetlands may absorb up to 100 kg of phosphorus (P) and 1,000 kg of nitrogen (N) per hectare annually. Such optimal conditions are not to be expected from all wetlands, but an average annual uptake of 50 kg P and 500 kg N per hectare is a reasonable assumption (Weisner, Johannesson, and Tonderski 2015). The benefits in terms of avoiding or reducing eutrophication can be monetised using a damage function approach where the avoided damage costs can be valued either averting prevention costs (such as water purification expenses), replacement costs (in terms of building a water treatment plant with the capacity of needed to capture the nutrients captured by the wetland), or stated preference methods (Contingent valuation (CV) or Discrete Choice Experiment (DCEs) in terms of mapping affected households' WTP to avoid this eutrophication scenario. For this report we use the values recommended by the Swedish Environmental Protection Agency which are based on contingent valuation surveys of households willingness-to-pay for improved water quality from reduced eutrophication (Söderqvist and Wallström 2017).

Besides nitrogen and phosphorus, wetlands might also capture microplastics from runoff storm water. The filter effect varies depending how close to an urban area the wetland is, and since microplastic have only recently been identified as an environmental stressor, there is a lack of empirical scientific evidence to quantify the impacts. The damage cost of plastics that reach the ocean was however, estimated to be between $3,300 and $33,000 per metric ton in 2019 by Beaumont et al. (2019).

Another positive water related effect is the reduction of water flow peaks in the water management system, when water is slowed down on its way out to the ocean, rather than running directly to the drainage systems. This benefit is hard to estimate, since a water treatment plant has both running cost in the form of energy used, but also an investment cost based on load at the peaks. For this report we only estimate the reduction in operational costs, and this is estimated to between SEK (2.0–5.0)/m^3 (Karras and Read 2016)

Increased Biodiversity

Increased biodiversity increases people's wellbeing by providing both use and non-use values, in terms of recreational value and existence and bequest values, respectively. These benefits can be measured in stated preference (SP) surveys where a representative sample of the affected population (usually those living close to an implemented NBS) are asked their willingness to pay (WTP) for a specific increment in biodiversity in the area. In a study in Germany, Meyerhoff, Angeli, and Hartje (2012) found a value of €2,360 to €8,780 per year and hectare of restored wetlands. Another way of monetising increased biodiversity from greening is to estimate the value of reduced land-use. This method is particularly useful in dense urban or industrialised areas. Sustainable Impact Metrics estimate the eco cost value by reduced land-use in the Nordics to €6,900/hectare (Sustainability Impact Metrics 2024). This estimate is based on a biodiversity factor for the Nordic countries of 0.125 on a scale from 0 to 1, where 1 represents countries where a large part of the country consists of rainforest.

Recreational and educational values

Besides contributing to increased biodiversity, reestablished wetlands may also contribute with cultural ES in terms of educational, landscape aesthetical, and recreational values to the people living nearby. Both the educational as well as the recreational values may be enhanced with information boards and excursion spots in and nearby the wetlands. A discrete choice experiment (DCE) in England and Wales estimates the annual educational benefits to be in the range of £93 to £98 per hectare reestablished wetland, and the corresponding span for annual recreational value per hectare in the same study is £245 to £472 (Christie and Rayment 2012). Vegetation is known for its calming effect on people, especially in urban areas. There is therefore a recreational value from greening in terms of increased blue and green infrastructure in urban areas. Here we use estimates from Fruth et al. (2020) indicating annual values of 94 - 105 €/person for street greening, and 68 -100 €/person for green facades.

Reduced effects from Urban Heat Islands

Urban Heat Islands (UHI) occur in urban areas due to an increased amount of heat absorbing materials such as concrete and asphalt combined with a lack of temperature regulating vegetations. This together with additional heat emissions from anthropogenic activities results in the UHI phenomenon. In a warmer climate the adverse effect from UHI is increasing, and health issues correlated to heatwaves are thereby increasing. In a Nordic context this effect is still relatively small, but a study by Huang et al. (2023) indicates that also for the bigger Nordic cities there is an estimated annual UHI related cost of deaths of around €50/capita. The same study concludes that a reduced imperviousness by 10 percent reduces the cost related to increased mortality by around one € per person per day during a heatwave. One way to reduce the UHI effect is to increase the surface greenery in the city. This may be done by green roofs, green facades, trees, and plant boxes in the streets as well as more parks. Measures like this may reduce the surrounding temperature from 1°C up to as much as 6°C in the surrounding areas (Bergen 2010) .

Opportunities for benefit transfer

Desk research, such as this, does not include performing new Revealed Preference (RP) or Stated Preference (SP) studies to value the identified externalities. Instead, we rely on existing studies and use benefit transfer techniques (or more general; value transfer, as both benefits and costs can be transferred): we apply recent guidance for environmental benefit transfer (Johnston et al. 2021) and seek to find valuation studies that value approximately the same change in the environmental good as in our case studies; both in terms of the baseline level, size and direction of change (increment/decrement), over the same type affected population (local, regional, national) and close geographically (same country or neighbouring countries) and in time (recent valuation studies are preferred over older ones). As individual preferences for both public health and environmental goods and ecosystem services vary spatially, with income level and over time; recent high-quality valuation studies from countries with similar average income level (in terms of Gross Domestic Product (GDP) per capita) as well as institutional and cultural contexts are preferred for benefit transfer. When there are spatial and temporal differences, these need to be adjusted for and/or transfer error bounds added to the monetary estimates used (Ready and Navrud 2006). In the valuation of ESs from NBS, Zanini et al. (2024) points out the importance of considering the quality and validity of the original valuation studies used for benefit transfer, and described a framework for benefit transfer from ESS impacted by NBS, that will be applied here.

Discount rates and time horizons

When annual future costs and incomes are recalculated to a Net Present Value the discount rate, the rate at how we valuate the future compared with today, must be set. On this topic there are suggestions ranging from 1.4% p.a. discussed in the Stern report up to 3.5-4% p.a. used by countries when discounting future events. Another approach used by some Nordic countries is to use a discount rate declining over time in two or more steps. Since the choice of discount rate has a significant impact on the net present value, especially under longer time horizons, we in our report perform the calculations with the three different discount rates 2, 3, and 4 percent.

Regarding the choice of time horizon, we choose to base our calculations on a 70-year timespan. The principle here is to base it on the expected life-length of the implemented solution, but rather than using different time horizons for the different projects we see a value in increasing the comparability by having the same horizon for all our identified solutions. We also assume that for implementation with a short life expectancy, reinvestments will be made during the 70-year span to maintain the full effect. Further, since the discounting effect on the net present value is high, the difference between 70 and 100 years in time horizon increases the NPV with less than 10%.

3. Method

Categorisation of Ecosystem Services from Nature-Based Solutions

We use the Millenium Ecosystem Assessment (2005) (MA) framework to categorise positive externalities from nature-based solutions. This globally recognised framework provides a comprehensive approach to understanding the benefits that ecosystems offer to human well-being, which is crucial for designing and implementing effective NBS. By aligning our categorisation with the MA framework, we aim to emphasise the multifunctional role of regulating environmental processes and supporting sustainable development goal, in addition to providing protection.

The Millenium Ecosystem Assessment (MA)

MA was an initiative conducted between 2001 and 2005 to evaluate the impacts of ecosystem changes on human well-being. Initiated by the United Nations, MA involved over 1,360 experts globally. The MA identifies four main categories of ecosystem services, which we adopt in our categorisation of nature-based solutions seen in Table 1:

1. **Regulating services:** Benefits from regulating ecosystem processes, such as climate regulation, disease control and water purification.
2. **Provisioning services:** Products derived from ecosystem processes, including food, fresh water, timber, and fibre.
3. **Cultural services:** Non-material benefits that ecosystems provide, including recreation, aesthetic experiences, and spiritual enrichment.
4. **Supporting services:** Fundamental processes that support all other services, such as soil formation, photosynthesis, and nutrient cycling.

Table 1 ESS Categories, as defined by the Millenium Ecosystem Assessment

regulating	provisioning	cultural	supporting
purification	food	cultural	nutrient cycling
climate regulation (UHI)	raw materials	spiritual and historical	primary production
waste decomposition	genetic resources	recreational	soil formation
Predation	biogenic minerals	science and education	habitat provision
pest and disease control	medicinal resources	therapeutic	
pollination	energy		
disturbance regulation	ornamental resources		

The Millenium Ecosystem Assessment provides a well-structured framework for understanding and categorising ecosystem services, making it highly suited for assessing nature-based solutions. Its systematic approach ensures that all key dimensions of ecosystem functionality – provisioning, regulating, cultural and supporting services – are considered. This holistic perspective enables a thorough evaluation of externalities from nature-based solutions.

Benefit transfer

We apply the framework for benefit transfer outlined in the work of Zanini et al. (2024), which simplifies the process of transferring monetised ecosystem service values from study sites (where the original valuation study was performed) to the policy sites (where the CBAs are performed). This framework reduces the risk that valuation studies are used out of their context, and thereby it increases the possibilities for decision-makers to effectively evaluate nature-based solutions (NBSs).

The benefit transfer methodology is divided into three main steps, each systematically designed to refine transferred values and ensure they align with the specific characteristics of the policy site.

1. PPP adjustment

The first step involves converting monetary values from the original study site to the currency of the policy site. This is done using purchasing power parity (PPP) to account for differences in economic conditions and price levels between regions.

2. Inflation adjustment

The values are then inflation-adjusted to a common year – in this case adjusted to EUR 2023. This ensures the comparability of values over time and avoids distortions caused by purchasing power. Note that this assumes that people's valuation of environmental goods increases at the same rate as the basket of goods that is used to calculate the change in the consumer price index.

3. Correction factor

To address the contextual differences between study sites and policy sites, a correction factor is applied based on three attributes:

- **Suitability of the study site** to the policy site, scored from 1 (low) to 5 (high), in terms of environmental, socio-economic and policy characteristics. Factors include ecosystem and climatic similarity, economic and cultural comparability, governance alignment, scale and scope and baseline conditions. A score of 5 indicates a near perfect alignment, while lower scores reflect increasing divergence and the need for adjustments.
- **Valuation methodology** used in the original study, assigned a binary value. Cost-based or market pricing methods and value transfer or other indirect methods correspond to score one and score zero, respectively.
- **Reliability of indicators** used to quantify benefits, assigned as a binary value with one for high reliability and zero for low reliability. Reliable indicators are scientifically validated, contextually relevant, and based on accurate, up-to-date data. Transparent documentation of data sources and assumptions ensures replicability and trustworthiness, making the indicators suitable for benefit transfer and robust decision-making.

The correction factor is derived from the sum of these scores, with adjustments made to the final transferred value as follows,

- Score 7 = correction factor of 1 (no adjustment).
- Score 6 = correction factor of 0.9.
- Score 5 = correction factor of 0.8.
- Score 4 = correction factor of 0.7.
- Score < 4 = correction factor of 0.5.

The corrected monetised value is obtained by multiplying the PPP and inflation adjusted benefit by the correction factor, resulting in the final monetised value for the policy site. Since a low correction factor will reduce the monetised value being transferred to the policy sites cost benefit analysis, this method ensures a conservative approach during the benefit transfer.

The Zanini et al. (2024) framework is an accessible and flexible tool for benefit transfer, allowing decision-makers to apply it without extensive expertise in economic valuation. Its adaptability accommodates diverse NBS characteristics, economic conditions, and valuation methods, ensuring reliable results across varying contexts. Scalable from local to European applications, the framework is particularly suited for preliminary evaluations. In this report, it enables the efficient transfer of benefits from previous studies to our policy sites, supporting the monetisation of NBS for challenges like sea-level rise and storm surges while maintaining methodological rigor.

4. Case studies: Nature-based solutions in the Nordic countries

This section presents different nature-based solutions implemented in Åland, Sweden, Norway, and Denmark, focusing on their socio-economic benefits.

Åland

Nabbens Wetlands in Mariehamn

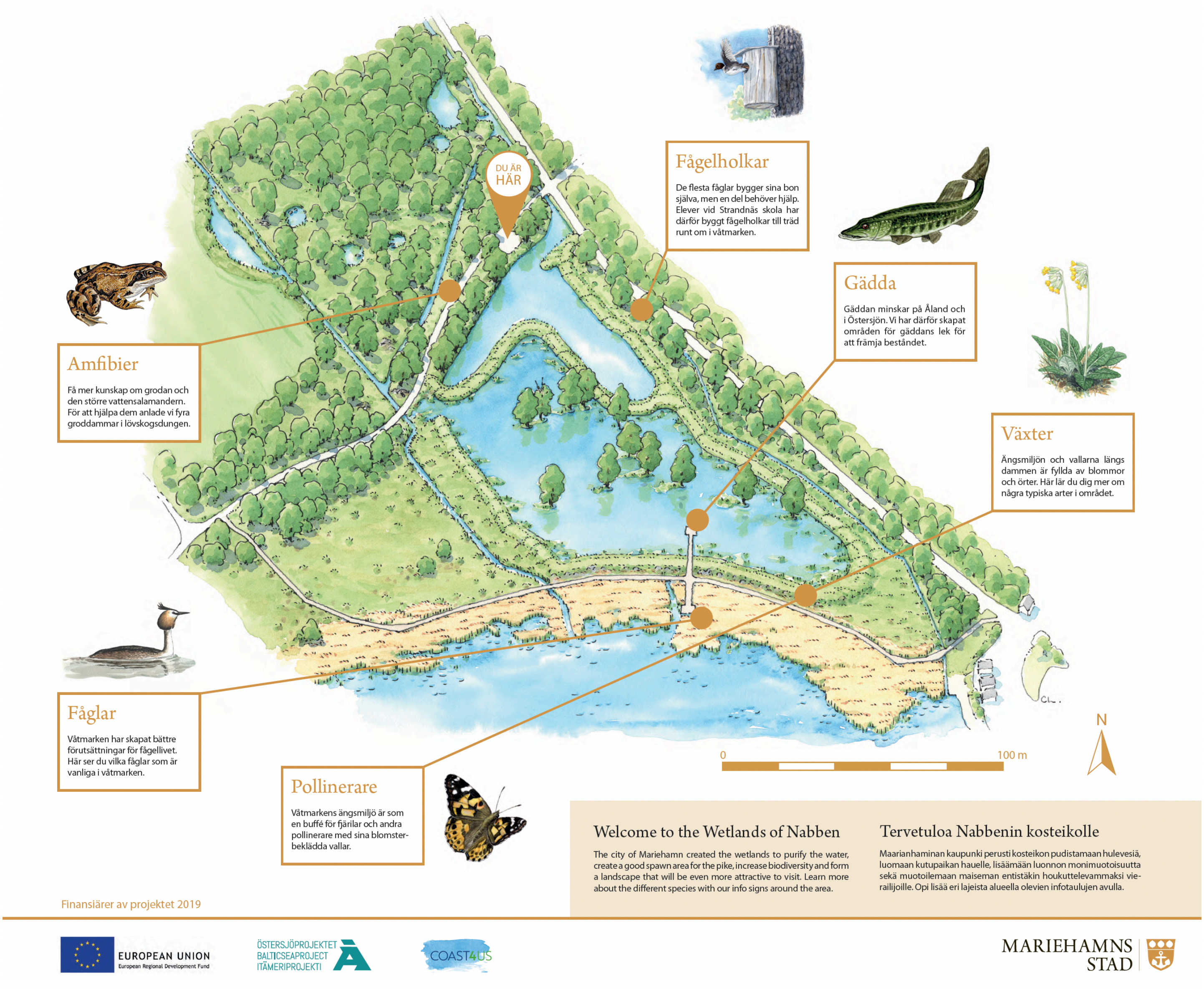
Description

With the main purpose of purifying storm water and increasing biodiversity in the Baltic Sea, a wetland at Nabben (a coastal area next to Mariehamn in the bay Slemmern) was constructed between 2016 and 2020. The three-hectare area consists of small streams, a sediment pond, and a wetland. Every year approximately 1.000.000m^3 of water passes through the wetland. Passing water is first filtered through sand in a meandering flow, then it passes through the sediment pool where water is purified of phosphorus and heavy metals. Next the water enters the wetland, where nitrogen is being transformed or taken up by vegetation. Estimates by the municipality of Mariehamn suggest that the wetland annually purify 800 kg of nitrogen, 100 kg of phosphorus and 1.5 ton of plastics. Wetlands are also good at sequestering carbon and estimates on annual carbon sequestration in Nabben comes to between 5 and 40 ton.

Besides its obvious benefit in purifying storm water before it enters the Baltics, the wetland protects against storm surges. To increase the recreational and education values of Nabben, there are walkways in and around the surrounding park. Further, there are information boards explaining both the water purification as well as its biodiversity in and around the park surrounding the wetland.

To help the aquatic fauna in the Slemmern, 10,000 juvenile pikes were released in the wetland. Since pikes are territorial, some of them are expected to come back to reproduce, further increasing the biodiversity.

The rich fauna in and around the wetland also generates social benefits in terms of increased biodiversity in the area.



Fågelholkar

De flesta fåglar bygger sina bon själva, men en del behöver hjälp. Elever vid Strandnäs skola har därför byggt fågelholkar till träd runt om i våtmarken.

Gädda

Gäddan minskar på Åland och i Östersjön. Vi har därför skapat områden för gäddans lek för att främja beståndet.

Amfibier

Få mer kunskap om grodan och den större vattensalamandern. För att hjälpa dem anlade vi fyra groddammar i lövskogsdungen.

Växter

Ängsmiljön och vallarna längs dammen är fyllda av blommor och örter. Här lär du dig mer om några typiska arter i området.

Fåglar

Våtmarken har skapat bättre förutsättningar för fågellivet. Här ser du vilka fåglar som är vanliga i våtmarken.

Pollinerare

Våtmarkens ängsmiljö är som en buffé för fjärilar och andra pollinerare med sina blomster-beklädda vallar.

Welcome to the Wetlands of Nabben

The city of Mariehamn created the wetlands to purify the water, create a good spawn area for the pike, increase biodiversity and form a landscape that will be even more attractive to visit. Learn more about the different species with our info signs around the area.

Tervetuloa Nabbenin kosteikolle

Maarianhaminan kaupunki perusti kosteikon pudistamaan hulevesiä, luomaan kutupaikan hauelle, lisäämään luonnon monimuotoisuutta sekä muotoilemaan maiseman entistäkin houkuttelevammaksi vierailijoille. Opi lisää eri lajeista alueella olevien infotaulujen avulla.

Finansiärer av projektet 2019

Figure 2 Map over Nabben, with educational information. (mariehamn.ax 2024)

Existing CBA

To our knowledge no initial cost benefit analysis was conducted as a part of the decision to build the wetland and its connecting streams and sediment pond.

Specific Societal Challenges addressed

Climate change mitigation and adaptation; Disaster risk reduction; Environmental degradation and biodiversity loss; Human health; Water security.

Sweden

Flood protection in Getinge

Description

The village of Getinge, located in Halland in southern Sweden, has experienced repeated flooding due to increased water flow in the Suseån River. To address this issue and protect critical infrastructure, the municipality of Halmstad initiated an investigation into the feasibility of implementing a nature-based solution. As part of the effort, a Cost-Benefit Analysis (CBA) of direct costs and benefits was conducted.

The flood protection system, shown in Figure 2, consists of two embankments (marked in red) with a total length of 1.2 km. These embankments, constructed using clay, soil and sand, protect key infrastructure in the village. The red-shaded areas represent zones at risk of flooding before the embankments were built, while the purple area indicates the reduced flood zones after construction.

A 16-hectare wetland was also established between the embankments. During normal water levels, runoff from nearby agricultural fields flow directly into the river. However, during high water events, gates are closed to retain water within the wetland, reducing downstream flood risks. The wetland also serves as a buffer zone, capturing excess nutrients from agricultural runoff and supporting local biodiversity.

The project also incorporates educational and recreational benefits. Walkways were built around the wetland to provide residents with opportunities for recreation, and educational research stations were established to engage schoolchildren in learning about local ecosystems and water management.

Existing CBA

The decision to build the sand banks was preceded by a CBA that took direct costs and direct savings from reduced damages on strategic infra-structure into consideration. The CBA used a project lifetime of 83 years and social discount rates of -3.5, as well as with 1.4 percent p.a. were applied when calculating the net present value. Both discount rates gave a positive net present value; 1 and 10 MSEK for 1.4 and 3.5%, respectively.

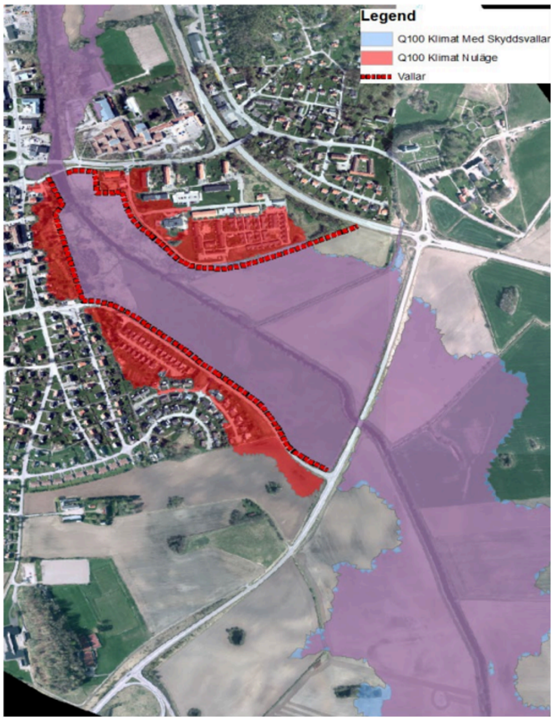


Figure 3 Map over Flood protection in Getinge, where the red striped line symbolises the sand banks, the shaded red colour symbolises the previous flooded areas and the shaded purple colour symbolise the areas that will be partially flooded after the sand banks are built.

Identified positive externalities

Since the runoff from the surrounding agricultural areas into the river is being slowed down, a regulating ES effect is the removal of Nitrogen (500–1000 kg/ha) and Phosphorus 50–100 kg/ha from the river that would otherwise have increased the eutrophication of the sea. (Weisner, Johannesson, and Tonderski 2015). A wetland of this size can also be estimated to sequester 30–200 tons of CO_2. Another benefit from the project is the positive impact on the supporting ES of habitat provision since the areas directly outside of the sand banks are being transformed into wetlands and thereby increase the biodiversity in the area. Further, the areas in and around the sand banks increase cultural ES in the form of recreation for people living nearby, as well as educational purposes for nearby schools.

Specific Societal Challenges addressed

Climate change mitigation and adaptation; Disaster risk reduction; Environmental degradation and biodiversity loss; Human health; Water security.

Norway

Flood able park (retention basin) in Nesbyen, Norway

Description

Due to increased flood risk along the Hallingdal River in Nesbyen, Norway, the village has experienced regular flooding incidents, impacting local infrastructure and agricultural areas. In response, the municipality of Nesbyen has designed a nature-based solution to mitigate these floods through the construction of a "floodable park". The project includes constructing soil banks, a retention basin, and a floodplain area spanning just under one hectare which serve as water retention and storage during high-flow periods. Additionally, the floodplain area provides a seasonal wetland that supports biodiversity and habitat formation, enhancing the ecological value of the area.

During typical river flow, water freely flows through channels in the park, allowing nearby agricultural runoff to enter the floodplain for natural filtration. In high-flow events, the floodplain holds excess water, which is gradually released after flood peaks, reducing downstream pressure and safeguarding infrastructure.

Figure 4 Retention basin, Nesbyen Norway

Existing CBA

A simplified Cost-Benefit Analysis (CBA) and risk assessment for Nesbyen's floodable park project has been conducted, focusing exclusively on reduced damages to residential houses, commercial businesses, and apartment buildings in the event of a 200-year flood. This CBA spans a 100-year analysis period with a declining discount rate (4%, 3%, 2%)[1] and the analysis reveals a marginal surplus when factoring in the reduced damages from only rare, extreme flood events.

Importantly, this CBA does not account for potential cost savings from less severe, more frequent flooding events, which are also likely to be reduced due to the flood park's protective infrastructure. By excluding the benefits of mitigating these lesser flood events, the analysis may underestimate the park's economic benefits. More frequent flooding incidents can cumulatively contribute to severe damage over time, impacting infrastructure stability, community displacement, and ongoing repair costs for local municipalities. Including these additional benefits in future analyses could improve the project's financial outlook and potentially highlight greater long-term savings.

The Norwegian Water Resources and Energy Directorate (NVE) is conducting a more thorough investigation into the flooding dynamics of the area, including an assessment of the severity of flooding events of different frequency. However, the results of this study were not available at the time of this report's publication.

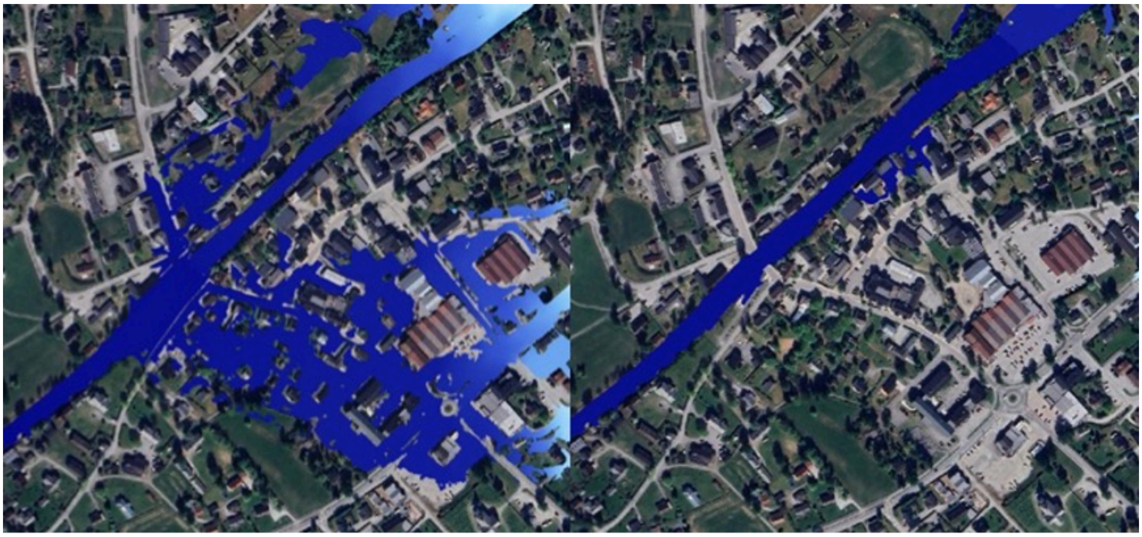


Figure 5 Simulation of 200-year flood, where the left pane shows the simulation without the measure, and the right pane shows the simulation with the measure.

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[1] 4% for the first 40 years, 3% until year 75 and 2% for following years. Common Norwegian practice.

Identified positive externalities

The park contributes to water purification by filtering runoff from nearby agricultural areas, which reduces the levels of nutrients like nitrogen and phosphorus entering the river and helps maintain better water quality. It also aids in disturbance regulation by acting as a flood buffer, holding back excess water during high-flow events and reducing flood risks for surrounding areas.

The park provides recreational opportunities through pathways and observation points, allowing the local population and visitors to engage in outdoor activities and connect with the natural landscape. It also supports science and education, serving as a learning site for schools and researchers interested in ecological processes, water management, and nature-based solutions. The park also contributes to public health and well-being by offering a natural space for residents, which can have positive effects on mental health and overall quality of life.

The park supports nutrient cycling by capturing agricultural runoff, which contributes to a healthier river ecosystem through natural nutrient processing. The floodplain creates habitat provision in the form of seasonal wetlands, supporting local biodiversity and attracting various species. Additionally, by slowing the entry of pollutants into the river, the park helps maintain water quality over time.

Specific Societal Challenges addressed

Climate change mitigation and adaptation; Disaster risk reduction; Environmental degradation and biodiversity loss; Human health; Water security.

Stream daylighting of Hovin Stream, Oslo

Description

The daylighting of Hovinbekken, a stream in Oslo, involves gradually reopening its previously enclosed sections to restore its natural flow and bring ecological, recreational, and environmental benefits to urban areas. The project has transformed Hovinbekken from being around 70% enclosed to almost 70% open, following a multi-decade process of strategic daylighting along various sections of the stream. The stream originates in Lillomarka near Linderudkollen and converges with the Akerselva under Oslo Central Station.

The daylighting efforts at Hovinbekken have included several notable stretches, such as:

- **Årvoll pond**: A section where the stream now flows through a pond.
- **Bjerkedalen Park**: A significant park feature incorporating the stream.
- **Teglverk pond at Hasle**: Opened in 2015, this stretch has become a popular spot with naturalistic design elements.
- **Ensjø and Jordal**: Ensjø is an area undergoing transformation from industrial to residential, allowing for open water spaces and integration with urban development. The segment at Jordal was reopened in 2020.

The project aims to mimic natural watercourse characteristics as closely as possible. This includes creating varied, meandering paths, vegetative buffers, and even deeper pools for aquatic life, providing shelter for fish and ensuring ecological balance. Additionally, these naturalistic features support flood control by managing urban runoff and increasing infiltration.

Figure 6 Daylighting of Hovin Stream in Oslo, showcasing the transformation of urban spaces with new green areas like The Teglverk Dam, The Tiedemann Park and The Stårlverk park.

The daylighting of Hovinbekken allows the stream to naturally manage stormwater through a series of open channels, wetlands, and retention areas. By slowing down and absorbing excess water during heavy rainfall, the stream reduces the risk of urban flooding, protecting nearby infrastructure and neighbourhoods. This natural flood management is increasingly crucial as climate change leads to more frequent and intense rain events. Additionally, it lessens the load on Oslo's drainage systems, potentially reducing the need for costly artificial flood control infrastructure.

Existing CBA

To our knowledge no initial CBA has been conducted.

Identified positive externalities

Climate Regulation

Exposing Hovinbekken and integrating it into green spaces creates microclimates that help mitigate the urban heat island effect. Water from the stream evaporates, cooling the surrounding air, especially during warmer months. The vegetation along the stream also provides shade and further cools the area. This natural cooling reduces the need for energy-intensive air conditioning in nearby buildings, which in turn contributes to lower greenhouse gas emissions. The green corridor along Hovinbekken thus supports both local climate comfort and broader climate goals for Oslo.

Recreation

The daylighted Hovinbekken offers a scenic, accessible environment for recreational activities. Parks, pathways, and open areas along the stream are popular spots for walking, jogging, picnicking, and other outdoor activities. These green spaces enhance physical and mental well-being for residents, providing a natural retreat within the urban environment. Moreover, by creating accessible water features, the project encourages residents to connect with nature and engage in outdoor exercise, fostering a healthier community.

Sense of Place

Daylighting Hovinbekken restores a natural feature that was previously hidden, reconnecting Oslo’s residents with an important part of the city’s ecological and historical heritage. The stream becomes a living reminder of Oslo's natural landscape, creating a unique urban identity rooted in environmental stewardship. By bringing nature into the city, the project strengthens residents’ connection to their environment and enhances community pride. This sense of place is invaluable in cultivating a collective responsibility for Oslo’s green spaces and waterways.

Specific Societal Challenges addressed

Climate change mitigation and adaptation; Environmental degradation and biodiversity loss; Human health.

Denmark

Climate adaptation at Karens Minde

Description

The cloudburst and urban space project Karens Minde Axis in the Copenhagen area of Sydhavn combines retention of up to 15,000 m^3 of rainwater with the development of parks, urban spaces, and nature. A tiled path wavers like a yellow river in and out between the many large old trees in the area. In the event of a cloudburst, water is transported through a 600 meters long course from Ellebjergvej in the north, past Karens Minde Culture House, and finally collected in a recreational rainwater basin.

Figure 7 Karens Minde, Copenhagen Denmark. The green areas symbolise the implemented park and the included rainwater retention

The project aims to improve the physical framework of the positive development that Sydhavnen is undergoing, where a unique grassroots spirit is paired with culture, nature, and wildlife. In the future, a large part of the area's cultural life, social activities and everyday life will unfold in the Karens Minde Axis, which at the same time creates a green connection between Vestre Kirkegård in the north and Tippen in the south. The project was constructed in 2023.

Figure 8 Karens Minde, Copenhagen Denmark

Existing CBA

For both the Danish projects in this report, a CBA has been conducted for the entire municipality of Copenhagen, but not for sub-projects. The results show a net present value of approx. DKK 5 billion. In the CBA, the following benefit components in terms of avoided damages are included: Damage to buildings and infrastructure, clean-up, traffic delays, lost earnings, and production loss.

Identified positive externalities

The Karens Minde project is part of Copenhagen municipality's cloudburst program which aims to reduce damage during cloudbursts. In addition to reducing damage during cloudbursts, the project has a positive effect on biodiversity as a recreational pond has been established to store rainwater during cloudbursts, as well as a "trickle meadow" has been established to function as a green cleaning measure. In addition, the facility receives everyday rain from the area, which reduces the amount of overflow water from the common sewer to the harbour, and then improving the environmental condition in the sea. The project has made a large area accessible to the citizens of the neighbourhood and made staying in the area more attractive.

Specific Societal Challenges addressed

Climate change mitigation and adaptation; Environmental degradation and biodiversity loss; Human health.

Climate adaptation at Skt. Kjelds neighbourhood

Description

The vision for Skt. Kjelds Square and Bryggervangen has been to transform the area into the green heart of the Climate-Resilient Neighbourhood, and to make it an urban space where nature is permitted to spread and where traffic operates in fine interaction with recreational areas. At the same time, Skt. Kjelds Square and Bryggervangen have been transformed, so it can protect the entire area from the future increase in precipitation and cloudbursts.

Figure 9 The intersection at Bryggervangen
Photo: Troels Heien

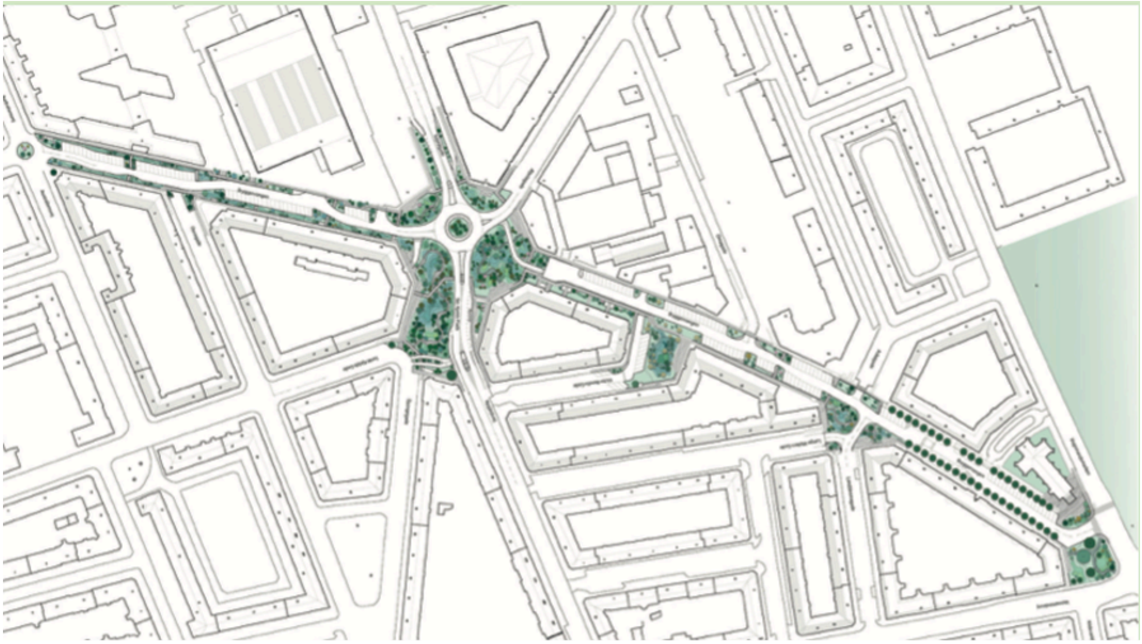

Figure 10 St Kjelds neighbourhood

Existing CBA

As mentioned above, a CBA has been conducted for the entire municipality of Copenhagen, but not for sub-projects. The results show a net present value of approx. DKK 5 billion. In the CBA, the following benefit components in terms of avoided damages, are included: Damage to buildings and infrastructure, clean-up, traffic delays, lost earnings, and production loss.

Identified positive externalities

Before the project began, the project area had around 15,300 m^2 of road area and no nearby places where the residents could meet or go for a walk. Now there is only 5,600 m^2 of that road area left, and the rest of the area has been transformed into green areas. The transformation of the area means that there are now far more recreational areas including trees, bushes, and plantations and thereby the biodiversity has become much greater. This allows the citizens of the area to have nature experiences close to where they live.

The green basin in the project receives everyday rain from the area, which reduces the amount of overflow water from the common sewer to the harbour. The extensive greening of the area also means that the project helps to reduce the UHI effect. It is estimated that the surface temperature and the temperature in the urban space during heat waves are reduced by 6–8 °C.

Specific Societal Challenges addressed

Climate change mitigation and adaptation; Environmental degradation and biodiversity loss; Human health.

5. Result

Value transfer

The below presented Table 2 summarises the assessment of various valuation studies used for cost benefit analyses in the identified nature-based solutions in this report. They were all chosen for their applicability to specific Nordic contexts, including Oslo, Copenhagen, Åland, and Getinge. We took extra care in deciding on the suitability score where three experts assessed it independently. Suitability scores were evaluated based on their relevance to the given locations, cost-based valuation, and the quality of indicators used. Overall, the method of assigning suitability scores to identified studies on monetised values enhances the importance of context-specific applicability and methodological robustness when transferring valuation frameworks to Nordic environmental and urban settings.

Key findings include high suitability scores for studies addressing urban heat islands (Huang et al. 2013) and combined sewage overflow reduction (Karras & Read 2016), both scoring six due to their alignment with local priorities and robust methodologies. Studies of the purification of nitrogen and phosphorus (Söderqvist & Wallström 2017) also scored six, showcasing strong relevance to Åland and Getinge's environmental goals. Similarly, Christie & Rayment (2012), which evaluates educational and recreational ecosystem services, also achieved a score of 6, reflecting its methodological robustness and relevance to the Nordic context. In contrast, studies with limited geographical or thematic overlap, such as increased Biodiversity in wetlands (Meyerhoff et al. 2012), and microplastic filtering (Beaumont et al. 2019), received lower scores of four, indicating increased uncertainty for their value transfer to the Nordic contexts.

Table 2 Correction factors for value transfer between chosen research papers and the six NBS.

Study	Site	Category	Applicable to	Suitabi	Cost-based	Quality	Sum
Barton et al. (2015)	Oslo	Recreational	Oslo, Copenhagen	4	0	1	5
Meyerhoff et al. (2012)	Germany	Biodiversity	Åland, Getinge	3	1	0	4
Beaumont et al. (2019)	Global	Microplastic filtering	Åland	4	0	0	4
Fruth et al. (2019)	Berlin	Urban greenery	Copenhagen	4	1	0	5
Christie & Rayment (2012)	England & Wales	Educational, recreational	Åland, Getinge	4	1	1	6
Huang et al. (2013)	Cities in Europe	UHI	Copenhagen	4	1	1	6
Karras & Read (2016)	Sweden	CSO reduction	Oslo, Copenhagen	4	1	1	6
Söderqvist & Wallström (2017)	Baltic	Purification of Nitrogen, Phosphorous	Åland, Getinge	4	1	1	6

Table 3 illustrates the process of adjusting valuation data from chosen studies to reflect the use of purchasing power parity (PPP)-corrected exchange rates and inflation adjustment to convert the estimates to 2023-euros, ensuring comparability and currency standardisation across studies. The columns labelled "Low" and "High" represent the original valuation ranges reported in the studies.

To account for differences in currency value and economic conditions, these original values were converted using PPP-corrected exchange rates, as shown in the PPP € Low and PPP € High columns. Subsequently, these PPP-adjusted values were updated to 2023 prices, reflecting inflation, in the €$_{2023}$ Low and €$_{2023}$ High columns. This adjustment ensures that all values are comparable in current economic terms, facilitating meaningful cross-study analysis.

Table 3 Temporal and Spatial adjustments from research papers to the Nordics 2023

Category	Unit	Study	Low	High	PPP € Low	PPP € High	€$_{2023}$ Low	€$_{2023}$ High	Adj. Low	Adj. High
Supporting										
Habitat provision	€/ha	eco-cost	6,900	6,900	6,900	6,900	6,743	6,743	4,720	4,720
Habitat provision	€/ha	Meyerhoff et al. (2012)	2,360	8,780	2,360	8,780	3,060	11,384	2,142	7,069
Water quality reduced (CSO)	SEK/m^3	Karras & Read (2016)	2	5	0.2	0.4	0.2	0.5	0.2	0.4
Regulating										
Purification plastic	$/ton	Beaumont et al. (2019)	3,300	33,000	2,196	21,961	2,644	26,438	1,850	18,500
Climate regulation	€/ton CO_2	WGI 2021	7	222	7	222	8	258	8	258
Purification Avoided P	SEK/kg	Göteborgs stad rapport nr.2022:09	16	16	1.2	1.2	1.5	1.5	0.7	0.7
Purification Avoided N	SEK/kg	Göteborgs stad rapport nr.2022:10	5	5	0.4	0.4	0.5	0.5	0.2	0.2
Purification N	SEK/kg	Söderqvist & Wallström (2017)	420	500	35	41	46	55	42	49
Purification P North Baltics	SEK/kg	Söderqvist & Wallström (2017)	4,662	5,334	345	395	430	492	387	443

Purification P South Baltics	SEK/kg	Söderqvist & Wallström (2017)	2,965	3,345	220	248	274	309	246	278
Purification P Kattegat	SEK/kg	Söderqvist & Wallström (2017)	2,052	2,395	152	177	189	221	170	200
Cultural										
Recreational	NOK/pers.	Barton et al. 2015	1,538	1,528	106	106	135	135	108	108
Recreational Street greening	€/person	Fruth et al. (2019)	94	105	94	105	115	128	92	103
Recreational Green facades	€/person	Fruth et al. (2019)	68	100	68	100	83	122	42	61
Recreational Green Initiative	€/person	Fruth et al. (2019)	29	31	29	31	35	38	18	19
Science and educational	£/ha	Christie & Rayment (2012)	93	98	93	99	121	128	109	115
Recreational	£/ha	Christie & Rayment (2012)	245	472	246	475	319	616	287	554
Science and educational	int$/ha	esvd.net	200	500	124	311	124	311	62	156
Recreational	int$/ha	esvd.net	300	600	187	373	187	373	93	187

The adjusted values from the table, standardised for PPP and inflation, are applied to the identified nature-based solutions (NBS) to estimate the benefits derived from externalities.

This application allows for a consistent and robust calculation of the externalities' monetary value, ensuring comparability across different NBS projects and providing a clear basis for assessing their cost-effectiveness and contribution to sustainable development goals.

Identified NBS

In the rest of the result chapter, we discuss our findings for each of the identified nature-based solutions. The NPV calculations are made on 2, 3, and 4 percent discount rate, and with a time horizon of 70 years. This horizon might seem a bit long for some of the solutions, and a bit short for others, but for comparison we mean its beneficial to use the same time horizon for all our analysis. In the following tables we present the high and low values for all estimations, we also present how the use of 2%, 3%, or 4% discount rate affects the calculated net present value.

Nabbens Wetland in Mariehamn, Åland

For the wetland Nabben outside of Mariehamn at Åland, Table 4 shows the monetised values for identified positive externalities. The net present values for purifications at a 3 percent discount rate are between € 0.98–1,2 M for Nitrogen, € 1,2–1.3 M for phosphorous, and purifying plastics contribute with € 75–750 k. The wetlands cultural support is estimated to be in the span of €36–60 k. Also, the two eco system services Habitat Provision and Carbon sequestering contributes with respectively €190–720 k and €5–170 k to the total monetised value for positive externalities of between €2.5–4.2 M. For the lower discount rate of two percent, the corresponding interval is €3.1–5.4 M, and for a four percent rate the sum is between €2.0 and 3.4 M. The summarised value of all identified positive externalities could be added to the value of protection against sea level rising and storm surges to then be compared with the cost of constructing and maintaining the wetland in a complete cost-benefit analysis.

Table 4 NPV for Nabben wetland

				Adj. price low	Adj. price high	NPV (3%) Low	NPV (3%) High
regulating	Purification	N	800 kg	€41	€49	€984,000	€185,000
regulating	Purification	P	100 kg	€387	€443	€1,161,000	€1,328,000
regulating	Purification	microplastic	1,350 kg	€1,851	€18,507	€75,000	€749,000
supporting	Habitat provision	biodiversity	3 ha	€2,142	€7,969	€,193,000	€717,000
Cultural	Recreational	Residents	3 ha	€287	€554	€,26,000	€50,000
cultural	educational	schools	3 ha	€109	€115	€,10,000	€10,000
Binding CO_2	Regulating	CO_2	22 ton	€8	€257	€5,000	€174,000
Sum						€2,454,000	€4,214,000
Sum (2%)						€3,128,000	€5,373,000
Sum (4%)						€1,990,000	€3418,000

Flood protection in Getinge, Sweden

Net present values for the positive externalities for the constructed flood protection in Getinge in Sweden is shown in Table 5. Here the purification of Nitrogen and phosphorous has the highest impact which sums up to between €19 M and €22 M at a 3 percent discount rate. This benefit is remarkably high, and if the purification benefit should be included in the original cost-benefit analysis, the expected amount of purified nitrogen and phosphorous would need to be verified. Further we see that the wetlands habitat provision contributes with between €1.0–3.8 M, while the cultural values are being estimated to be in between €190 k and €280 k for the seventy-year timespan. The wetlands carbon sequestration contributes with between €28 k up to €930 k to the total sum of €20–28M. The corresponding intervals for 2% and 4% discount rate are €26–35 M, and €16–22 M. These numbers should be compared to the calculated surplus of about M€1 over the 83-year time span at a discount-rate of 1.4 percent, based on production, maintenance, and protection against floodings.

Table 5 NPV for flood protection in Getinge

				Adj. price low	Adj. price high	NPV (3%) Low	NPV (3%) High
regulating	purification	nitrogen	12000 kg	€41	€49	€9,952,000	€11,848,000
regulating	purification	phosphorous	1200 kg	€387	€443	€9,288,000	€10,627,000
supporting	Habitat provision	biodiversity	16 ha wetland	€2,142	€7,969	€1,028,000	€3,825,000
Cultural	recreational	residents	16 ha	€287	€554	€138,000	€266,000
Cultural	Educational	schools	16 ha	€109	€115	€52,000	€55,000
Regulating	Climate regulation	CO_2 binding	120 ton	€8	€257	€28,000	€927,000
Sum						€20,487,000	€27,548,000
Sum (2%)						€26,122,000	€35,125,000
Sum (4%)						€16,616,000	€22,344,000

Retention basin in Nesbyen, Norway

Table 6 that contains the net present values for benefits from positive externalities at the retention basin in Nesbyen, indicates that at a 3 percent discount rate the cultural value over the coming 70 years is estimated to be between 5.5 M€ and 6.5 M€, while the habitat provision contributes to the span k€64–240. This sums up, at a 3.5 discount rate, from M€5.6 to M€6.7. For the two optional discount rates the corresponding spans are M€7.1–8.6 for 2% and M€4.5–5.5 for 4%. Since the recreational value for this NBS is high we would recommend further willingness to pay studies among the people living nearby the basin, before this number is included in a cost benefit analysis.

Table 6 NPV for retention basin in Nesbyen

				Adj. price low	Adj. price high	NPV (3%) Low	NPV (3%) High
cultural	recreational	residents	1,500 inh.	€108	€108	€4,851,000	€4,851,000
cultural	Education	School	350 pupils	€62	€156	€653,000	€1,633,000
supporting	Habitat provision	biodiversity	1 ha	€2,142	€7,969	€64,000	€239,000
Sum						€5,569,000	€6,723,000
Sum (2%)						€7,100,000	€8,573,000
Sum (4%)						€4,517,000	€5,453,000

Stream daylighting of Hovin Stream, Oslo

The results for the analysis on Hovin Stream in Oslo are displayed in Table 7. Like the retention basin in Nesbyen, we also here observe a high cultural value for the people living nearby the stream daylighting (close to M€100 at a 3 percent discount rate). This value might seem extremely high but considering 50 000 inhabitants benefit from the increased cultural value for a time span of 70 year, the annual benefit per capita is not particularly high. The daylighting is also estimated, again at a 3 percent discount-rate, to support water quality in the range of k€100–260 and habitat provision with approximately M€1.3. The Stream Daylighting at Hovin thereby is estimated to contribute with 98 M€ to the society. For the two optional discount rates the sums are estimated to M€125 at 2%, and M€80 at 4%.

Table 7 NPV for daylighting in Hovin Stream, Oslo

				Adj. price low	Adj. price high	NPV (3%) Low	NPV (3%) High
supporting	Water quality	CSO	20 000 m3	€0.2	€0.4	€103,000	€257,000
cultural	recreational	residents	50 000 inh	€108	€108	€97,022,000	€97,022,000
Supporting	Habitat provision	Reduced land use	9 ha	€4,720	€4,720	€1,274,000	€1,274,000
Sum						€98,399,000	€98,553,000
Sum (2%)						€125,466,000	€125,663,00
Sum (4%)						€79,810,000	€79,935,000

Climate adaptation at Karens Minde, Denmark

The estimated net present values from Karens Minde are, as seen in Table 8, also driven by the recreational values for the 8,800 inhabitants living nearby the 3.7-hectare park. At a 3 percent discount rate this value contributes with M€28 over the 70-year time span, while Habitat provision contributes with k€520, and increased water quality by between €1,000 and 3,000. The total net present value from positive externalities at Karnes Minde thereby sums up to M€29 at a 3% discount rate. With M€37 at 2%, and M€24 at 4%.

Table 8 NPV for climate adaption at Karens Minde, Copenhagen

				Adj. price low	Adj. price high	NPV (3%) Low	NPV (3%) High
cultural	recreational	residents	8800 inh	€ 108	€ 108	€ 28 460 000	€ 28 460 000
supporting	Habitat provision	Reduced land use	3,7 ha	€ 4 720	€ 4 720	€ 524 000	€ 524 000
supporting	Water quality	CSO	200 m3	€ 0.17	€ 0.43	€ 1 000	€ 3 000
Sum						€ 28 985 000	€ 28 986 000
Sum (2%)						€ 36 958 000	€ 36 960 000
Sum (4%)						€ 23 509 000	€ 23 510 000

Climate adaptation at Skt. Kjelds neighbourhood, Denmark

Table 9, that represents the net present value calculations, at a 3% discount rate, for Skt. Kjelds neighbourhood in Copenhagen, indicates that the Greening supports the habitat provision with k€140 and that the recreational value for the 19,000 inhabitants living nearby sums up to M€10 over the next seventy years. Again, the recreational value is driving the net present value, and the contribution of water quality of k€2–5 has only a minor effect on the total NPV at a 3% discount rate of M€10–11. For the lower discount rate at 2%, the NPV sums up to M€13–14, while span for the higher rate at 4% comes to the interval M€8.3–8.9.

Table 9 NPV for climate adaption at Skt. Kjelds, Copenhagen

				Adj. price low	Adj. price high	NPV (3%) Low	NPV (3%) High
cultural	recreational	residents	19,039 inh.	€18	€19	€10,095 000	€10,792,000
supporting	Habitat provision	Reduced land use	1 ha	€4,720	€4,720	€142,000	€142,000
supporting	Water quality	CSO	400 m^3	€0.17	€0.43	€2,000	€5,000
Sum						€10,239,000	€10,938,000
Sum (2%)						€13,056,000	€13,947,000
Sum (4%)						€8,305,000	€8,872,000

6. Discussion

Our main conclusion is that Nature based solutions may come with high positive social benefits. Therefore, a well-informed cost benefit analysis should include as well direct costs and damages as positive externalities such as increased biodiversity, water purification, human health, and recreational values. This will help decision makers to conduct well informed decision that maximises societal benefits, and at the same time helping to efficient adapt to climate change.

To make well informed decisions regarding how to tackle a specific problem related to increased sea levels, storm surges, and extreme rain, a cost benefit analysis (CBA) should be included in the process. In this report we have shown that the inclusion of positive externalities from nature-based solutions in the CBA can contribute at such a magnitude that the effect should not be neglected. During this project we realised that the important CBA was not included in all decision processes, and on some occasions, they seem to have been conducted after the decision to justify it, rather than with the purpose to inform the process.

To monetise externalities from the NBS we have used valuation studies of high quality in the benefit transfer. However, the match between the study sites and our analysed policy sites is often not perfect. We therefore see great need for more primary environmental valuation studies of positive externalities of NBS, both in general and particular in the Nordic countries. The externalities in question include both recreational, landscape aesthetic and educational ecosystem services benefits, as well as increased biodiversity and purification of nutrients (nitrogen and phosphorous) and pollutants like microplastics. For an example of the former, see a recent Stated Preference survey of opening a stream as a local NBS in Eastern Norway (Dugstad, Hammou, & Navrud, 2024).

During the process of adapting results from existing surveys to our identified cases, several uncertainties occur. First, the magnitude of the impact or change in the individual ESs (and the baseline from which the change took place) valued from the primary valuation study is different from in our policy case sites. Second, the individuals' valuation of the impact might not be the same at our policy sites as in the original study, as people's preferences vary geographically and over time, and our procedure for correcting for this in the benefit transfer might not capture all this variation. In our benefit transfer exercise, we have taken a conservative approach and tried to underestimate rather than overestimate the external benefits of NBS.

The main principle for handling negative externalities is the polluter pay principle, but sometimes this is not applicable and then the society must take responsibility. Since the scope of the positive externalities from implemented NBS may be larger than the scope of the direct climate adaption, this may have implications on who should pay for the NBS. This aspect is even more important when the provider of the NBS is a private agent, and then a CBA including positive externalities can be a helpful tool in deciding if and to what extent to compensate the agent.

Policy recommendation

In this report, we find socio economic gains by using nature-based solutions in climate adaptation. Although the results are fraught with uncertainty, our calculations show that there are significant benefits in using NBS that are overlooked in a traditional cost-benefit analysis. We therefore recommend that when including socio-economic calculations in the decision-making basis for the establishment of projects to counter climate change, a wider range of parameters shall be identified and used. The values used in this report provides a good starting point for future CBAs on Nature Based Solutions in the Nordic region.

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Technical appendix

Computing Net Present Value (NPV) in Cost-Benefit Analysis

Net Present Value (NPV) is a core tool in cost-benefit analysis, used to evaluate the economic viability of projects by comparing the present value of all benefits and costs associated with a project over time. NPV helps determine whether the benefits outweigh the costs and by how much, thus aiding in decision-making for policy or project implementation.

The formula for calculating NPV in a cost-benefit analysis context is:

$$NPV = \sum_{n=0}^{T} \frac{B_t - C_t}{(1+r)^t}$$

Were,

- B_t is the benefit at time t,
- C_t is the cost at time t,
- r is the discount rate reflecting time preference or opportunity cost,
- t is the time period, usually in years
- T is the total number of periods over which the analysis is conducted.

Due to lack of cost data, we have only computed the net present value of *benefits* in our computations, i.e. we set

Data sources for PPP and Inflation adjustment

In the benefit transfer framework applied, monetary values were adjusted for regional economic conditions and time consistency. For the PPP adjustment, we used Eurostat data on purchasing power parities (doi: 10.2908/prc_ppp_ind), based on the index set at $EU27_{2020}=1$. For inflation adjustment, values were brought to the price level of the year 2023 using the Harmonized Index of Consumer Prices (HICP) annual data (doi: 10.2908/prc_hicp_aind) for the European Union.

About this publication

Economic benefits of nature-based solutions in relation to sea level rise, storm surges and extreme rain

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TemaNord 2025:516

ISBN 978-92-893-8173-4 (PDF)
ISBN 978-92-893-8174-1 (ONLINE)
http://dx.doi.org/10.6027/temanord2025-516

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Cover photo: Ida-Lina Strang
Published: 26/2/2025

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The Nordic Council of Ministers
Nordens Hus
Ved Stranden 18
DK-1061 Copenhagen
pub@norden.org

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