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Cost-benefit analysis of municipal water protection measures

Environmental benefits versus costs of implementation

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Report of the CITYWATER project – *Benchmarking water protection in cities* with the contribution of the LIFE financial instrument of the European Community

Project number LIFE11 ENV/FI/000909

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Preface

This cost-benefit analysis (CBA) study is conducted in the CITYWATER – *Benchmarking water protection in cities* project. The CITYWATER project works to improve the state of coastal waters and to strengthen civil servants' capabilities to better take into consideration water protection aspects in their work. In addition to the CBA study, the CITYWATER project implements storm water management solutions in three cities, develops environmental communication in the Baltic Sea region and promotes the Baltic Sea Challenge network. The Baltic Sea Challenge network is an international network for local actors, e.g. cities and municipalities, supporting their work for healthier local waters and the entire Baltic Sea. The CITYWATER project partners are the City of Helsinki (lead partner), City of Turku, Tallinn City and Tallinn University. The project is co-financed by the European Commission Life+ programme (50%), the Finnish Ministry of the Environment and the partners.

In addition to the CBA study, the cost-benefit analysis work package in the CITYWATER project included two workshops and several excursions to the case cities participating in the study. The first workshop was arranged in March 2013 and the second in April 2014 in Helsinki. The excursions to the cities of Turku, Lahti, Liepaja and Pori and to the Port of Helsinki were made in autumn 2013–winter 2014.

On behalf of the CITYWATER project and the City of Helsinki I would like to thank everyone who has participated in the study, the workshops or the excursions. Especially I want to thank case city representatives in Turku, Lahti, Liepaja, Pori and Helsinki for providing material and data for the case studies and for helping with identification of the impacts. I would also like to thank everybody who gave valuable comments on the study and this report, especially experts from the City of Helsinki, University of Helsinki and MTT Agrifood Research Finland.

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Helsinki, 17 December 2014

Summary

Cost-benefit analysis of municipal water protection measures: Environmental benefits versus costs of implementation

The cost-benefit analysis study conducted in the CITYWATER – *Benchmarking water protection in cities* project focuses on assessing the role of local actors, e.g. cities and municipalities working in saving the Baltic Sea. The study consists of five case studies representing differing water protection measures implemented by the municipalities within the Baltic Sea catchment area: centralising of municipal wastewater treatment to Luotsinmäki WWTP in Pori, an investment in new aerators in Liepaja WWTP, reception of sewage waters from ships in the Port of Helsinki, a constructed stormwater wetland in Lahti and agricultural buffer zones in the city of Turku. The study aims at providing information on the impacts of municipal water protection measures, the environmental benefits in monetary terms and the net benefits gained by the society. The main research method is cost-benefit analysis, which assesses the potential of measures to increase social welfare by comparing their overall benefits and costs during their lifespan.

The results from the case studies show that local actors are in a crucial role in protecting the Baltic Sea. Remarkable nutrient load reductions are achieved by investments in WWTPs in Pori and Liepaja as well as port reception facilities in Helsinki, but also natural solutions such as stormwater wetland in Lahti and agricultural buffer zones in Turku were estimated to reduce nutrient load rather efficiently. The reductions have an impact both on the state of the Baltic Sea and the local waters, such as lakes, rivers and coastal waters. In addition, case measures can also provide various other benefits, for example energy savings, reduced climate emissions, biodiversity and recreational values.

If the state of the Baltic Sea remains poor in the future, the value of single nutrient reductions is very high. In this case, the studied measures seem to provide substantial positive net benefits, suggesting that they are clearly worthwhile from the society's point of view. However, if a good state of the sea will be achieved in the future, the overall benefits would be higher, but additional nutrient reductions become less valuable while the state of the sea improves leading to a decrease in the value of the estimated net benefits or to even negative net benefits depending on the measure in question. Although a comprehensive sensitivity analysis was performed, the results include some uncertainty related to the prediction of future impacts and the lack of data. Many important local impacts were identified but only some of them were possible to measure and monetise and thus the net benefits are likely underestimated. Hence, the quantitative results should be taken as rough estimates.

In conclusion, different kinds of water protection actions around the Baltic Sea are needed: the protection of the Baltic Sea should be seen as an entirety and every single measure is an important part of it. The study encourages implementing diverse water protection measures both by the coast and elsewhere in the catchment area and to prefer measures that provide multiple benefits. It also suggests putting effort on local water protection research, in order to enable taking local impacts into account in decision-making concerning water protection, even at the Baltic Sea level. The study recommends using a cost-benefit analysis and the Baltic Sea Challenge network as supportive tools for implementing new water protection measures.

The CITYWATER project aims to promote implementing water protection actions to improve the state of the local waters and the Baltic Sea. The project is realised in collaboration between the Cities of Helsinki, Turku and Tallinn, as well as Tallinn University. The project is co-financed by the EU Life+ financial instrument.

Yhteenveto

Kustannus-hyötyanalyysi kunnallisista vesiensuojelutoimenpiteistä: Ympäristöhyödyt vastaan toteuttamisen kustannukset

CITYWATER – *Benchmarking water protection in cities* -projektissa toteutetussa kustannus-hyötyanalyysissä tarkastellaan paikallistoimijoiden, kuten kuntien ja kaupunkien, roolia Itämeren suojelutyössä. Tutkimus sisältää viisi tapaustutkimusta erilaisista vesiensuojelutoimista, joita kunnat ovat toteuttaneet Itämeren valuma-alueella: jätevedenpuhdistuksen keskittäminen Luotsinmäen keskuspuhdistamoon Porissa, investointi uusiin ilmastimiin Liepajan jätevedenpuhdistamolla, laivajätevesien vastaanotto Helsingin satamassa, rakennettu hulevesikosteikko Lahdessa ja peltojen suojavyöhykkeet Turussa. Tutkimuksen tavoitteena on tarjota tietoa kunnallisten vesiensuojelutoimien vaikutuksista, rahamääräisistä ympäristöhyödyistä ja yhteiskunnan saamista nettohyödyistä. Tutkimuksen päämenetelmä oli kustannus-hyötyanalyysi, joka arvioi toimenpiteiden potentiaalia lisätä yhteiskunnan hyvinvointia vertailemalla niiden elinkaaren aikaisia kokonaishyötyjä ja -kustannuksia.

Tapaustutkimuksen tulokset osoittavat, että paikallistoimijat ovat keskeisessä roolissa Itämeren suojelussa. Investoinnit jätevedenpuhdistukseen Porissa ja Liepajassa sekä laivajätevesien vastaanottoon Helsingissä tuovat merkittäviä ravinnepäästövähennyksiä. Myös luonnollisten ratkaisujen, kuten Lahden hulevesikosteikon ja Turun suojavyöhykkeiden, arvioitiin vähentävän ravinnekuormitusta verrattain tehokkaasti. Ravinnepäästöjen vähennyksellä on vaikutusta sekä lähivesien, kuten järvien, jokien ja rannikkovesien, että Itämeren tilaan. Lisäksi, tutkitut toimenpiteet tarjoavat myös lukuisia muita hyötyjä, esimerkiksi energiansäästöjä, vähennyksiä ilmastokuormituksessa, biodiversiteettivaikutuksia ja parantuneita virkistysmahdollisuuksia.

Jos Itämeren tila pysyy heikkona tulevaisuudessa, yksittäiset päästövähennykset ovat hyvin arvokkaita. Tässä tapauksessa tutkitut toimenpiteet näyttävät tuovan suuria positiivisia nettohyötyjä ja olevan täten yhteiskunnallisesti selvästi kannattavia. Jos tulevaisuudessa saavutetaan meren hyvä tila, sen kokonaishyödyt ovat suuremmat, mutta yksittäisen päästövähennysten arvo kuitenkin pienenee meren tilan parantuessa. Tämä laskee yksittäisen toimenpiteen tuomaa nettohyötyä ja joidenkin toimenpiteiden tapauksessa johtaa jopa negatiivisiin nettohyötyihin. Tuloksille suoritettiin kattava herkkyysanalyysi, mutta niihin sisältyy silti jonkin verran epävarmuutta johtuen tulevaisuuden vaikutusten ennustamisesta ja aineiston rajallisuudesta. Nettohyödyt ovat todennäköisesti aliarvioita, koska monia tärkeitä paikallisvaikutuksia tunnistettiin, mutta vain osa niistä oli mahdollista mitata ja arvioida rahamääräisinä. Tämän vuoksi kvantitatiivisia tuloksia tulee pitää karkeina arvioina.

Johtopäätöksenä voidaan todeta, että monenlaisia toimenpiteitä eri puolilla Itämerta tarvitaan: Itämeren suojelu tulee nähdä kokonaisuutena ja jokainen yksittäinen toimenpide on tärkeä osa sitä. Tutkimus kannustaa erilaisten vesiensuojelutoimien toteuttamiseen sekä rannikolla että muualla valuma-alueella ja suosimaan toimenpiteitä, jotka tuovat moninaisia hyötyjä. Tutkimuksen mukaan paikalliseen vesiensuojelututkimukseen tulisi panostaa, jotta paikalliset vaikutukset voidaan ottaa huomioon vesiensuojelua koskevassa päätöksenteossa, myös Itämeren tasolla. Tutkimus suosittelee kustannus-hyötyanalyysiä ja Itämerihaaste-verkostoa uusien vesiensuojelutoimien toteuttamista tukevina työkaluina.

CITYWATER-projektin tavoitteena on edistää Itämeren ja lähivesien tilaa parantavien vesiensuojelutoimien toteuttamista. Projekti toteutetaan Helsingin, Turun ja Tallinnan kaupunkien ja Tallinnan yliopiston yhteistyönä, ja se saa rahoitusta EU:n Life+ -ohjelmasta.

Sammandrag

Kostnadsnyttoanalys av kommunala vattenskyddsåtgärder: Miljönytta kontra kostnader för implementering

Kostnadsnyttoanalysen har utförts inom ramen för projektet CITYWATER – *Benchmarking water protection in cities* och undersöker vilken roll lokala aktörer, t.ex. städer och kommuner, har i arbetet för att skydda Östersjön. Undersökningen omfattar fem fallstudier där kommuner inom Östersjöns avrinningsområde har implementerat vattenskyddsåtgärder: centralisering av avloppsvattenrening till Luotsinmäki centralreningsverk i Björneborg, investering av nya luftare i vattenreningsverket i Liepaja, mottagning av avloppsvatten från fartyg i Helsingfors hamnar, en konstruerad våtmark i Lahtis och skyddszoner längs åkrar i Åbo. Syftet med undersökningen är att ge kunskap om effekten av kommunala vattenskyddsåtgärder, den monetära miljönyttan och den samhälleliga nettonyttan. Med kostnadsnyttoanalys som huvudsaklig undersökningsmetod kunde åtgärdernas potential för att öka samhällets välfärd bedömas genom att jämföra de sammantagna nyttorna med de sammantagna kostnaderna under åtgärdernas hela livscykel.

Fallstudierna visade att lokala aktörer har en central roll i att skydda Östersjön. Investeringarna i vattenrening i Björneborg och Liepaja samt mottagningen av fartygsavaloppsvatten i Helsingfors leder till betydande utsläppsminskningar. Även naturliga lösningar, så som dagvattenvåtmarken i Lahtis och skyddszonerna i Åbo, uppskattades minska näringsbelastningen relativt effektivt. Näringsutsläppsminskningen har betydelse såväl för de lokala vattendagen - sjöar, åar och kustvatten – som för Östersjöns tillstånd. Dessutom medför de undersökta åtgärderna flera andra nyttor, t.ex. energibesparingar, reducerade klimatutsläpp, ökad biodiversitet och förbättrade rekreationsmöjligheter.

Om Östersjöns tillstånd förblir svagt även i framtiden, är enskilda utsläppsminskningar mycket värdefulla. Om så är fallet verkar de undersökta åtgärderna föra med sig stor positiv nettonytta och är därmed samhälleligt klart lönsamma. Uppnår man däremot ett gott tillstånd i Östersjön i framtiden blir de sammanlagda nyttorna större, medan värdet på en enskild åtgärd sjunker i och med förbättringen av tillståndet i havet. Detta medför en sänkning av nettonyttan för enskilda åtgärder och leder för vissa åtgärder till negativ nettonytta. En omfattande känslighetsanalys utfördes, men resultaten innehåller trots den en del osäkerhet på grund av uppskattningar av framtida effekter och begränsningar i tillgänglig data. Värdet på den uppskattade nettonyttan är antagligen i underkant, eftersom många av de identifierade lokala effekterna inte var möjliga att mäta och monetärisera. Följaktligen skall de kvantitativa resultaten betraktas som grova uppskattningar.

Sammanfattningsvis kan konstateras att olika åtgärder runt Östersjön behövs: skyddet av Östersjön skall ses som en helhet, där varje enskild åtgärd utgör en viktig del. Undersökningen uppmuntrar till implementering av olika vattenskyddsåtgärder både längs kusten och inom andra delar av avrinningsområdet och till att främja åtgärder som samtidigt ger flera andra nyttor. Undersökningen fastslår även att man borde investera i vattenskyddsforskning för att bättre kunna beakta lokala effekter i beslutsfattande om vattenskydd, även på Östersjönivå. Studien rekommenderar kostnadsnyttoanalys och nätverket Östersjöutmaningen som stöd för att implementera nya vattenskyddsåtgärder.

Målsättningen för CITYWATER-projektet är att främja implementeringen av vattenskyddsåtgärder som förbättrar Östersjöns och de lokala vattendragens tillstånd. Projektet förverkligas som ett samarbete mellan städerna Helsingfors, Åbo och Tallinn samt Tallinns Universitet och delfinansieras av EU Life+-programmet.

Kokkuvõte

Omavalitsuste veekaitsemeetmete tasuvusanalüüs: keskkonnakasude võrdlus elluviimise kuludega

Projekti «CITYWATER – veekaitsemeetmed Läänemere linnades» raames läbi viidud tasuvusuuring keskendub kohaliku tasandi tegutsejate s.t. linnade ja omavalitsuste tööle Läänemere kaitseks. Uuring vaatleb viit näidet, mis esindavad erilaadseid omavalitsuse poolt ellu viidud veekaitsemeetmeid Läänemere vesikonnas: omavalitsuse reoveepuhastuse tsentraliseerimine Luotsinmäki puhastusjaamas Poris, uute aeraatorite soetamine Liepaja puhastusjaamas, laevadelt reovee vastuvõtmine Helsingi sadamas, sadevete jaoks rajatud märgala Lahtis ning põllumajanduslikud puhvertsoonid Turu linnas. Uuring püüab pakkuda teavet omavalitsuse veekaitsemeetmete mõjude, keskkonnakasude rahalise väärtuse ja ühiskonna saadud kogukasu kohta. Peamine uuringumeetod on tasuvusanalüüs (*cost-benefit analysis*), mis hindab meedete potentsiaali suurendada ühiskondlikku heaolu, võrreldes nende üldiseid ning eluea jooksul kogunevaid tulusid ja kulusid.

Näidisjuhtumid kinnitavad, et kohaliku tasandi tegutsejad on Läänemere kaitsel võtmetähtsusega. Pori ja Liepaja reoveepuhastitesse tehtud investeeringud, aga ka sadamarajatised Helsingis, tõid kaasa märkimisväärse toitainete koormuse vähenemise. Looduslikud lahendused nagu märgala Lahtis ja puhvertsoonid Turus aitasid samuti tõhusalt kaasa toitainete koormuse vähenemisele. Koormuse vähenemise mõju on märgata nii Läänemere kui ka sinna suubuvate siseveekogude nagu jõgede ja järvede seisundist. Lisaks pakuvad vaadeldud meetmed muidki kasusid, näiteks energiasäästu, väiksemaid kliimaemissioone, suurenenud elurikkust ja puhkeväärtust.

Kui Läänemere seisund jääb ka tulevikus nigelaks, on iga üksiku toitainete koormust vähendava tegevuse mõju oluline. Sel juhul pakuvad uuritud meetmed olulist kogukasu, viidates, et ühiskonna jaoks on tegu selgelt kasutoovate tegevustega. Kui aga Läänemeri saavutab aja jooksul hea seisundi, on kogukasu suurem, kuid iga toitainete koormust vähendav tegevus on mere seisukorra paranedes väiksema kaaluga. See viib tegevuste kogukasu vähenemiseni või isegi negatiivse netotuluni, sõltuvalt meetme olemusest. Kuigi viidi läbi ulatuslik tundlikkuse analüüs, sisaldavad tulemused mõningas määramatust, tulenevalt tuleviku mõjude ennustamisest ja andmete nappusest. Tuvastati mitmeid olulisi mõjutusi kohalikul tasandil, kuid vaid mõningaid oli võimalik mõõta ja rahaliselt väljendada, seega on kogutulu tõenäoliselt alahinnatud. Nii tuleks uuringu kvantitatiivseid tulemusi võtta ligikaudsete hinnangutena.

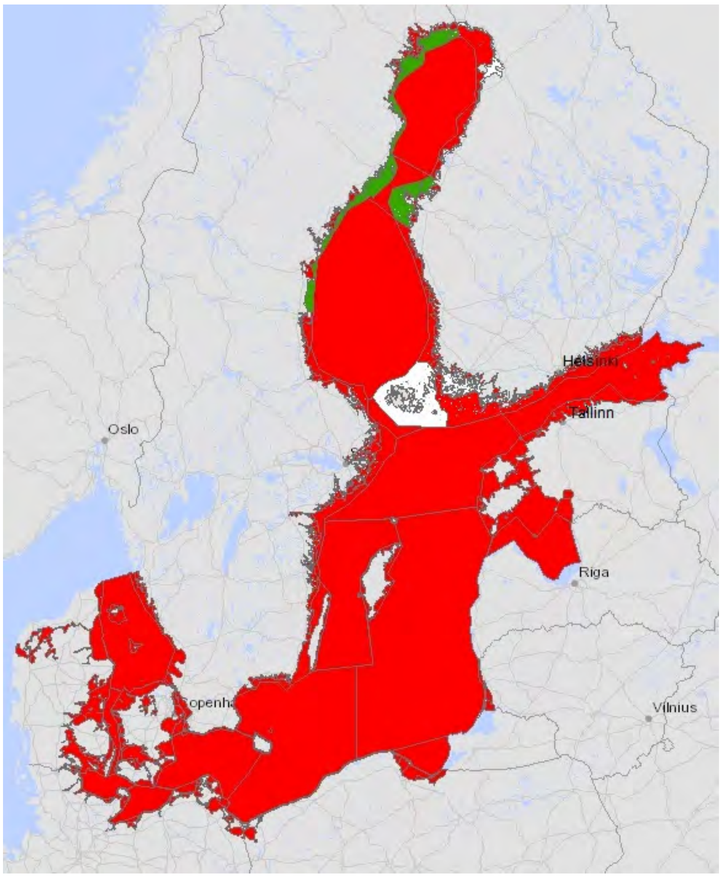
Kokkuvõttes vajab Läänemeri erilaadseid veekaitsemeetmeid: Läänemere kaitset tuleks vaadelda tervilikuna ning iga tegevust selle olulise osana. Uuring julgustab rakendama erinevaid veekaitsemeetmeid nii rannikualadel kui mujal vesikonnas ning eelistama neid meetmeid, mis pakuvad laialdasi kasusid. Raport soovitab panustada ka kohaliku veekaitse alastesse uuringutesse, võimaldamaks veekaitse alaste, sh Läänemere-kaitse alaste, otsuste langetamisel võtta arvesse mõjusid kohalikul tasandil. Uuring soovitab uute veekaitsemeetmete ellu viimisel kasutada toetava vahendina nii tasuvusanalüüsi kui ka Läänemere väljakutse võrgustikku (*Baltic Sea Challenge network*).

Projekti CITYWATER eesmärk on toetada veekaitsemeetmete elluviimist, et parandada siseveekogude ja Läänemere seisundit. Projekt viiakse ellu Helsingi, Turu ja Tallinna linnade ning Tallinna Ülikooli koostöös. Projekti kaasrahastab Euroopa Liidu programm Life+.

1 Introduction

1.1 Background

The Baltic Sea is the second largest brackish water body in the world in terms of water volume, but at the same time is very sensitive due to its shallowness, low salinity and slow replacement of water. Eutrophication is the main threat to the Baltic Sea ecosystem (The Baltic Sea Portal, 2014). According to the latest assessment by the Helsinki Commission, HELCOM (2014d), almost the entire Baltic Sea is suffering from eutrophication (Picture 1). The eutrophication of the Baltic Sea is driven mainly by nitrogen and phosphorus over-enrichment in water due to external nutrient load from riverine inputs, atmospheric deposition, direct discharge to water and runoff from diffuse sources (HELCOM, 2014d). Municipal waste water treatment plants, industry, fish farms and shipping produce point source nutrient load while diffuse nutrient load sources are originated from agriculture, forestry and storm waters (HELCOM, 2011). Nutrient over-enrichment causes excessive growth of algae and plants, algae blooms, oxygen depletion in bottom waters, decreased visibility and changes in composition of species (HELCOM, 2014d; The Baltic Sea Portal, 2014).



Picture 1. Eutrophication status of the Baltic Sea in open and coastal sea areas in 2007–2011 (green = good ecological status; red = less than good ecological status, based on EU classification) (modified from HELCOM (2014c))

Although it is commonly known that the main reason for eutrophication is the excess nutrient loads caused by human activities, the state of the Baltic Sea has not been restored to a good ecological level because reduction of nutrient loads has turned out to be challenging. Because the sea is common to 14 states, eutrophication is also a common problem, and all states in the Baltic Sea catchment area should be involved in the protection. Although there are guidelines and recommendations on what should be done to improve the state of the sea (e.g. EU Baltic Sea Region Strategy, the Water Framework Directive, the Marine Strategy Framework Directive, The Baltic Sea Action Plan by HELCOM), they are not powerful enough to reduce nutrient loads efficiently. Joint protection is challenging for many reasons, for example, because the impacts become apparent in delay and the division of benefits and costs of protection is asymmetric (e.g. BalticSTERN, 2013; Hyytiäinen & Ahlvik, 2014).

To achieve a good ecological status of the Baltic Sea in the future as described in the Baltic Sea Action Plan, a nutrient reduction scheme by HELCOM, the total annual nitrogen load should be reduced by 118,000 tonnes and total annual phosphorus load by 15,000 tonnes (HELCOM, 2013). Although HELCOM has state-level targets, the reductions are realised through water protection measures implemented on a local level. Nutrient loads to the Baltic Sea may be reduced by taking measures both by the coast and on land, since all nutrient load reductions within the Baltic Sea catchment area have an impact on both the state of the Baltic Sea and the local waters, such as lakes and rivers. In other words, when local actors, e.g. cities and municipalities, are implementing water protection measures to reduce nutrient load to their local waters, they protect the Baltic Sea at the same time. Thus local actors are in a crucial role in saving the Baltic Sea.

It is important to protect the Baltic Sea, because it provides many kinds of benefits. In the Baltic Sea catchment area there are living over 84 million people from 14 states (HELCOM, 2011), all using the common sea and benefiting from it more or less. As an example, in many Baltic Sea countries about 80–90% of people are used to spending their leisure time on the Baltic Sea by swimming or walking or picnicking (Söderqvist et al., 2010, pp. 25-28). SEPA (2008) identified in total 24 different ecosystem services that the Baltic Sea provides. These ecosystem services consist of well-known services like food and recreational opportunities that provide direct benefits for people, but also supportive and regulative services that are essential in sustaining the balance of the marine ecosystem. Eutrophication has shown to have an impact on the ecosystem functioning negatively by decreasing habitat provision, diversity and even resilience of the sea. This means decreased food supply and recreational opportunities among others (SEPA, 2008).

Decreasing eutrophication in the Baltic Sea provides notable benefits, but it also costs. The benefits should be taken into account when deciding on resource allocation regarding the water protection, but how much money should be put on water protection, if we want to use our budgets effectively? The environmental benefits for people can be measured in monetary terms by economic valuation methods to enable comparison of the benefits and the costs of environmental protection. The BalticSTERN (2013) study evaluated that the total benefits of achieving a good ecological status of the Baltic Sea would be at least 3800 million euros for the citizens around the Baltic Sea. These benefits were estimated using the contingent valuation method with a survey on willingness to pay for improved state of the Baltic Sea among citizens of nine coastal states (Ahtiainen et al., 2012). The costs of achieving these reductions by the most cost-effecient allocation of measures would be 2300–2800 million euros annually (BalticSTERN, 2013). The monetary benefits exceed the costs, and thus, the protection of the Baltic Sea increases social welfare. In fact, the net benefits are even higher if the benefits from the improved state of local waters would be included (Ahlvik & Ahtiainen, 2014). In addition, the protection provides many ecological benefits that have intrinsic values and are not possible to measure in monetary terms. However, with no water protection actions any of these benefits are not achieved.

1.2 The objectives of the study

As discussed above, protection of the Baltic Sea appears to be worthwhile in general. However, there is lack of information on the role of local actors, e.g. cities and municipalities working for saving the Baltic Sea. Which and how large impacts can be related to municipal water protection measures? How are they affecting the state of the local water systems or the state of the Baltic Sea? How large are the environmental benefits gained compared to the costs of these measures? Are the measures worthwhile from the perspective of social welfare? This study aims to search for answers to these questions, through studying five case measures that cities and municipalities have implemented: improvements in waste water treatment plants in the cities of Pori and Liepaja, reception of sewage waters from ships in the Port of Helsinki with no special fee praxis, a constructed urban wetland in Lahti and agricultural buffer zones in Turku (Table 1).

Table 1. The CITYWATER cost-benefit analysis study aims to find answers to the study questions by performing cost-benefit analysis on five case studies in four themes of water protection

Wastewater treatment	**Wastewater discharge in harbours**
Case Luotsinmäki WWTP: Centralising of municipal wastewater treatment as a collaboration of municipalities **Case Liepaja WWTP**: Investment in new aerators and PC-program	**Case Port of Helsinki**: Wastewater reception from passenger ships with no special fee
Questions concerning municipal water protection measures Which and how large impacts can be related to municipal water protection measures? How are municipal water protection measures affecting the state of the local water systems or the state of the Baltic Sea? How large are the environmental benefits gained compared to the costs of these measures? Are the measures worthwhile from the perspective of social welfare? ↓ **Cost-benefit analysis on five case studies in four themes**	
Natural stormwater management	**Agriculture**
Case urban wetland in Lahti: Constructed wetland functioning as a natural stormwater management system in a residential area	**Case buffer zones by the river in Turku**: Special condition in lease contracts to establish buffer zones on city-owned fields

The aim of this study is to provide information on the environmental and other impacts and their monetary values, as well as the net benefits of five different municipal water protection measures. The research method, cost-benefit analysis (CBA), focuses on the social consequences of measures by comparing overall benefits and overall costs accruing for society during the lifespan of a measure. Important phases in the CBA are to identify and predict all potential impacts, e.g. environmental benefits, and turn them into monetary values. There are several economical methods to assess the monetary value of environmental benefits for people by estimating their willingness to pay for improvement in the enviroment. Having information about the potential positive and negative impacts and their monetary values may support and promote discussion about new water protection measures. When talking about water protection, a holistic view and a long-term perspective are needed.

The cost-benefit analysis is a method that has been developed to support decision-making (e.g. Boardman, Greenberg, Vining, & Weimer, 2013). In the CBA all relevant impacts from the whole lifespan of a project or policy are quantified and turned into monetary and present values, to sum them up into net present value. The net present value will tell if the overall benefits exceed overall costs, or, in other words, is the project or policy worthwhile. This kind of an economic approach is needed in environmental discussion because it is a way to compare environmental projects with other projects when a city or municipality is deciding how to allocate the resources. The CBA can broaden the discussion also by providing a holistic, long-term assessment from a society's point of view.

The results will give useful information for planning new projects, and, of course, positive results will promote their implementing. Positive results may also attract new cities, municipalities and other organisations to take part in the water protection work for saving the common Baltic Sea and to join the Baltic Sea Challenge network, a network for local actors to improve the state of the local waters as well as of the entire Baltic Sea.

1.3 Selection of municipal water protection measures for the analysis

In this study, the focus was decided to be put on stormwater management, wastewater treatment, wastewater discharge in harbours, and agriculture, because cities and municipalities have good opportunities to do water protection work within these themes. In order to achieve the study aim of providing useful information for cities and municipalities to support their water protection work, criteria for choosing the case measures were the following. In order to maximise the usefulness of the results, the measures should represent diverse, exemplary and easily applicable water protection measures. Thus, the cases were selected within different themes, both large and small and from shore and inland, and from different parts of the Baltic Sea region. In addition, the cases should have been implemented voluntarily, not only by legislative demands. Lastly, it was decided to choose only case measures that were already implemented, because then realised costs and other information were available to use in the analysis.

The criteria mentioned above were used in searching for the case measures for the cost-benefit analysis. The main searching method was contacting municipalities and asking if they had implemented some potential measures within the four themes and asking them to participate in the analysis with their case. Contacted municipalities included Baltic Sea Challenge partners in Finland and also in the Baltic States where it was decided to contact directly on municipal wastewater treatment plants. Depending on the cities' interests and possibilities to participate in the study, three case measures from from Pori, Liepaja and Lahti were chosen in this way to be studied in the cost-benefit analysis (Figure 1).

Figure 1. Location of the case cities (modified from OpenStreetMap contributors, 2014)

One of the three cases was the investment in new aerators to improve the efficiency of the biological treatment process and decrease the energy consumption in Liepaja WWTP. The second measure was chosen from the Pori region where wastewater treatment was centralised to Luotsinmäki WWTP in Pori. The third of these measures came from the Finnish inland City of Lahti, where a wetland was constructed to retain and purify the storm waters in the residential area.

In addition, two case measures from Turku and Helsinki (Figure 1) were picked up from the common Baltic Sea Action Plan of the cities Helsinki and Turku (The Baltic Sea Challenge, 2014). One of them was the Port of Helsinki which had invested in port reception facilities and receives sewage from passenger and cruise ships with no special fee system. The sewage is treated in the municipal WWTP in Helsinki. The other measure comes from the City of Turku, which leases its agricultural land to the local farmers with the special condition in the lease contracts of establishing buffer zones on the fields by the river.

1.4 Structure of the report

The report is structured as follows. Chapter 2 illustrates what cost-benefit analysis is about. It gives an overview about the cost-benefit analysis as a research method, why it is needed and what phases the analysis includes. In this chapter it is also told in general terms how the analysis of each case study was performed, including descriptions of how environmental benefits were monetised and how the sensitivity analyses were performed. Furthermore, chapters 3–7 include the case studies introduced above. In these chapters the potential impacts related to the case measures are first listed and then the material and methods used in each case study are described. In addition, the cost-benefit analysis results and discussion of each case study will be found from these chapters. Lastly, chapter 8 includes the summary of the results from case studies, general conclusions and discussion and chapter 9 recommendations as to how the information provided by this study could be utilised.

2 Overview of the cost-benefit analysis

In this study, cost-benefit analysis (CBA) is used to estimate the overall benefits and costs of five water protection measures that are implemented by cities and municipalities. In CBA all relevant impacts, at the present and in the future, will be quantified and turned into monetary terms, benefits and costs, which are discounted to present values. This way the environmental impacts in the future can be compared with the current costs when both are in the same value. The sum of the discounted benefits and costs, net present value, gives information on how worthwhile water protection measures are in the long term from the perspective of the whole society. In other words, net present value answers the question, did the water protection measure lead to efficient resource allocation and to an increment in social welfare.

In this study, cost-benefit analysis focuses on measures that were already implemented, and thus it is an *ex post* analysis. *Ex post* analysis provides information not just about a particular measure but also about the similar measures, and thus supports learning about them (Boardman et al., 2013, p. 3). *Ex post* analyses are usually performed to assess whether the excepted results were achieved after the implementation, what impacts occurred and whether the measure was worthwile of implementing (HM Treasury, 2003, pp. 45-48). However, it is more common to perform the cost-benefit analysis before the implementation, and then it is called *ex ante* analysis. *Ex ante* analysis gives information on whether the project would be worthwhile to be implemented, or which one of the alternative projects should be chosen (Boardman et al., 2013).

The *ex post* analysis aims at providing feedback for decision-making, through the results and the recommendations of the evaluation (HM Treasury, 2003, pp. 45-48) and thus, it suits well with the study aim of providing information about implemented water protection measures. Measures that succeed well in the analysis provide good ideas and encourage decision-makers to implement new projects, and projects that lead to negative CBA results can teach about the reasons of failure and how the similar measures could be implemented in a more efficient way. The results can be applied in planning new water protection projects, for example in assessing the environmental impacts, benefits and costs of measures. However, there might be very different types of measures within one theme, so it must be kept in mind that the cases which were chosen for this analysis represent single examples of measures within different themes and the results of a particular project must not be generalised too widely.

2.1 Steps in the cost-benefit analysis

The first step in this study was to search for municipal water protection measures to study. The choices were made among the objectives (p. 12). The set of selected cases included two wastewater treatment plants in Pori (Finland) and Liepaja (Latvia), one harbour in Helsinki (Finland), one stormwater solution in Lahti (Finland) and one agriculture-related measure in Turku (Finland). The cases are specified in more detail in chapters 3–7. This step was also the first step in performing the CBA, where the main phases are (Boardman et al., 2013, p. 6):

1. Specify the set of alternative projects
2. Decide whose benefits and costs count
3. Predict the impact categories, catalogue them, and select measurement indicators
4. Predict the impacts quantitatively over the life of the project
5. Monetise all the impacts
6. Discount benefits and costs to obtain present values
7. Compute the net present value for each alternative
8. Perform a sensitivity analysis
9. Make a recommendation

The *ex post* cost-benefit analysis focuses on measures that are already implemented. It studies whether a situation where all the impacts are already occurred, or a situation where some of the impacts are occured and some of the impacts are expected to occur in the future. Steps 2–6 focus on assessing these impacts. The case studies will be limited only to the implemented measures, which means that if there were any alternative measures planned to be implemented, they are only discussed and not analysed.

2.2 Identifying and measuring the impacts

Whose benefits and costs count, depends on the implemented measure. Sometimes the answer is simple: in this study the investment and annual operating costs of the water protection measures are paid by the municipality or municipal company. But more challenging and also an essential question is who will get the benefits from reducing nutrient load into the Baltic Sea by single local water protection measure. Some measures may have visible local impacts on water quality, but due to the transportation of the nutrients, the impacts are more extensive than just local. The nutrient load reduction of a single water protection measure is also a small part of the total nutrient load reduction that is required to achieve a good ecological status of the Baltic Sea as a whole. However, the impacts are identified and discussed case by case.

Identification and prediction of the impacts are probably the most challenging parts of the analysis, as well as deciding which of them are relevant. In each case study chapter, the potential positive and negative impacts have been first identified and then is discussed which of them are relevant within the studied case measure and is it possible to measure them within existing data and include them in the analysis. The identification of impacts gives useful information when similar measures are considered in municipalities.

Then, to assess the total impacts of the measure's lifespan, the impacts are first estimated for each year using different impact indicators. For example, costs are measured in euros (in the value of 2013), the eutrophication reduction indicators are the reduced amounts of nitrogen and phosphorus (kg N; kg P) and the climate impacts indicator is the amount of CO_2-equivalent tons unreleased to the atmosphere (tons CO_2-eqv). Measuring and predicting future impacts is explained in more detail for each case – including the discussion about the case-specific lifespan.

2.3 Monetising environmental benefits

Monetising the environmental benefits can be done by using existing benefit estimates from economic valuation studies. The economic valuation of environmental benefits aims to quantify people's willingness to pay (WTP) for improvement in ecosystem services (see e.g. Hanley, Shogren, & White, 2007). It should be noted that the valuation methods measure how much people value the ecosystem services, not what is the intrinsic value of the ecosystem. There are several methods to evaluate the benefits for people, and they can be classified to stated and revealed preferences methods. In stated preference methods people are asked directly their WTP (contingent valuation method) or asked to choose one of the given alternatives (choice experiment). The revealed preferences method seeks to recover estimates by observing the behaviour in related markets, from house markets for instance (hedonic pricing method) or from travel expenditures (travel cost method). (Hanley et al., 2007, p. 322.)

In the case of the Baltic Sea, Ahtiainen, Artell, and Czajkowski (2014) performed a comprehensive contingent valuation (CV) study where citizens from all nine states around the Baltic Sea were asked their willingness to pay for achieving the improved state of the sea defined in the Baltic Sea Action Plan (BSAP). Ahlvik and Ahtiainen (2014) prepared for the CITYWATER project a report in which they calculated the marginal benefit estimates for nitrogen and phosphorus for each sea basin of the Baltic Sea. The calculations were based on the CV survey data (Ahtiainen et al., 2014) and marine model of nutrient dynamics (Ahlvik, Ekholm, Hyytiäinen & Pitkänen, 2014) which estimates the impacts of nitrogen or phosphorus reduction on each sea basin depending on the location of the reduction. The marginal benefit estimates were calculated for two scenarios of the future development of the nutrient reductions to the Baltic Sea:

1. BSAP scenario, in which the nutrient reductions follows the BSAP targets set by HELCOM (2014b)
2. BASELINE scenario, in which the current level of water protection is maintained, but no additional actions are made

Marginal benefit estimates in net present values are listed in Table 2. The marginal benefits depend strongly on the sea basin where the nutrient reductions are carried out, the nutrient (nitrogen or phosphorus), and the scenario of the future development of the nutrient reductions. In the BASELINE scenario, the future state of the sea is poor, and one unit nutrient reduction today is very valuable. In the BSAP scenario, then, the state is improved and one unit nutrient reduction is less valuable. In both scenarios the marginal benefits decrease in time as the state of the sea improves for the same reason. However, the total benefits of the Baltic Sea protection are higher, the higher is the level of the protection and the better is the state of the sea. The marginal benefit estimates are likely underestimates, because the benefit estimation was unable to take into account the benefits gained from improved water quality of coastal and inland waters. (Ahlvik & Ahtiainen, 2014.)

Table 2. Aggregated marginal benefits of reducing one additional unit (kg) of nitrogen and phosphorus to each sea basin in 2014 euros (Ahlvik & Ahtiainen, 2014)

	Nitrogen		Phosphorus	
	Baseline development	**Baltic Sea Action Plan development**	**Baseline development**	**Baltic Sea Action Plan development**
Bothnian Bay	39.0	1.4	611.5	98.0
Bothnian Sea	46.8	1.7	634.3	75.9
Baltic Proper	38.9	1.8	515.8	63.5
Gulf of Finland	64.0	3.8	757.9	88.0
Gulf of Riga	83.7	4.0	1028.6	93.5
Danish Straits	50.0	2.4	212.4	47.0
Kattegat	44.9	2.0	239.4	27.3

The benefits from reducing climate emissions come from avoiding the climate change damages, such as decrease in agricultural productivity and health and property damages due to flooding. The social cost of carbon (SCC) defines the marginal cost of climate change, i.e. the long-term social cost in present value from releasing one additional unit of carbon into the atmosphere, or the avoided cost from reducing one unit of carbon emissions. (Tol, 2011; US EPA, 2013.) Tol (2011) reviewed 311 estimates for SCC in his meta-analysis. According to his study, there is a lot of variation in the estimates. Because the distribution is left skewed and has a long right tail, the average estimate ($177 per C-ton) is higher than the modal estimate ($49 per C-ton). When splitting the sample by only peer-reviewed, equity weighted, uncertainty analysed or to the newest studies, the standard deviations decrease and average estimates for SCC are between 68 and 168 dollars. Also, the higher the discount rate, the lower the average and standard deviation. Due to the large variation of SCC estimates, the range of SCC estimates for the CBA is cut from the distribution of SCC estimates. The 50th percentile is 116 dollars, and 33rd and 67th percentiles respectively 35 and 213 dollars. When converting these estimates into marginal cost of carbon dioxide and expressing them in 2014 euros, they are respectively 23.9; 7.2 euros and 43.9 euros[1].

2.4 Calculating the net present value

The next step is discounting and summing up all benefits and costs (Boardman et al., 2013, p. 12) into present values (PV) of benefits (B) and costs (C) by following the equations 1.1 and 1.2. In the equations, B_t and C_t are the costs and benefits at the time t, and r is the interest rate. Discounting takes into account the decrease in interest in future impacts compared to present impacts. The discount rate that was used in this study was 3.5%, as was suggested by European Commission (2008), but also other discount rates (1% and 6%) are tested in the sensitivity analysis.

[1] The converting was done by dividing the mass of the carbon ton by the mass of the similar amount of material of CO_2, and turning 2011 USD into 2014 EUR (Bank of Finland, 2011; Official Statistics of Finland (OSF), 2014).

$$PV(B) = \sum_{t=0}^{n} \frac{B_t}{(1+r)^t} \tag{1.1}$$

$$PV(C) = \sum_{t=0}^{n} \frac{C_t}{(1+r)^t} \tag{1.2}$$

The result of the CBA, net present value (NPV) is the difference between the net present values of benefits and costs (Boardman et al., 2013, p. 13):

$$NPV = PV(B) - PV(C) \tag{1.3}$$

The net present value is one way to measure social efficiency in cost-benefit analysis studies but alternative economic performance indicators also exist. The European Commission (2008, p. 57) suggests three possible economic performance indicators (Table 3):

Table 3. Economic performance indicators (European Commission, 2008)

Indicator	**Abbreviation**	**Definition**	**Decision-making criterion**
Economic net present value	ENPV	Discounted benefits minus discounted costs	ENPV > 0
Economic internal rate of return	ERR	Discount rate that gives zero-value ENPV	ERR ≥ social discount rate r
Benefit-cost ratio	B/C ratio	Ratio between discounted benefits and costs	B/C ratio > 1

The ENPV is regarded as the most important and reliable indicator in CBA, while other indicators are independent on a scale of the project but can give useful additional information (European Commission, 2008, p. 58). According to Boardman et al. (2013, p. 13) the net present value is the only appropriate decision-making criterion, because it answers the questions of whether the projects are worthwhile from society aspects, and also, how large are the net benefits for the society. Thus, NPV will be the main indicator used in this analysis, but in addition, B/C-ratio is used to illustrate the relationship of costs and benefits of each case measure.

2.5 Analysing the uncertainty

Due to making assumptions and predicting the future impacts in the CBA, uncertainty is always related to the results. Thus, performing a sensitivity analysis is an essential part of the CBA. In this study, three different sensitivity analyses are performed. At first, conducting a partial sensitivity analysis helps to see if some single factor affects the sign of NPV. Then, in Monte Carlo sensitivity analysis, all uncertainties are taken into account at the same time, and it gives the most probable NPV and the distribution of NPVs as results. At last, the worst and best case analysis gives a scale for NPVs from most pessimistic to most optimistic scenarios and shows the scale of uncertainty, which is useful if a Monte Carlo analysis is not possible to perform for some reason. In this study worst and best case analysis will give additional information on how uncertainty grows together with longer assumed lifespan. (See e.g. Boardman et al., 2013, pp. 181 - 182.)

In practice, the partial sensitivity analysis will be done by changing systematically the value of one variable at a time to its minimum or maximum value and observing how this affects the NPV. In the Monte Carlo sensitivity analysis, then, the probability distributions of all variables are taken into account at the same time when calculating NPV. Every variable can have values in a certain range, and some values are more probable than others. If there is no information about the probability distribution of a variable, it is assumed that the variable has a uniform distribution. The uniform distribution is triangle-shaped with the minimum and maximum values in corners and the best guess value in the top and in the middle being the most probable value. Then NPV will be calculated using variable values that are chosen randomly from their probability distributions, and this will be repeated e.g. 10,000 times. The frequency distribution of NPVs gained this way describes the probability distribution of NPV, and it gives information on how probable it is that NPV is positive or negative, and what is the range for most probable NPVs. In this study, the Monte Carlo simulation will be performed in Excel. For how to perform Monte Carlo analysis manually in a spreadsheet, see e.g. Boardman et al. (2013, pp. 200 - 201).

Worst and best case scenario analysis has similarities with partial and Monte Carlo sensitivity analyses. In the worst case scenario, every variable will get the most pessimistic value: the value that decreased net present value in partial sensitivity analysis. It can be either minimum or maximum value. In the best case scenario, every value will get the most optimistic value: the minimum or maximum value that increased the net present value. As a result, worst and best case analysis gives the highest and lowest possible values for NPV. All values got in Monte Carlo analysis will be between these two values. In this study, the worst and best case analysis will give valuable information on how uncertainty develops in time.

2.6 Strengths and weaknesses of a cost-benefit analysis

Performing a CBA can be recommended for its holistic and long-term perspective. It is a tool to help allocate public resources in a way that provides the highest benefit for society. The cost-benefit analysis is a way to compare both market and non-market goods, like costs and environmental impacts, as well as present and future impacts. It takes into account all relevant impacts, as well as those impacts that don't affect an actor itself who implements the project or policy. CBA is also independent from certain stakeholder's preferences or demands, and aims at improving the whole of society's welfare.

On the other hand, performing a CBA may be very challenging and expensive, because it may require multidisciplinary expertise. It has to deal with uncertainty due to assumptions and predicting the future. Although the analysis itself is performed step-by-step using instructions, the analysed projects or policies are always unique and identifying and measuring the relevant impacts may be difficult and monetising the impacts may be even impossible. If so, the alternatives for CBA are e.g. qualitative cost-benefit analysis, cost-effectiveness analysis and multigoal analysis. (See e.g.Boardman et al., 2013.) In case of water protection, reducing nutrients improves the state of the ecosystem, but the CBA is able to take into account only how much people value it, not the intrinsic value of the ecosystem.

Photo: Vilmars Bogovičš, Liepaja Water

Municipal wastewater treatment

Nutrient emissions from municipal wastewater treatment plants (WWTPs) cover most of the nitrogen and phosphorus point source emissions to the Baltic Sea (HELCOM, 2011, pp. 36-37). There is a lot of potential within this theme – improving municipal wastewater treatment to HELCOM recommendation levels in those countries would lead to nutrient reductions that cover about two thirds of needed phosphorus reductions and one fifth of nitrogen reductions (HELCOM, 2011, p. 91) or even more, if the plant sets the targets higher. Improving waste water treatment is in particular regarded as a cost-efficient way to reduce nutrient loads, especially phosphorus loads (e.g. Hyytiäinen & Ahlvik, 2014).

There are a lot of measures that can be carried out in wastewater treatment plants to improve treatment efficiency, for example by improving sludge management or the sewage network (Leppänen, Nevalainen, Rosqvist, & Sopanen, 2012; Project on Urban Reduction of Eutrophication (PURE) & Union of the Baltic Cities (UBC) Environment Commission, 2012). Here, we study two case measures within the municipal wastewater treatment theme. The first case from Pori represents an example of improving the treatment efficiency by centralising wastewater treatment, and the second case, from Liepaja, an aerator investment which improved both energy and treatment efficiency.

3 Case: Luotsinmäki WWTP in Pori, Finland

In Finland, many wastewater treatment plants are close to the end of their lifespan, and new investments would be required. One option is to improve the old facility, but when neighbouring municipalities are in the same situation, another option is to join forces and realise the wastewater treatment upgrade as a collaboration among municipalities. Luotsinmäki WWTP case represents an example of centralised wastewater treatment in an area of several municipalities.

3.1 Background

The City of Pori is located in the southwestern part of Finland, by river Kokemäenjoki and on a coast of the Bothnian Sea. It has approximately 80,000 citizens and it is the 11th biggest city in Finland. The City of Pori joined the Baltic Sea Challenge in 2007. In Pori, there is in operation a municipal water supply and sewage treatment company, Porin Vesi (Pori Water). Porin Vesi has three wastewater treatment plants in Luotsinmäki, Reposaari and Ahlainen. The Luotsinmäki WWTP is the largest plant treating 98% of the total amount of collected wastewater (total amount 11.3 million m^3 in 2013) and the rest are treated in two smaller WWTPs in Pori (Porin Vesi, 2013).

In Luotsinmäki WWTP, large renovations and expansions were made during 2008–2010. At the same time, the surrounding municipalities of Harjavalta, Ulvila, Nakkila and Eura and fabric-producer Suominen Kuitukankaat Ltd, established a new company, Jokilaakson Ympäristö Ltd, to build up and manage a sewer line which connects sewerage networks of the mentioned partners to the new Luotsinmäki WWTP (Figure 2). After finishing these two investments, six old smaller treatment plants were run down. Four of these – the municipal WWTPs of Harjavalta, Ulvila and Nakkila and the WWTP of the Suominen Kuitukankaat factory – are partners in the established company that takes care of the sewer line. The fifth closed treatment plant was the municipal WWTP of Luvia, which is a coastal municipality located to the south of Pori. The sixth plant that was run down was located in the Pihlava region of the City of Pori. The locations of Luotsinmäki WWTP and the old plants are in Figure 2. The above-mentioned smaller municipalities are part of the Karhukunnat regional co-operation, and Karhukunnat joined the Baltic Sea Challenge also in 2007.

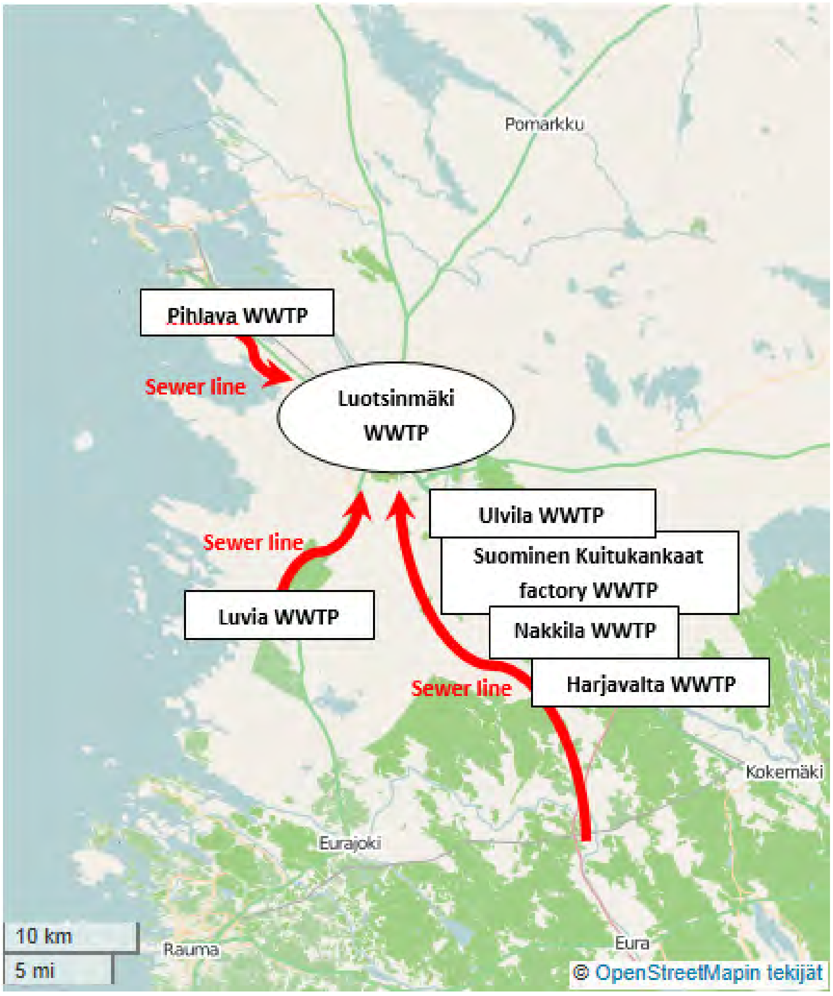


Figure 2. Luotsinmäki WWTP, old WWTPs and sewer lines on the map (modified from OpenStreetMap contributors, 2014)

Today Luotsinmäki WWTP treats wastewater from Pori and five surrounding municipalities. One 32-km-long sewer has collected wastewater from Harjavalta, Ulvila, Nakkila and from the northern part of Eura, Kiukainen, since summer 2010. The other sewers have collected wastewater from Pihlava since summer 2010 and Luvia since spring 2009. The share of wastewater collected by Jokilaakson Ympäristö Ltd of the treated wastewater in Luotsinmäki WWTP is annually 0.2–0.3 million m^3.

Previously the treated wastewater from the six plants was led to river Kokemäenjoki or directly to the sea, and the nitrogen removal efficiency in these plants was poor (11–47%). The actual reason behind the investments was the new legislative demands for improved nitrogen treatment efficiency, which would have required large investments in each WWTP. (Mykrä, 2011.) It was obvious that centralising wastewater treatment into one large plant was less costly than upgrading each old and small plant separately. It was also discussed to build up another large centre plant to Ulvila, but it was revealed to be more expensive than investing in Luotsinmäki WWTP and a sewer line.

In addition to possible savings in total wastewater treatment costs, this example of centralising wastewater treatment seems to have a large positive impact on nutrient load and it may have an impact on the state of the water in the River Kokemäenjoki, the local archipelago of the Baltic Sea and the Baltic Sea as a whole. Since wastewater treatment was centralised to improved Luotsinmäki, where treatment efficiency was significantly higher, less nutrient pollution ends up in the Baltic Sea. In a report written by Mykrä (2011), the change in nutrient load followed by the centralisation and improvements in Luotsinmäki was discussed. When comparing the total nutrient load of all plants in 2009 and the new Luotsinmäki plant in 2011, the phosphorus load was reduced by 57% and nitrogen load by 60%. Nowadays, Luotsinmäki WWTP achieves the treatment efficiency levels recommended by HELCOM (2007).

3.2 Identification of the impacts

The centralising of wastewater treatment has several impacts on society. The potential impacts of Luotsinmäki WWTP case as well as similar cases of centralising wastewater treatment are listed in Table 4. Centralising requires investments in improvements of the sewerage network and increment in capacity of the central WWTP, but in this case the investment costs were lower than improving all the old WWTPs separately or, alternatively, building another large centre plant in Ulvila. In the Luotsinmäki WWTP case, the treatment efficiency was also improved and this reduced the nutrient emissions to river Kokemäenjoki and the Baltic Sea, especially nitrogen emissions but also phosphorus emissions. The higher efficiency and capacity increased the maintenance and operating costs in Luotsinmäki, but on the other hand, the costs of other plants were avoided and only the costs of the sewer lines remained. Employment did not change in this case, because employees from old plants moved to other jobs inside the municipalities or moved to Luotsinmäki, which required more labour than before. If there is a change in total energy consumption then it has an impact both on energy costs and on climate emissions. There might be a decrease in the total energy consumption, while there is nowadays one large central plant instead of seven smaller ones. On the other hand, more energy is required for higher treatment efficiency and pumping the wastewater forward through long sewer lines.

Table 4. Potential positive and negative impacts of centralising the wastewater treatment. The ones marked with a grey background were included in the analysis.

Positive impacts	**Negative impacts**
Impact on the state of the Baltic Sea from reduction of nutrient emissions	Investment costs
Impact on the state of the coastal and other local waters from reduction of nutrient emissions	Increment in risk for overload due to longer sewer network and a greater number of pumping stations
Avoided costs of improvements in old plants	
Future improvements will be easier to realise (efficiency, knowledge etc.)	
Less negative local impact (e.g. traffic, noise and odours) when old treatment plants are run down	
Improvement in collaboration between municipalities	
Positive or negative impacts	
Changes in maintenance and operating costs: avoided costs of closed plants but higher costs in new plant due to increased volume of water and higher treatment efficiency	
Employment: increment in number of jobs in new plant but reduction in closed plants	
Change in total energy consumption: change in climate emissions	

There are also other potential impacts that were not included in this cost-benefit analysis due to difficulty in measuring and monetising them and the scale of the case study. Closing the old treatment plant has several positive local impacts related to its operation – it probably reduced e.g. the traffic, noise and odours in the surrounding area of the plant. Although achieved nutrient reductions are measured, their local effect to the state of the river Kokemäenjoki and coastal waters were not included either. Also positive impacts, such as improved collaboration between municipalities, and easier realisation improvements in wastewater treatment in future, for example technical improvements or educational development, were not included in the analysis. Centralising the wastewater treatment requires long sewer lines and a greater number of pumping stations, which can lead to increased risk for overloads in combined sewerage network, but these were not studied either.

3.3 Material and model

In this case, total impacts of the measure were analysed by comparing situations with and without the implementation of the Luotsinmäki WWTP renovation and new sewer lines. As mentioned before, the renovation of Luotsinmäki was made during 2008–2010 and the sewer lines were taken into use in autumn 2009 and in summer 2010. This construction and implementation phase causes some uncertainty to e.g. annual treatment numbers, so it is partly excluded from the analysis. For this reason the situation without the implementation is defined as the situation until the year 2007. The present situation is defined as the situation beginning from the year 2011, because it is the first complete operation year after implementation.

The lifespan of the measure was chosen to be 30 years. The previous WWTPs were also approximately 30 years old. In the Luotsinmäki WWTP, the depreciation time for the machinery is 15 years and for the rest of the parts 50 years. For the sewer line, the depreciation time for pieces of equipment varies from 6 to 40 years.

Investment and maintenance costs

The investment costs of expanding and improving the Luotsinmäki WWTP and building up three sewer lines to Luotsinmäki during 2008–2010 are listed in Table 5. These numbers include all costs: construction, planning, material, labour etc. The local municipal water utility, Porin Vesi, paid the largest part of the total costs (for Luotsinmäki WWTP and the Pihlava–Luotsinmäki sewer line). Jokilaakson Ympäristö paid the largest part of the sewer line costs and took part also in investment costs of Luotsinmäki with 3.3 million euros. The Finnish Government gave 2.8 million euros financial support for building up the sewer line from Kiukainen to Luotsinmäki and for investments in Luotsinmäki. Data concerning the Luvia sewer line was not included.

Table 5. Investment costs of centralising the wastewater treatment to Luotsinmäki WWTP (in initial values)

Investment	Cost and timing
Expanding and improving Luotsinmäki WWTP	26.5 M€ in 2008–2010
Kiukainen–Harjavalta–Nakkila–Ulvila–Luotsinmäki sewer line	8.3 M€ in 2009-2010
Pihlava–Luotsinmäki sewer line	2.5 M€ in 2009

The annual operating and maintenance costs of the present facilities, the new Luotsinmäki and sewer lines, and past facilities, closed plants, are listed in Table 6. Operation and maintenance costs do vary between years, depending on e.g. weather conditions. The costs listed in the table are averages of realised annual costs, which were used also in the prediction of future impacts. Data concerning the Luvia sewer line was not included.

Table 6. Annual operating and maintenance costs of present and old facilities (in initial values)

	Annual operating and maintenance cost
Present facilities	
Renovated Luotsinmäki WWTP	2.4–2.6 M€
Kiukainen–Harjavalta–Nakkila–Ulvila–Luotsinmäki sewer line	0.2–0.3 M€
Pihlava–Luotsinmäki sewer line	0.1 M€
Old facilities	
Unrenovated Luotsinmäki WWTP	1,469,000 €
Harjavalta WWTP	240,000 €
Kiukainen	60,000 €
Nakkila WWTP	110,000 €
Suominen Kuitukankaat Ltd WWTP	190,000 €
Ulvila WWTP	230,000 €
Pihlava WWTP	280,000 €

Change in nutrient emissions

The change in nutrient emission load to the Baltic Sea was calculated by multiplying the change in nutrient concentrations in the effluent (kg/m^3) and the amount of wastewater (m^3). For calculating the change, data on the quality and quantity of treated wastewater was required. Most of this data was found from the public database managed by Finnish Environment Institute (2013): annual treatment data of Luotsinmäki WWTP as well as four old plants Luvia, Ulvila, Nakkila and Pihlava WWTPs. The data of Suominen Kuitukankaat and Harjavalta WWTPs was received directly from the actors.

The change in nutrient concentrations was assessed by comparing nitrogen and phosphorus concentrations in effluent in situations with and without implementation of improved and centralised treatment. In the realised situation, the treatment efficiency was assumed to be in the future at a similar level as it has been in Luotsinmäki WWTP after the investment phase, so it is defined by average nutrient concentrations in 2011–2013. Without implementation, the annual treatment efficiency was assumed to remain at the same level as during the years before 2007. Thus the concentrations in this situation were defined by average nutrient concentrations from the previous 10 years, 1998–2007.

A prediction for development of wastewater treatment quantity in the Pori region (City of Pori & AIRIX Ympäristö Oy Turku, 2011) was used in the calculations. The prediction was based on development of the population and the sewerage network in Pori and surrounding municipalities. Predicted amounts of wastewater from the City of Pori and from the other municipalities from 2010 to 2030 at five-year intervals were available. Annual wastewater amounts from other municipalities – Luvia, Ulvila, Harjavalta and Nakkila – were estimated from a fitted curve which was drawn by using predicted amounts of the mentioned years. Annual wastewater amounts from Pori were estimated respectively. In the calculations, the amounts of wastewater treated by two other plants in Pori were excluded from these numbers. The estimated amounts of wastewater as well as predictions can be seen in Figure 3. In the same figure, the realised amounts from 1998 to 2009 are included. It can be seen from the figure that prediction may underestimate the amounts of wastewater: the realised total amount is on average 13 million m^3 while the estimated is approximately 12 million m^3.

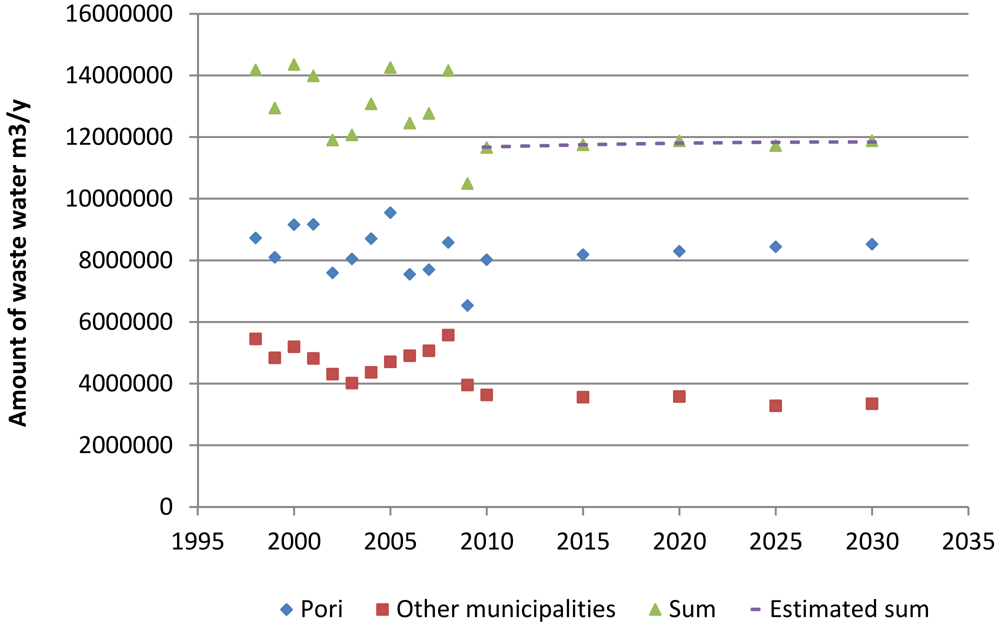


Figure 3. Realised amounts of wastewater in 1998–2009 and predicted amounts in 2010–2030 from the city of Pori and surrounding municipalities

Change in greenhouse gas emissions

The change in the total energy consumption was estimated by a similar idea as in nutrient emission estimations: by comparing the realised situation with a scenario where the measure was not implemented. It was assumed that the energy consumption equals the electricity consumption, because electricity consumption covers the majority of the energy consumed in wastewater treatment plants.

The realised annual electricity consumption (kWh/y) after the investment was calculated by summing up the present electricity consumption of Luotsinmäki WWTP and the electricity consumption of pumping stations of the three sewer lines. The electricity consumption in the previous situation before the investment was calculated by summing up the previous electricity consumption of Luotsinmäki WWTP and all six old plants. Because there was no electricity consumption data for all old plants, it was estimated for those plants from the amount of treated wastewater by using the factor 1.2 kWh/m^3. This factor is the average electricity consumption for similar plants.

The last step was to assess the change in greenhouse gas emissions (in CO_2-equivivalent kg) due to the change in electricity consumption. According to Hippinen and Suomi (2012, pp. 7-8), the average climate impact from one unit produced electricity in Finland is 210 CO_2-eqv kg/MWh.

3.4 Results

The nitrogen and phosphorus load reduction to the Baltic Sea was clear in the case of Luotsinmäki WWTP. In Figure 4 and Figure 5, the annual aggregated nutrient loads from all old plants and the old Luotsinmäki and loads from the new Luotsinmäki are illustrated for the best guess of the life span of the current plant (30 years). Please notice that the assessed loads during 2011–2012 are calculated with realised amounts of wastewater, and after this the loads are calculated according to prediction (see pages 28 - 29). The estimated loads from the renovated Luotsinmäki are on average approximately 80,400 kg N/y and approximately 1,400 kg P/y, while estimated loads from old plants would be on average approximately 207,900 kg N/y and 4,500 kg P/y. This means that annually about 127,500 kg nitrogen load and 3,100 kg phosphorus load to the Sea are avoided and the nutrient loads decreased respectively by 61% and 69%. Compared to BSAP targets (HELCOM, 2014b), the nitrogen and phosphorus load reductions are respectively about 5% and 1% of the reduction target allocated to Finland, and they are remarkable on the country level.

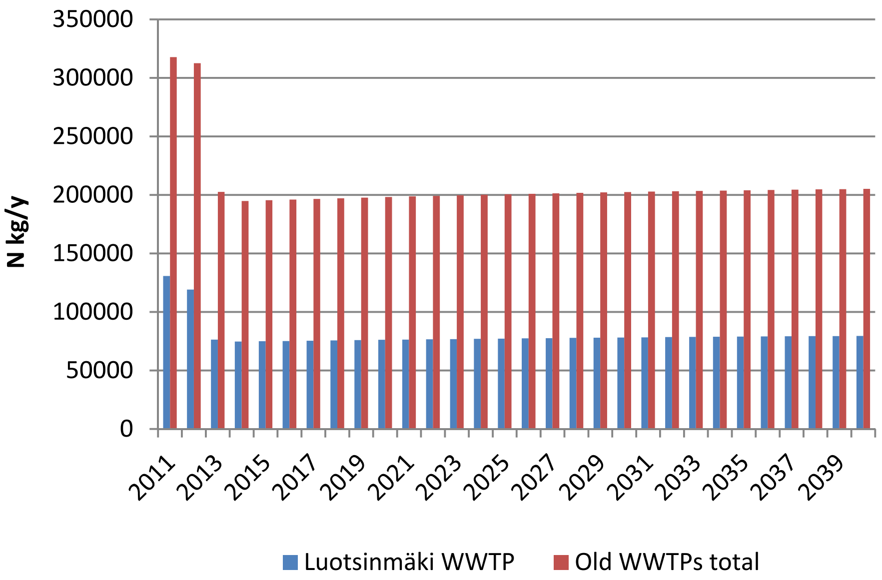


Figure 4. Annual aggregated nitrogen loads from all old WWTPs and from the renovated Luotsinmäki WWTP. The differences between pillar heights illustrate the estimated amounts of reduced nitrogen loads during the assumed lifespan (30 years). Annual nitrogen load reduction was estimated to be on average 127,500 kg.

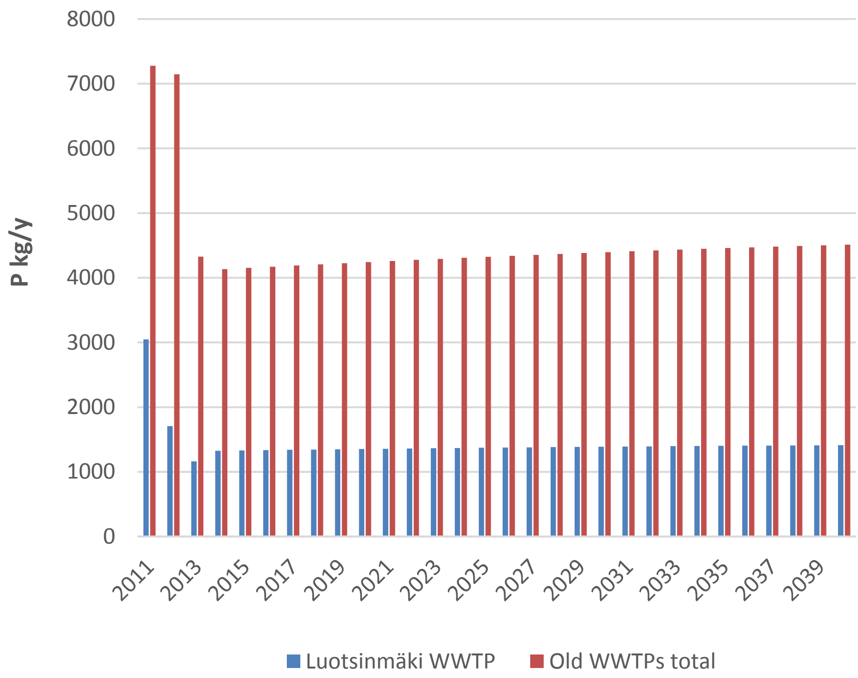


Figure 5. Annual aggregated phosphorus loads from all old WWTPs and from the renovated Luotsinmäki WWTP. The differences between pillar heights illustrate the assessed amounts of reduced phosphorus loads during the estimated lifespan (30 years). Annual phosphorus load reduction was estimated to be on average 3,100 kg.

In the BSAP targets there are no reduction targets to the Bothnian Sea (HELCOM, 2014b), so it is difficult to say how significant the load reductions are on a basin level. The nutrient reductions may also have local impacts, especially on the river Kokemäenjoki and the coastal waters near to the river mouth. Currently the ecological status of the water quality in the coastal area near to the Kokemäenjoki river mouth is partly satisfactory, partly mediocre, and the seawater suffers from eutrophication (Alahuhta, 2008; Westerberg, Bonde, Mäensivu, & Mäkinen, 2014, pp. 93-94). Before the centralising, the nitrogen load from municipal wastewater covered approximately 36% and phosphorus load 13% of the total nutrient load of the river Kokemäenjoki to the sea (Sarvala & Sarvala, 2005). Proportioning the relative nutrient reductions to these numbers, the nitrogen load of river Kokemäenjoki would be decreased by 22% and phosphorus load by 9%. However, the ecological status develops slowly and the possible impacts may be seen only in a long timespan.

The total energy consumption was also reduced in the Luotsinmäki WWTP case. Although improvement of treatment efficiency and sewage transportation increased energy consumption, running down old plants provided energy savings. However, the energy consumption reduction was declining in time and turned to negative after 30 years. The reason is that energy consumption in old plants was assumed to depend on the wastewater flow rates, which also declined in time according to the prediction (see pages 28-29). In the near future, the energy savings are about 400 MWh, which provides about 80 tons less CO_2-emissions to the atmosphere.

The next phases in the CBA were to monetise the environmental impacts and discount all costs and benefits to the present value, as was explained in greater detail in Chapter 2. The benefit from reduced eutrophication in the Baltic Sea due to nutrient reductions were calculated in two scenarios on how the nutrient reductions will develop in the future BSAP and BASELINE scenarios. The annual costs and benefits in their present values are illustrated in Figure 6 (BSAP scenario) and Figure 7 (BASELINE scenario). In the BSAP scenario, the total nutrient reduction benefits are small compared to other cost and benefits, but in the BASELINE scenario they are relatively large. All other benefits and costs are the same in both figures. The figures show also that there are high investment costs in the beginning of the timespan and the maintenance costs and maintenance cost savings of closed WWTPs are approximately the same. Climate benefit is relatively small compared to other impacts. The present values of future costs and benefits are decreasing in time due to discounting. Please notice that Figures 6 and 7 are based on calculations with best guess values, and the uncertainty related to numbers will be taken into account in the sensitivity analysis.

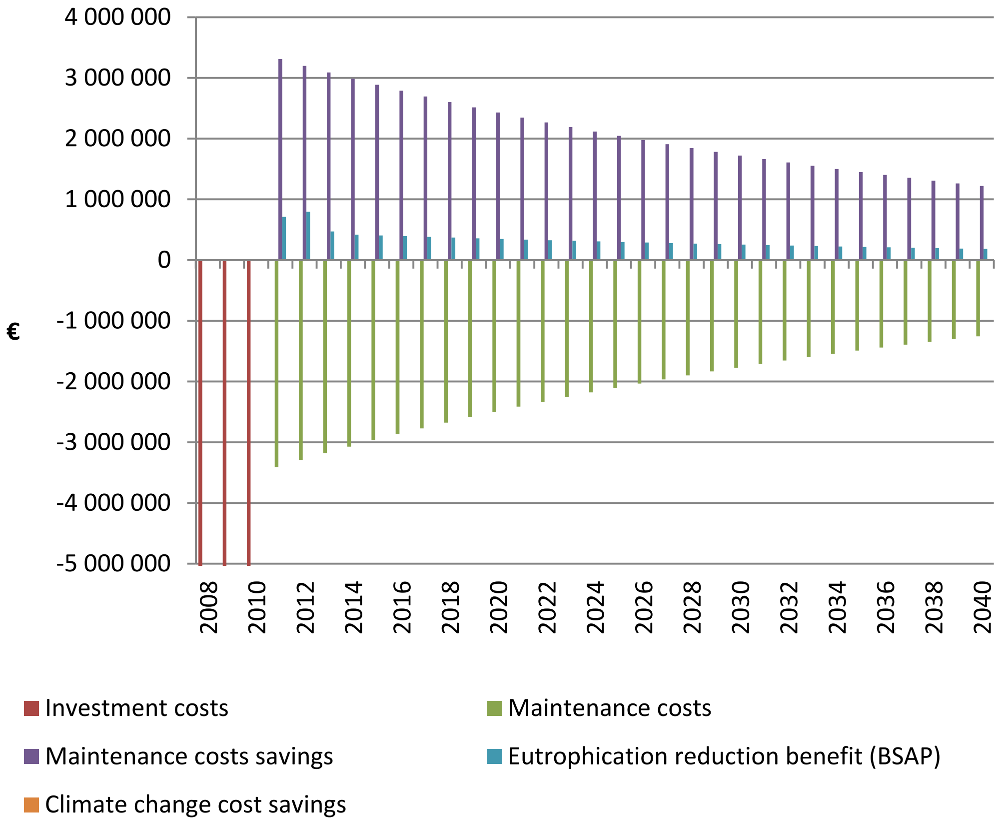


Figure 6. Annual present value costs and benefits in the Luotsinmäki WWTP case in the BSAP scenario calculated with the best guess values. The present value of investment costs is in total 48 M€. Investment cost pillars are cut in the figure in order to illustrate the scale.

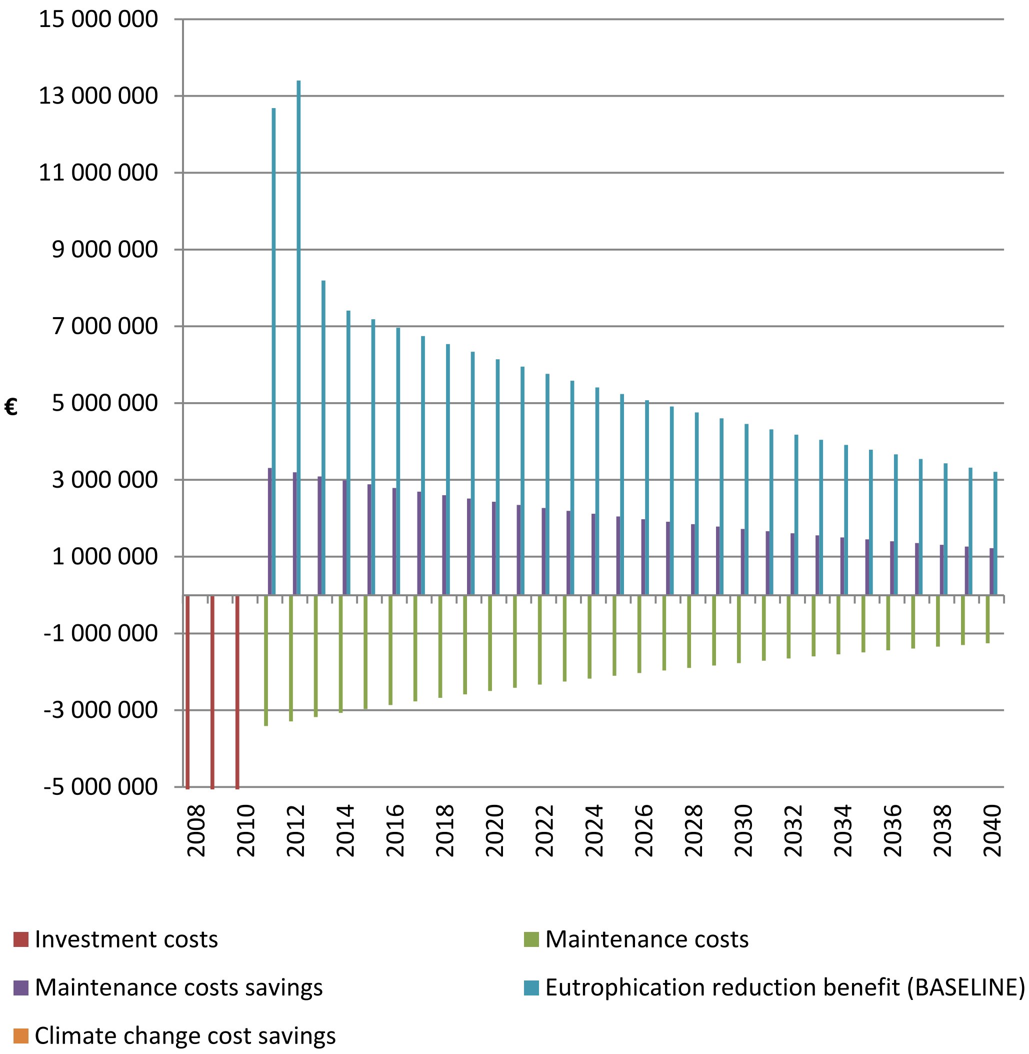


Figure 7. Annual present value costs and benefits in the Luotsinmäki WWTP case in the BASELINE scenario calculated with the best guess values. The present value of investment costs is in total 48 M€. Investment cost pillars are cut in the figure in order to illustrate the scale.

The large difference in nutrient reduction benefits between BSAP and BASELINE scenarios causes a significant difference also in annual net present values and total net present values. Figure 8 shows that in future the annual net benefits are slightly positive in the BSAP scenario, but clearly positive in the BASELINE scenario. During the first years, net benefits are clearly negative during the investment years.

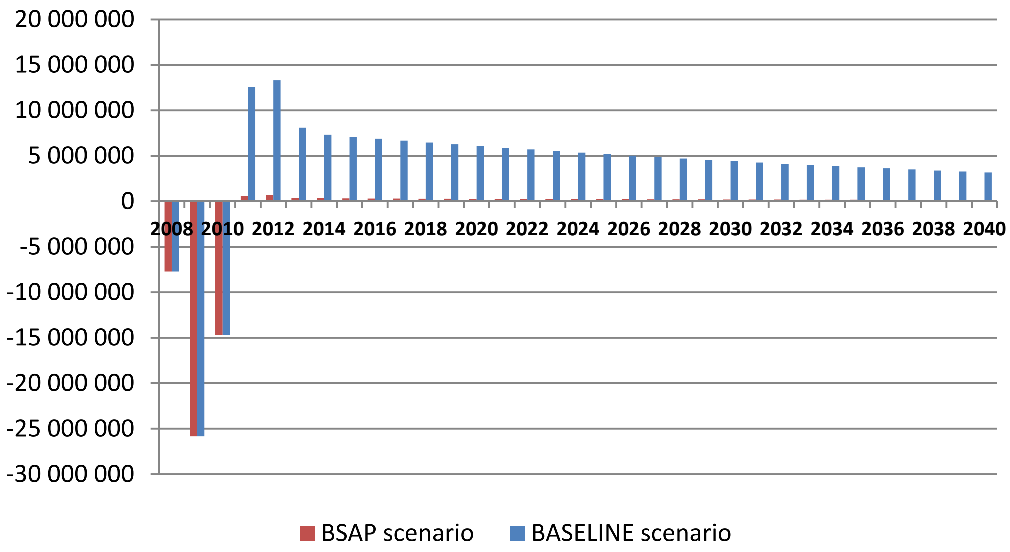


Figure 8. Annual net present values in the Luotsinmäki WWTP case in the BSAP and BASELINE scenarios calculated with the best guess values

When all costs and benefits in their present values until 2040 (assumed length of lifespan) are summed together to the total net present value (NPV), the best guess NPV is approximately -40 million euros and negative in the BSAP scenario but 121 million euros and positive in the BASELINE scenario. The B/C-ratios were respectively 0.64 and 2.07. The sign of NPV seems to be dependent on the scenario of how the general level of the Baltic Sea protection develops in the future. However, performing a sensitivity analysis is essential before interpreting the results, because it tells more about the results, for example how probable it is that the NPV is negative, or how sensitive the NPV is for the assumptions and predictions that had to be made in the cost-benefit analysis.

In partial sensitivity analysis, one variable at a time will get a different value and it shows how sensitive the NPV is for the variance of a single variable. All the analysed variables and their minimum and maximum values are listed in Table 7. Analysis included following minimum and maximum values concerning future impacts: 10% lower or higher maintenance costs, 50% lower or higher energy consumption in old plants and 30% lower or higher wastewater flow. Minimum and maximum value for nutrient concentrations in Luotsinmäki WWTP were sum or difference of averages and standard deviations of concentrations. Value choices of variables related to climate impacts and discount rate were explained in Chapter 2.

Table 7 presents also the relative changes which indicate the change in NPV compared to the NPV calculated with best guess values, when a value of one variable at a time is changed to its minimum or maximum. Results of the partial sensitivity analysis showed none of the variables in the partial sensitivity analysis turns the sign of NPV in either of the scenarios. Thus, the marginal benefit estimate of nutrient reduction is the only of the analysed variables which turns the sign of NPV. However, the discount rate, length of the lifespan, total wastewater flow in the future and annual operating and maintenance costs in the future have the some impact on NPVs (Table 7). In the case of the first three, the changes are larger in the BASELINE scenario compared to the BSAP scenario due to higher nutrient reduction benefits in the future. In the case of operating and maintenance costs, they impact on NPV more in the BSAP scenario than in BASELINE because their relative weight of the net annual present values is higher.

Table 7. Partial sensitivity analysis of the Luotsinmäki WWTP case: variables and their minimum, maximum and best guess values and their relative impact on NPVs in the BSAP and BASELINE scenarios

				BSAP scenario		BASELINE scenario	
	Min value	**Best guess value**	**Max value**	**Change (Min value)***	**Change (Max value)***	**Change (Min value)****	**Change (Max value)****
Discount rate	0.01	0.035	0.06	18.40%	–17.93%	40.44%	–28.01%
Operating and maintenance costs in future, %	90	100	110	16.09%	–16.09%	5.37%	–5.37%
Social cost of carbon, €/CO_2-ton	–7.2	–23.9	–43.9	–0.05%	0.06%	–0.02%	0.02%
Marginal climate impact, kg CO_2/ MWh	189	210	231	–0.01%	0.01%	0.00%	0.00%
Electricity consumption in old plants kWh/m^3	0.6	1.2	1.8	-0.36%	0.36%	–0.12%	0.12%
Total wastewater flow rate in future, %	70	100	130	–5.96%	5.96%	–33.98%	33.98%
P concentration in wastewater in Luotsinmäki WWTP in future, g/m^3	0.11	0.17	0.22	1.50%	–1.50%	4.19%	–4.19%
N concentration in wastewater in Luotsinmäki WWTP in future, g/m^3	8.99	9.38	9.77	0.24%	–0.24%	2.23%	–2.23%
Lifespan, years	20	30	40	–4.29%	3.10%	–30.65%	21.97%

* Relative change in NPV compared to best guess NPV in BSAP scenario (approx. –40 million euros)
** Relative change in NPV compared to best guess NPV in BASELINE scenario (approx. 121 million euros)

Further, Monte Carlo sensitivity analysis takes all variables and their possible values into account at the same time and it gives also information about the probability of negative NPV. The values for each variable, except the length of the lifespan, were selected randomly and this was repeated 10,000 times. As a result of this simulation, frequency distributions of 10,000 NPV values for both BSAP and BASELINE scenarios were obtained. Frequency distributions define the probability distribution of NPV. These distributions are seen in Figure 9. The variance of NPVs in the BASELINE scenario is larger than in the BSAP scenario. The explanation for this is that in the BASELINE scenario the higher marginal benefit estimate gives higher weight of nutrient reduction benefit in NPV, and many of the analysed variables impact on the estimated nutrient reduction. In the BSAP scenario the NPV is then always negative and in the BASELINE scenario always positive, independently of the lifespan length or discount rate (Appendix I).

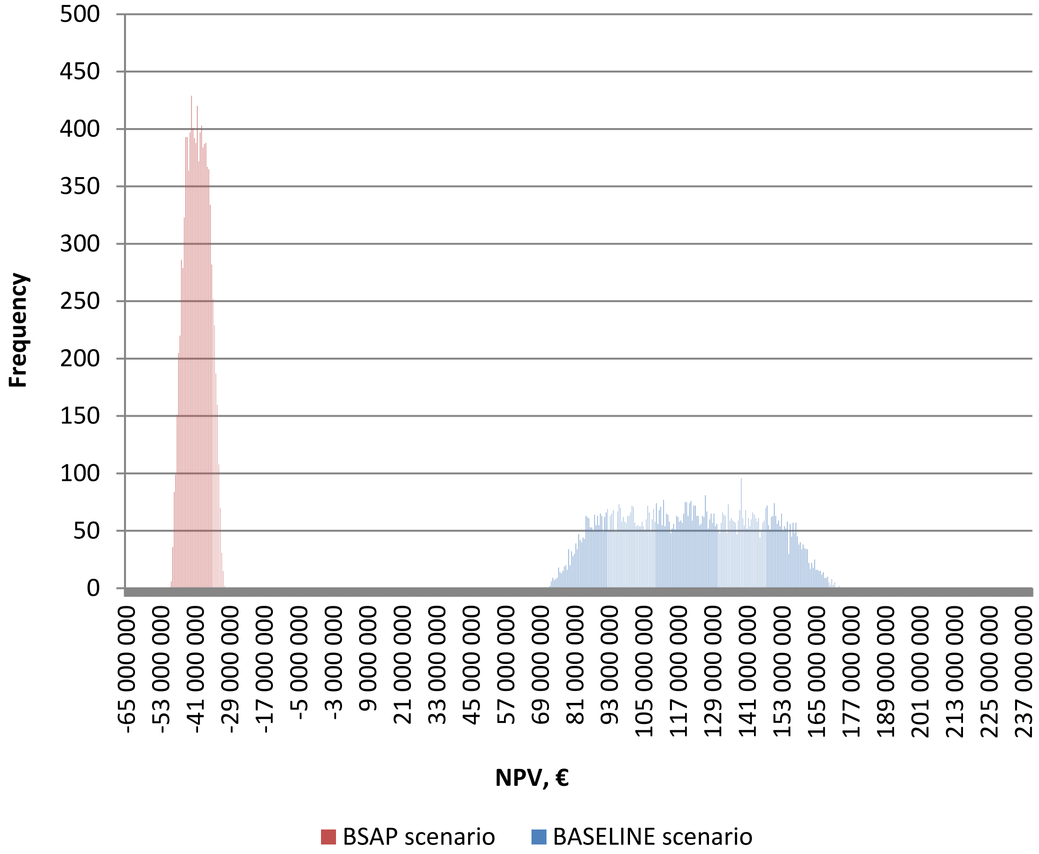


Figure 9. Monte Carlo sensitivity analysis and NPV distribution in the Luotsinmäki WWTP case in the BSAP and BASELINE scenarios (assumed lifespan length 30 years)

Finally, Figure 10 shows how net present value can develop in time. The results of worst and best case analysis (explained in Chapter 2) are included in this figure, because they illustrate minimum and maximum limits for the BSAP and BASELINE scenarios. During the first years, the net present value is negative, but it begins to grow in both scenarios due to positive annual net benefits. In the BASELINE scenario, the (best guess) net present value turns to positive in 2015. Figure 10 also shows that the worst and best case lines (minimum and maximum NPVs) diverge from the best guess line, especially in the BASELINE scenario, indicating that uncertainty increases in time and it is higher in the BASELINE scenario.

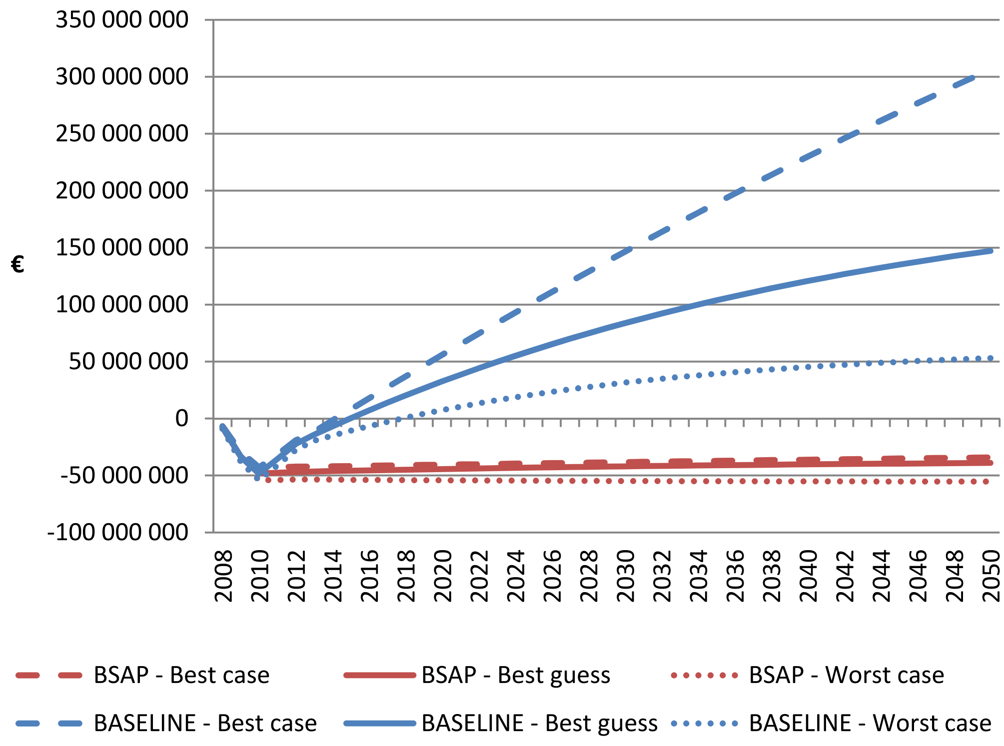


Figure 10. Development of net present value in time in the BSAP and BASELINE scenarios calculated with best guess values and in the worst and best case scenarios

3.5 Discussion

The case study of Luotsinmäki WWTP provided an overview of the potential impacts related to the centralising of wastewater treatment. The Luotsinmäki WWTP case was an example of collaboration between several municipalities, and it may have provided a very wide scale of positive local impacts which, however, were not possible to measure within this case study. For example, the estimated nutrient reductions to the Baltic Sea were remarkable, but their local impacts on the ecological status of the river Kokemäenjoki or coastal waters were not possible to measure in this study.

According to the results, the sign of net present value in the Luotsinmäki WWTP case depends on the general development of the Baltic Sea protection. If no additional actions to reduce nutrient loads are made and the state of the sea will remain poor in the future, as in the BASELINE scenario, nutrient reductions are very valuable, and the total benefits of centralising the wastewater treatment in the Luotsinmäki WWTP case clearly exceed the total costs (NPV 120 M€, B/C-ratio 2.07). If BSAP targets will be achieved, the marginal benefit gained from one reduced unit of nutrient is lower, although the total benefits of improved state of the water are higher – and in this BSAP scenario the costs would exceed the benefits (NPV –41 M€, B/C-ratio 0.64). The results can be interpreted so that currently the net benefits of the Luotsinmäki WWTP case are positive since additional actions to reduce nutrient loads are not yet made. If the amount of nutrient load reductions to the Baltic Sea increases to the BSAP targets level, the marginal benefit value will decrease and the net benefits turn negative. If BSAP targets are achieved, ways to centralise wastewater treatment cost-efficiently should be looked for. However, the benefits from Luotsinmäki WWTP are likely underestimates in both scenarios, because local impacts were not included in the analysis and the marginal benefit estimates do not cover the benefits of improved local water quality either.

The sensitivity analysis showed that the marginal benefit estimate was the only of the analysed variables which turned the sign of NPV. However, there were many possible impacts that were not included in the analysis and which should be noticed when interpreting the results. The centralising of wastewater treatment to Luotsinmäki WWTP was one of the alternative solutions to the new legislative demands of nitrogen treatment efficiency. Another alternative would be to improve all existing WWTPs which would, in practice, require building up new plants and thus cause substantial costs, because the plants were at the end of their lifespans. Also another central plant for Ulvila was under consideration, but it would have been a similar investment to the case of Luotsinmäki WWTP. It is important to understand that due to the centralising, substantial costs were avoided. Because the alternative solutions for Ulvila WWTP were not analysed, it remained unclear which one of the alternatives had the highest net benefits.

In addition, the costs related to transferring sewage from Luvia to Luotsinmäki and cost savings from Luvia WWTP were not available and thus missing from the analysis, although the nutrient reduction benefits at Luvia WWTP's part were included. There may be surprising maintenance costs in the future because the equipment and machines in the plants have different lifespans, but which are challenging to predict and thus not included in the analysis. There may be also impacts that were not identified in the analysis.

4 Case: Liepaja WWTP in Liepaja, Latvia

A municipal wastewater treatment plant, Liepajas Udens in Liepaja, Latvia, invested in the replacement of old aerators and PC-program with new ones in 2008–2010. The set of new aerators and PC-program investments represents an example of changing old technology to new, to more efficient and sustainable. Replacing aerators or a PC-program with new can be a potential future investment in other WWTPs, because the aerators are essential equipment in the biologic process and, similarly, the program to control the processes and equipment can be found from every WWTP. Although they are only parts of a complex treatment system, they represent examples of what benefits similar scale improvements can provide.

4.1 Background

The City of Liepaja is located in eastern Latvia, between the Baltic Sea coastline and Lake Liepaja. There are almost 80,000 citizens living in the city and it is the third biggest city in Latvia. (City of Liepaja, 2013). The City of Liepaja joined the Baltic Sea Challenge in 2008. The municipal company Liepaja Water (Liepajas Udens) takes care of the sewerage system and wastewater treatment in the city in addition to providing drinking water. Most of the households, 95%, are connected to sewerage system. The wastewater treatment plant is located in the northern part of Liepaja, close to the seashore. The plant purifies on average 25,000 m^3 of wastewater per day, and more than 85% of the sewage comes from households.

The plant was established during the Soviet time in 1972, and it was initially only a mechanical treatment plant. In 1980, the biological treatment part was added. During 1994–1998, large renovations were made in the plant: the pre-treatment part was rebuilt and the biological part renewed. These renovations were required because the equipment was old and inefficient, and the biological treatment part lacked the possibility to remove phosphorus and nitrates. Since the improvements in the late 90s, the treatment efficiency has been on a high level, achieving the treatment efficiency levels recommended by HELCOM (2007).

The investment in new aerators and PC-program was made in 2008–2010. The main reason for replacing the three old aerators with five new ones was that there were many problems with the old aerators since 2002 and they were close to the end of their lifespan. When choosing new aerators, sustainability aspects were considered. The new aerators were considered as a long-term investment providing energy savings. The PC-program that was used to control the whole process had to be replaced at the same time because the old one was not compatible with the new aerators. Because the investments improved the controllability of the whole treatment processes, they likely have many positive impacts that are discussed in the next section.

4.2 Identification of the impacts

Potential impacts of the combination of new aerators and the program are listed in Table 8. The investment caused costs from the acquisition of the new aerators, their installation and removing the old aerators. The change in operating and maintenance costs of the aerators may be positive or negative because there are no exact data on operating and maintenance costs of the old aerators (only energy consumption data). There were no changes in the maintenance costs of the program.

Table 8. Potential impacts of aerator and information technology investment in the WWTP. The ones marked with a grey background were included in the analysis.

Positive impacts	**Negative impacts**
Improved controllability: reduction in nutrient emissions due to e.g. less frequent bypass situations	Investment costs
Improved aeration: reduction in nutrient emission due to higher treatment efficiency	
Lower energy consumption: electricity cost savings and reduction in greenhouse gas emissions	
Positive and/or negative impacts	
Changes in annual operation and maintenance costs	
Impact on costs and climate in the other process phases, e.g. sludge treatment	
Labour impact	

The investment reduces the nutrient emission to the sea in two ways. The new aerators provide improved aeration in the biological process and this increases the treatment efficiency. The new aerators have frequency converters to adjust oxygen levels in the aerobic zone, and the new PC-program gives opportunity to put value limits for oxygen levels in the aeration tanks. The optimal aeration is important in the biologic process, because microbes degrading the nitrogen from sludge require aerobic circumstances.

In addition, the new program improves the controllability of the whole process due to less frequent bypass situations and other problems related to the controllability. The old program had several weaknesses: it turned off the equipment during the high flow rates, obtained data was not always reliable and the oxygen levels had to be confirmed on-site. There were also a number of new pieces of equipment in the plant that were not compatible with the old program. The new program solved all of these problems. The labour impacts were not included in the analysis due to lack of exact data.

4.3 Material and model

To measure the impacts of the investment, the realised situation needed to be compared with the scenario where the investment was not implemented. Because all old aerators were at the end or close to the end of their lifespan, there was no other choice than to replace them with new ones. In an imaginary situation, the second alternative would have been replacing the three old aerators with similar ones, when there would not have been need for replacing the PC-program and also the treatment efficiency and energy consumption would have remained at the same level as previously. The old aerators were put into operation in 1998, so the investment cost of this old technology would not be very high, and thus it was excluded from the analysis. Then all impacts related to the new aerators, beginning from the replacement, were compared with the annual costs and other impacts related to the scenario in which operation of old aerators would have been continued, as may be the case with other WWTPs.

The lifespan for aerators and the PC-program is assumed to be 15 years. The same lifespan is used as a depreciation time for aerators in Luotsinmäki WWTP. The experts in Liepaja WWTP expect that the aerators would stay in operation over 10 years.

Investment and operating costs

The installation costs of each new aerator by type and the PC-program are listed in Table 9. The costs were turned into 2014 values by using the Consumer Price Index (CPI) (Latvijas statistika, 2014). The installation costs of the aerators include dismantling the old aerators, a new concrete subfloor and the installation and adjustment of new aerators. The investment was financed by Liepaja Water.

Table 9. Investment costs of the PC-program and the aerators (in 2014 values)

		€
Investment cost of the PC-program		–171,257
Investment cost of an aerator with old frequency converter	M30.30 (aerator 1)	–46,230
Investment cost of an aerator with new frequency converter	M30.40 (aerator 2)	–62,583
Investment cost of aerators with Soft Start system	M30.50; M30.60; M30.70 (aerators 3, 4 and 5)	–172,290

Maintenance costs of the aerators consist of annual costs and other costs from oil changes and occasional service repairs. Annual maintenance costs include a thermograph for control cabinet (87 € per year), preventive maintenance for two frequency converters (372 €), maintenance for control cabinet (229 €) and vibration diagnostic for five aerators (1002 €). Total annual maintenance costs for aerators are approximately 1700 €. The maintenance costs are expressed in 2014 values, and they were turned into 2014 values by using the consumer price index (CPI) (Latvijas statistika, 2014). For the PC-program, the annual maintenance cost is

1252 €, but it was not taken into account because the maintenance cost remained the same after the investment.

In addition, an oil change will be made for the first time after 500 engine working hours and then after every 8000 working hours. The operation of the first new aerator began in 2008, and the operation of the three next aerators began in 2009. The last aerator began its operation in 2010. Average annual working hours were calculated from data from years 2010–2013, and they were used in estimating the total working hours until year 2025. According to the total working hours, an oil change was estimated to be made in total 8 times for aerators 1–3, 9 times for aerator 4, and 10 times for aerator 5 during the 15-year lifespan. A cost of one oil change per aerator is approximately 107 € (in 2014 value).

At the end of 2013, one of the aerators was sent to service repair because of the vibration measurements, and it produced an additional maintenance cost. This cost was 7309 € (in 2014 value), which included dismantling, transportation to the workshop and change of bearings, seals and gaskets, among other parts. This aerator was the last one, installed in March 2010. It is very difficult to predict when another aerator will need similar repair. In the plant there is a smaller aerator of same producer in a grit chamber, and it has been in use since 1998 (16 years) without any serious service repairs.

In general, the aerators consume the largest share of the total energy consumption of the whole process, about 74% in the Liepaja WWTP. The new aerators consume significantly less electricity than old aerators. Before the investment, the annual energy consumption of the aerators was 2.38 million kWh, and after it is has been between 1.36–1.67 million kWh. The electricity costs savings can be calculated by multiplying the consumption change by electricity price 10.3 cents per kWh. There is no data how much the energy or electricity consumption decreased in the other processes due to the new PC-program and improved controllability.

Benefits from climate emission reductions

In addition to energy cost savings, a decrease in energy consumption reduces also climate emissions. According to the International Energy Agency (2014) the main sources of electricity in Latvia are gas and hydropower. The average climate impact of one kWh of electricity can be calculated from the shares of energy sources and their life-cycle CO_2 emissions by source. By using 50th percentile CO_2-emission values for energy sources from Moomaw et al. (2011, p. 982), the marginal climate impact is 235 g CO_2-eqv per kWh, and by the 25th or 75th percentiles it is respectively 204 or 276 g CO_2-eqv per kWh. These values are used in assessing the change in climate impact of aerator investment.

Change in nutrient reductions

The change in nutrient reductions was estimated by comparing the nutrient concentrations in effluent before and after the investment. The average concentration before the investment was calculated from a 5-year period and the average concentrations after the investments from the 2011–2012 data. The change in concentration was multiplied by the average amount of treated wastewater to obtain the change in nutrient loads. The period when investments were made, from October 2008 to March 2010, is excluded from the comparison.

4.4 Results

The investment project in Liepaja WWTP improved both energy and treatment efficiency in the plant. The electricity consumption decreased a third: previously the electricity consumption was approximately 2.4 MWh/y and after investment on average 1.6 MWh/y, which reduces climate emissions by 180 CO_2-equivivalent tons annually. The improved controllability of the biological treatment phase and the whole process improved also the treatment efficiency and reduced annual nutrient loads to the Baltic Sea by 18,000 kg N and 1,000 kg P. Reductions cover 1.1% and 0.6% of BSAP targets for Latvia, and 0.02% and 0,11% of BSAP targets for the Baltic Proper basin for N and P respectively (HELCOM, 2014b). For a single investment in a wastewater treatment plant, the numbers are relatively high on a country-level.

Annual present value benefits and costs are illustrated in Figure 11 (BSAP scenario) and Figure 12 (BASELINE scenario). The only difference between these two figures is the eutrophication reduction benefits (please notice the scale of the y-axis in Figure 11 and Figure 12. In the BASELINE scenario, they are relatively large compared to other costs or benefits. Investment costs are the largest cost category and the eutrophication reduction benefits are the largest benefit category in both scenarios. The energy savings provide electricity cost savings for the plant which are the second largest benefit category, but relatively small benefits from reduced climate impacts if compared to other categories. Also the maintenance costs are a small cost source. The nutrient reduction benefits are different in 2011–2012 because the nutrient reductions were calculated using the same year values, but for following years using average values.

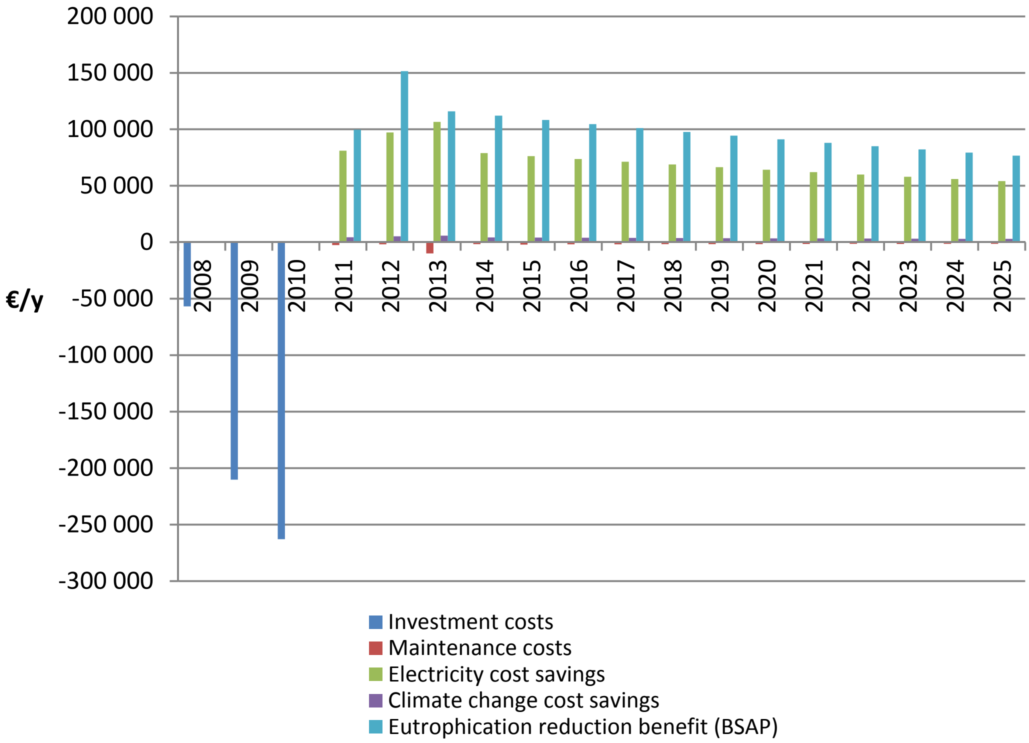


Figure 11. Present values of annual costs and benefits in the Liepaja WWTP case in the BSAP scenario

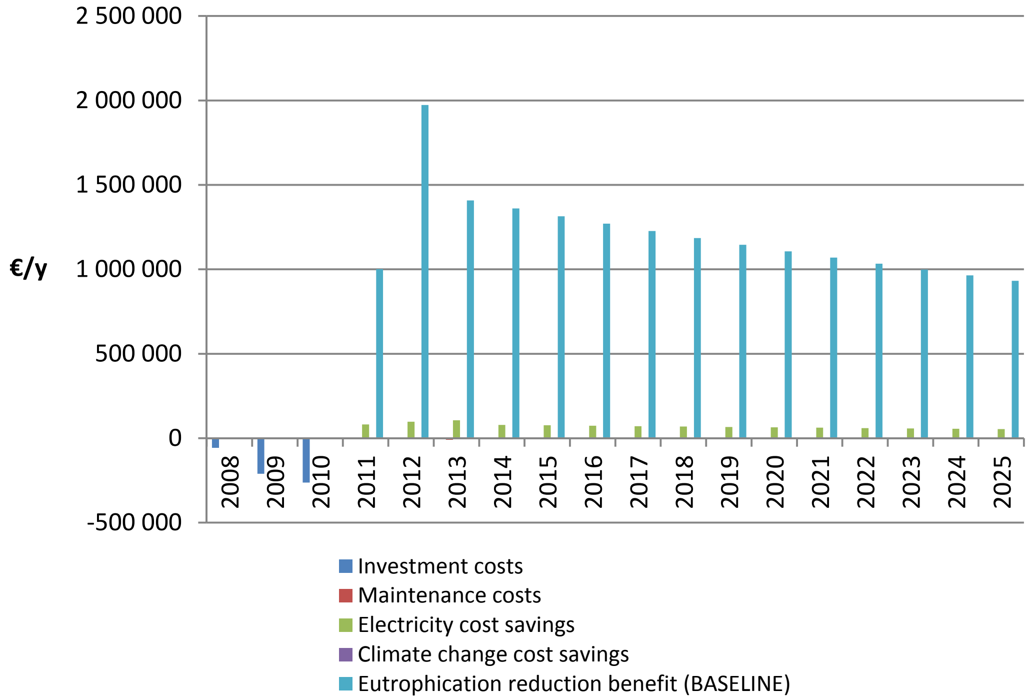


Figure 12. Present values of annual costs and benefits in the Liepaja WWTP case in the BASELINE scenario

Figure 13 shows the annual net present values in both scenarios (BSAP and BASELINE) during the assumed length of the lifespan (15 years). After the investment years, the annual net present values are positive but declining due to discounting. The difference in annual net present values after the investment years is significant between the BSAP and BASELINE scenarios.

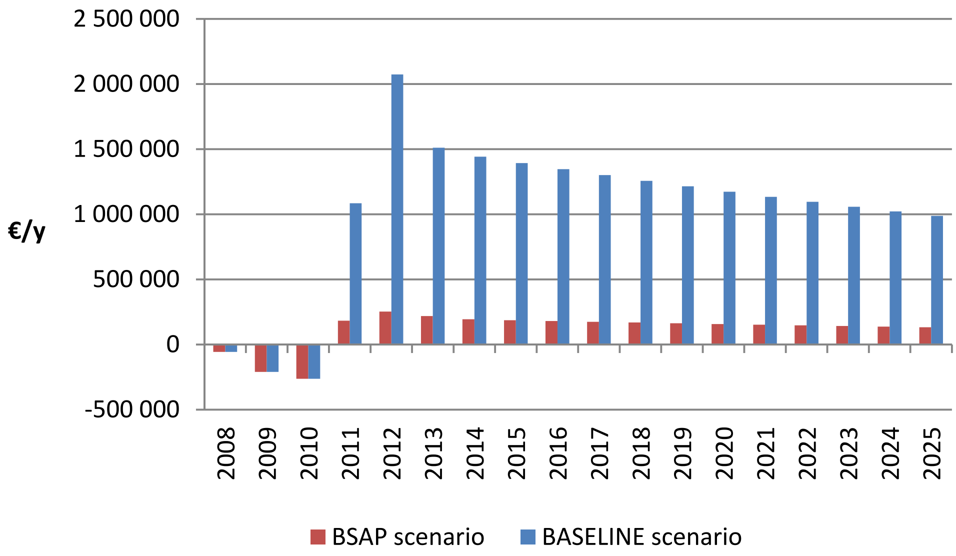


Figure 13. Annual net present values in the Liepaja WWTP case in the BSAP and BASELINE scenarios

When all present value costs and benefits until 2025 (best guess length of lifespan) were summed up to the total net present value (NPV), the NPV is positive in both scenarios: the best guess NPV is approximately 2.1 million euros in the BSAP scenario and 18.6 million euros the in BASELINE scenario. The B/C-ratios were respectively 4.65 and 33.92. The scenario about the achieved nutrient reductions in the future has an impact on the scale of NPV but does not turn the sign of NPV. What impacts other variables have on the NPV will be found in the sensitivity analysis.

The variables and their values that were studied in the partial sensitivity analysis are listed in Table 10. Minimum and maximum values were assumed to be 10% lower or higher than best guess values for maintenance costs, electricity price and total amount of wastewater in future, and realised limit values for other variables. Partial sensitivity analysis showed that none of the analysed variables turn the sign of the NPV. In Table 10, the relative changes indicate the change in NPV compared to the NPV calculated with best guess values, when a value of one variable at a time is changed to its minimum or maximum. Variables that have the largest impact on the NPV are length of lifespan, discount rate, nutrient concentrations in the effluent, and wastewater flow in the future. In the BSAP scenario, the relative changes are in most cases larger than in the BASELINE scenario, because the best guess NPV to which NPVs are compared, is smaller. However, in the case of N-concentration and wastewater flow rates the relative changes are larger in the BASELINE scenario because the benefit gained from nitrogen reduction has such a high weight in NPV. In some cases, the relative changes for minimum and maximum value are on a very different scale (e.g. in the case of energy consumption) because the best guess value is not the average of minimum and maximum values.

Table 10. Partial sensitivity analysis of the Liepaja WWTP case: variables and their minimum, maximum and best guess values and their relative impact on NPVs in the BSAP and BASELINE scenarios

				BSAP scenario		BASELINE scenario	
Variable	**Min value**	**Best guess value**	**Max value**	**Change (Min value)***	**Change (Max value)***	**Change (Min value)****	**Change (Max value)****
Discount rate	0.01	0.035	0.06	14.11%	–11.96%	9.77%	–7.82%
Social cost of carbon, €/CO_2-ton	7.2	23.9	43.9	–1.99%	2.39%	–0.22%	0.26%
Marginal climate impact, kg CO_2/ MWh	204	235	276	–0.38%	0.50%	–0.04%	0.06%
Energy consumption in future, kWh/y	1,369,661	1,602,211	1,666,532	12.26%	–3.39%	1.36%	-0.38%
N-concentration in effluent in future, mg/l	–3.17	–1.98	–0.75	10.52%	–10.95%	25.49%	–26.53%
P-concentration in effluent in future, mg/l	–0.16	–0.13	–0.13	8.19%	–1.80%	7.37%	–1.62%
Maintenance costs in future, %	90	100	110	0.10%	–0.10%	0.01%	-0.01%
Electricity price in future, %	90	100	110	–3.84%	3.84%	–0.43%	0.43%
Wastewater flow rate in future, %	90	100	110	–5.45%	5.45%	–7.33%	7.33%
Lifespan, years	10	15	20	–34.52%	29.06%	–28.53%	24.03%

* Relative change in NPV compared to best guess NPV in BSAP scenario (approx. 2.1 million euros)
** Relative change in NPV compared to best guess NPV in BASELINE scenario (approx. 18.6 million euros)

In Monte Carlo simulation uncertainty related to all variables in partial sensitivity analysis, except discount rate and lifespan, were taken into account at the same time (see Chapter 2). The NPV distributions in the Monte Carlo simulation for BSAP and BASELINE scenarios with best guess lifespan length and discount rate (15 years; 3.5%) can be seen from Figure 14. The variance of NPVs is larger in the BASELINE scenario than in the BSAP scenario due to higher weight of eutrophication reduction benefit, because there are many variables influencing the nutrient reduction. All of the 10,000 NPVs in the simulation were positive also with different lifespans and discount rates (Appendix II).

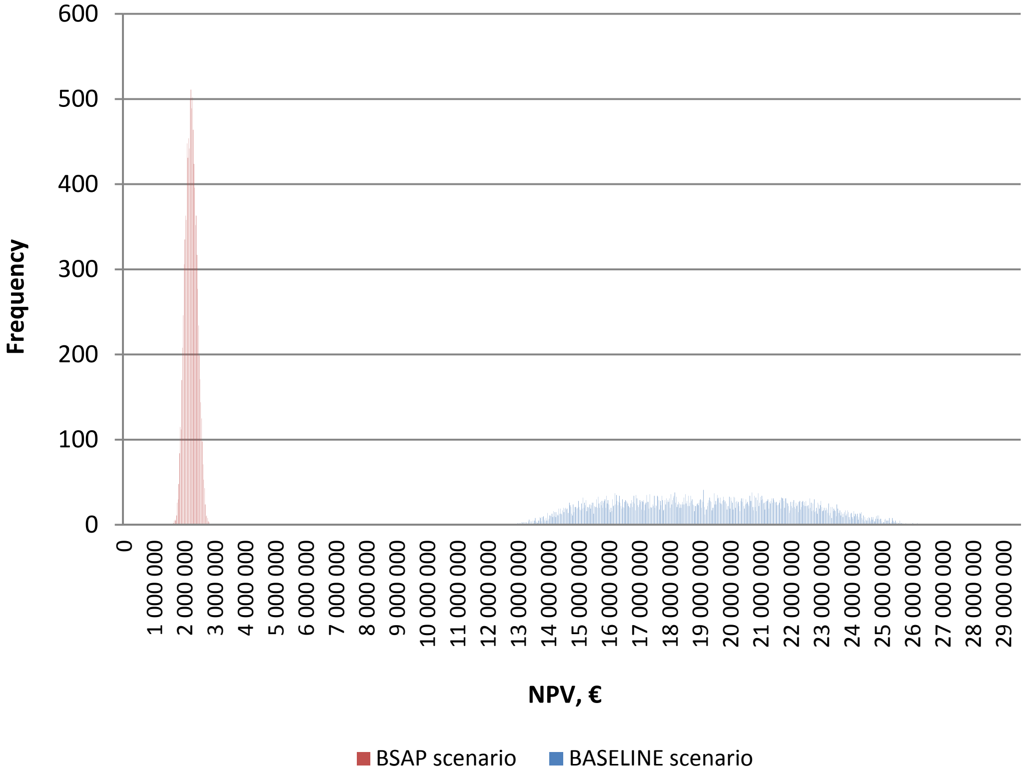


Figure 14. Monte Carlo sensitivity analysis and NPV distribution in the Liepaja WWTP case in the BSAP and BASELINE scenarios (with 15 years lifespan length)

The development of the best guess NPV and the worst and best case scenarios (minimum and maximum NPV) as functions of time are illustrated in Figure 15. During the investment years, the NPVs are negative but they turn to positive in 2011 in the BASELINE scenario and in 2013 in the BSAP scenario. The scope of uncertainty grows in time and it is larger in the BASELINE scenario. As a conclusion, although the benefits of reduced nutrient loads depend on the general development of the Baltic Sea protection and this has a significant impact on the net present value of the aerator investment, the net present values were positive in all cases, even in the worst case analysis.

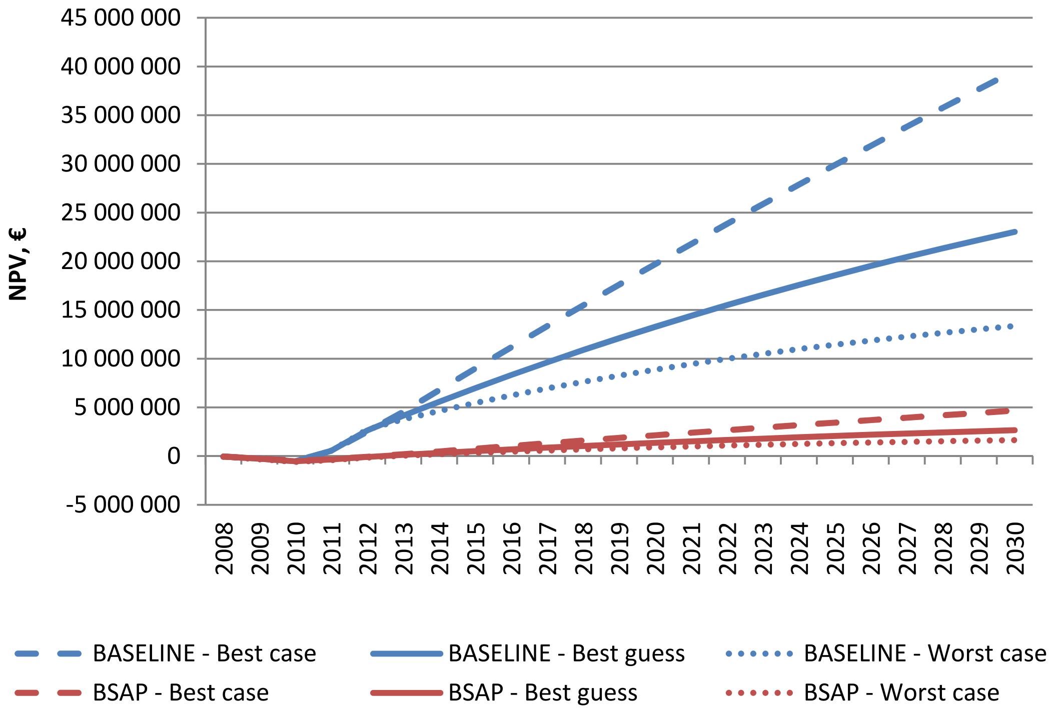


Figure 15. Development of total net present value (NPV) of Liepaja WWTP case with best guess, minimum (worst case) and maximum (best case) NPVs in BSAP and BASELINE scenarios

4.5 Discussion

The case study of Liepaja WWTP showed that even a single measure, the investment in aerators and PC-program in the WWTP in a plant, can bring remarkable nutrient reductions and net benefits. The estimated nutrient reductions were 18,000 kg/y for nitrogen and 1,000 kg/y for phosphorus. In addition, the investment provided significant energy cost savings to the plant and reduced climate emissions, because the total electricity consumption of the plant decreased by third. The results of cost-benefit analysis and sensitivity analyses showed that net present value of case Liepaja WWTP is positive in both the BSAP and BASELINE scenarios, and thus it seems to be a worthwhile investment from society's aspect (BSAP: NPV 2.1M€, B/C-ratio 4.65; BASELINE: NPV 18.6M€, B/C-ratio 33.92).

Despite sensitivity analyses, some uncertainty still remained in the results. Cost data related to the old aerators were not available, and there were problems with them before the last years before the investment which may have some impact on the results. The risk for larger repairs of aerators as in 2013 were not analysed. Also other factors in the plant may impact on the energy and treatment efficiency. The local impacts to the coastal waters were not analysed either. In addition, there may be impacts that were not identified.

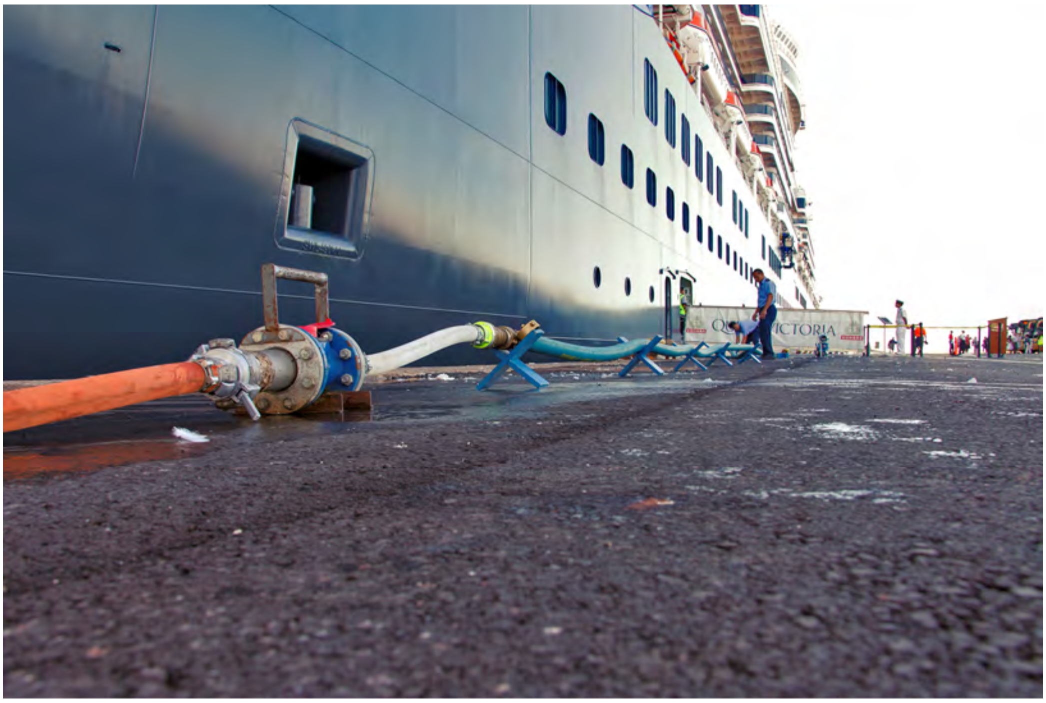


Photo: Port of Finland / Mikael Kaplar / Studio point

Wastewater discharge in harbours

There are approximately 90 million passengers travelling by ferry or cruise ship in the Baltic Sea every year (HELCOM, 2014a, p. 17), visiting cities around the Baltic Sea and enjoying the landscape and other experiences provided by the sea. Unfortunately, if the generated sewage on the passenger ships is not managed properly or it is not possible to discharge it in the port, the untreated sewage may be dumped to the sea, because binding legislation prohibiting the dumping has not been existing. However, according to the amendment to MARPOL Annex IV of International Maritime Organization (2011), the Baltic Sea is defined as a special area from January 2013. Due to this, dumping of untreated sewage into the sea will be prohibited from 2016 for new ships and from 2018 for existing ships, if the sewage reception capacity is sufficient in the ports of the Baltic Sea. Sufficient capacity means that all ships, independent of the size of the ship, can discharge the sewage to port reception facilities (PRF) in any port without any delays.

Currently there are only some of the passenger ports in the Baltic Sea region that have an adequate PRF system and many ports that should improve their system by e.g increasing their reception capacity (HELCOM, 2014a). Large costs from upgrading the reception systems in the port and the municipal sewage network to an adequate level may be required and running costs from treatment of sewage are typical hindrances in achieving the aim of sufficient capacity. According to the “polluter pays” principle, the ships should cover the costs, but on the other hand, direct sewage costs may cause an incentive to discharge sewage to the sea. In many ports the so-called “no special fee” system is applied, for example by covering expenditures indirectly via other fees. (Clean Baltic Sea Shipping, 2013.) An example from the Port of Helsinki on how PRF and no special fee system can be implemented is the next case study in the CITYWATER cost-benefit analysis.

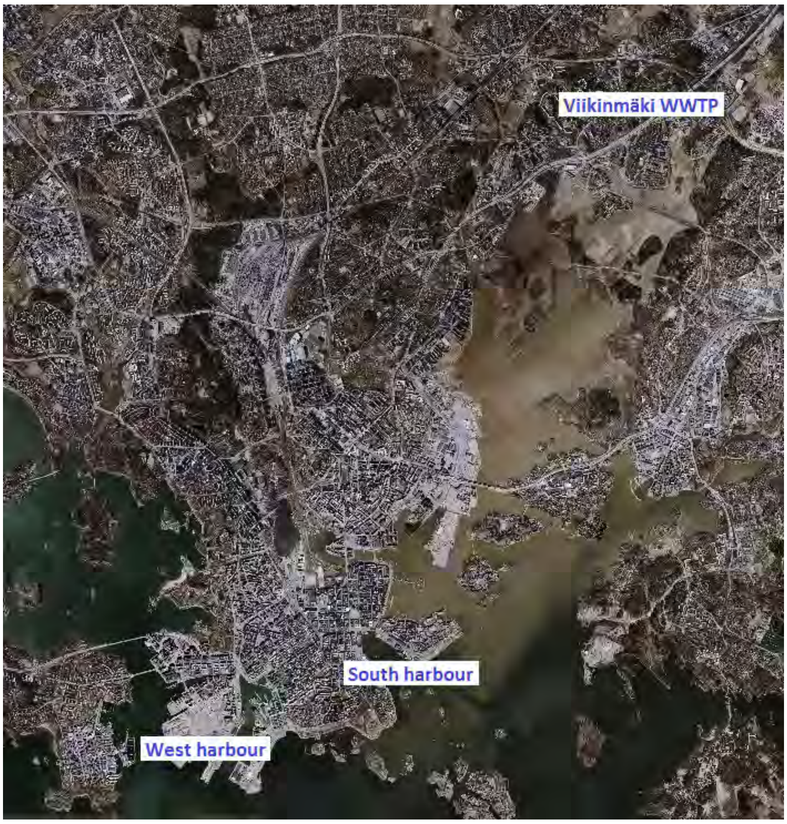
5 Case: Port of Helsinki, Finland

The Port of Helsinki receives wastewater mainly from passenger ships and the wastewater is treated in the municipal WWTP in Helsinki. The Port of Helsinki applies no special fee system by charging only a general waste fee, which depends on the size of the ship. The visiting ship pays the same waste fee whether discharging the sewage in the harbour or not. For receiving the sewage from vessels, the Port of Helsinki has invested in port reception facilities (PRF) from 1990 and the expansion of the sewer system is still continuing together with the construction of new quays. By investing in PRFs the Port wants to show a good example of how to take environmental responsibility into account in the operation of a port in the Baltic Sea region. This water protection measure is also one of the Baltic Sea Challenge actions of the City of Helsinki.

5.1 Background

The City of Helsinki is the capital of Finland, located in southern Finland on the coast of Gulf of Finland. It is the largest city in Finland having 0.5 million citizens. The City of Helsinki established the Baltic Sea Challenge initiative together with the City of Turku in 2007, and the activities within the Baltic Sea Challenge reaches all administrative parts of the city. The Port of Helsinki is a municipal company owned by the City of Helsinki and it is the main port of Finland in terms of passenger and unitised cargo traffic. The total number of passengers in the Port of Helsinki was 10.7 million in 2013 (Port of Helsinki, 2014). The Port of Helsinki comprises three separate harbours. Two of them, passenger harbours South Harbour and West Harbour, are located near to city centre (Picture 2). The third, cargo-focused Vuosaari Harbour, is located in eastern Helsinki.

The first fixed sewage pipelines in South Harbour quays were installed in 1990, and during 1999–2009 the pipelines were assembled on all existing quays in harbours near the city centre. During recent years, the installation has been made together with the construction of new quays. In 2008, Vuosaari Harbour was launched and it is equipped with sewage pipelines in all quays and piers. The no-special-fee policy was launched in May 2008. The PRFs are connected to the municipal sewage network and the received sewage is treated in the municipal wastewater plant in Viikinmäki (Picture 2).



Picture 2. Locations of the passenger harbours (South Harbour and West Harbour) and Viikinmäki WWTP in which received sewage is treated (modified from City of Helsinki, 2014)

According to the Port, the main reason for implementing this measure is, in addition to legislative demands, the benefit of improved image that the port gains from it. Because of the location of the passenger ports, the Port focuses on environmental responsibility work to save the citizens' acceptance to operate and to keep and expand the operation in the central location of the city. The high-level responsibility and the location are clear benefits for competitiveness.

5.2 Identification of the impacts

The potential impacts of the measure are listed in Table 11. The costs that were included in the analysis were the costs from PRF investments, operating and maintenance and wastewater treatment. Also the energy consumption from the heating of the PRF system and the climate impact due to this were measured and monetised. The most important benefit that was gained from this measure is the reduced nutrient emissions to the sea. Because reductions are related to marine traffic it is not clear in which part of the sea the sewage dumping is avoided and the highest impact achieved. The vessels visiting the Port of Helsinki travel within or through the Gulf of Finland, so for this reason it was assumed in the analysis that the Gulf of Finland gains the most benefit from the avoided sewage dumping.

Table 11. Potential impacts of implementing PRF and receiving sewage from vessels with no special fee system. The ones marked with a grey background were included in the analysis.

Positive impacts	**Negative impacts**
Reduced nutrient emissions into the Baltic Sea	Investment and operating cost of the PRF
Future improvements of the WWT are easier to realise in one large onshore plant than in several vessels	Wastewater treatment costs (fees paid to WWTP)
Avoided costs and energy consumption of treating the sewage on the ship	Increment in flow rates in WWTP: requirements for expanding the capacity, etc.
Passenger vessels prefer ports with PRF and no-special-fee system, more travelers visit the city	Energy consumption of PRF
Good management of environmental responsibility increases competitiveness and improvises image of the port -> competitors increase their level of environmental responsibility	Required time for ships visiting ports
	Collection of sewage in tanks before discharging it in ports

There are also other potential impacts that were not analysed. Receiving wastewater from ships may increase flow rates in the treatment plant, which may cause requirements for expanding the capacity and increment in operating costs and energy consumption. Because the port pays wastewater fees to Helsinki Region Environmental Services Authority (HSY), it can be assumed these fees cover the costs in the treatment plant. On the other hand, the treatment in the plant provides also benefits: the treatment of sewage will be easier to manage and upgrade in one plant than in several vessels on the sea. It is probably also more efficient in terms of treatment and energy efficiency. However, the sewerage system requires heating in the winter time and energy consumption causes climate impacts.

Other positive impacts may also be an increment in passengers visiting the City of Helsinki, because the PRF is adequate and no special fee is charged for discharging the sewage in the Port of Helsinki. For vessels this opportunity may provide cost-savings from avoided treatment of wastewater on the vessel. If they prefer the Port of Helsinki and visit there more often for this reason, the passenger rates may increase. The passenger rates in Helsinki have actually increased during recent years, but it is very difficult to assess which share of the increment is related to this measure.

As was mentioned, the port values the environmental responsibility very highly, and it was one of the main reasons behind implementing the PRF system. Good management of environmental responsibility increases the image value and competitiveness of a port. This may increase the general level of environmental responsibility in ports, if it is regarded as an advantage of competition, which decreases environmental impacts of ports and is beneficial for society.

5.3 Material and model

In this case study, the analysed water protection measure consists of constructing and maintenance of the port reception facilities, receiving sewage from passenger and cruising vessels with no special fee and treating the sewage in the municipal WWTP. The Port expects that the PRF will be in operation in 40-50 years, and thus, the impacts will be assessed until 2040 (taken as a best guess for a lifespan). Below is explained in more detail, how the impacts from this measure were calculated and what kind of data was used.

Investment and operating costs

The investment costs consisting of installation and materials are listed in Table 12. The investment costs beginning from year 1999 were available, so the investment costs made in 1990–1998 are not included in this analysis. The costs are expressed in 2014 euros excluding taxes. The total investment cost during 1999–2013 is approximately 3 million euros.

Table 12. Total investment costs of port reception facilities (PRF) installed in 1999–2013 in passenger ports in 2014 values

		South Harbour	West Harbour	
PRF installation cost		693,300	1,967,300	
PRF material costs		99,900	272,600	
TOTAL		**793,200**	**2,239,900**	**3,033,100**

The operating and maintenance costs of the PRF in passenger ports were approximately 30,600 euros (in 2014 value, excluding VAT) from October 2012 to September 2013. There was no other available value for these costs, so it was used also for other years. Because the electricity costs from heating are not included in the operating costs, it was estimated by multiplying the estimated consumption of electricity with the electricity price (0.08 €/kWh). In the South Harbour there is an approximately 1050 m of heated pipe, with heating power of 5 W/m. If it is used 4 months per year, the electricity consumption would be 15,120 kWh/y and the cost would be 1,210 €/y. Information on West Harbour was not received.

Nutrient load reductions

The avoided nutrient emissions to the sea was estimated from the amount of received sewage, the nutrient concentration in sewage and the treatment efficiency. The amount of received sewage from passenger and cruise ships has been increasing since 2007, and it was in 2012 over 300,000 m^3 (Figure 16). According to the Port, 350,000 m^3 is expected to be a maximum amount of received sewage in the next years. This amount is assumed to be the average amount of wastewater in future, because it is difficult to predict how the amount will change in future. It can be influenced by many factors, like amount of marine traffic, passenger numbers, legislation, wastewater treatment in vessels etc. The recent increase is probably due to an increase in PRF capacity and passenger traffic. It is difficult to say what has been the role of the no special fee system launched in 2008 in the increase in sewage amounts.

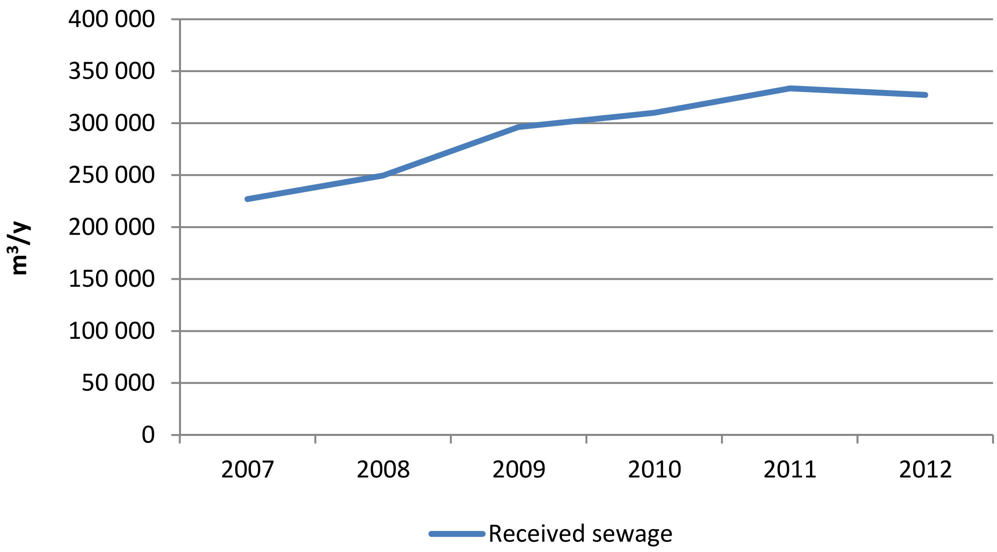


Figure 16. Annual amounts of received sewage water from passenger and cruise ships in the Port of Helsinki

Sewage from passenger ships consists of black water (human sewage, from e.g. vacuum toilets) and grey water (from kitchens and showers). The quality of sewage from passenger ships was analysed in the Port's wastewater report (Kollin, 2012). In South Harbour, the share of black water from studied passenger ships was assessed to be 15% and in West Harbour 11%, while the studied cruise ships discharged only grey water. Also four wastewater samples from ships were analysed: there was a large variation in the nutrient concentrations but it may be due to problems with taking samples of settled solid in the sewage and thus it is hard to make any conclusions.

The amount of wastewater treatment fee that a port pays to the regional water utility is based on estimated shares and concentrations of sewage from ships. The sewage includes approximately 10% of black water which includes on average 130 mg/l nitrogen and 14 mg/l phosphorus, and the remaining 90% is grey water which is comparable to normal household wastewater (60 mg/l N and 9 mg/l P) (data received from HSY). According to these numbers, the average concentrations in the sewage are 67 mg/l for nitrogen and 9.5 mg/l for phosphorus, values that were also used in this analysis. It should be noted that these numbers will give only a rough estimate of the total nutrient amount, because the concentrations in sewage from ships vary a lot, and the amounts are large.

In Viikinmäki WWTP, the average treatment efficiency for nitrogen was 88% and for phosphorus 96% in 2012 (HSY, 2013, p. 19) These reduction values were applied in estimating the reduced nitrogen and phosphorus load into the Baltic Sea, although the actual reduction rates may be lower for sewage from ships due to differences in concentrations.

Wastewater treatment costs

As was explained above, the sewage received in port is treated in the municipal wastewater treatment plant and the port pays wastewater fees which cover the expenditures of the wastewater treatment. The sewage water is regarded as industrial wastewater and the fee is higher compared to the wastewater fee for households. The amount of fee has been 1.32 euros per m^3 since 2013, when the charging system changed. Before that, the charging system was more complicated, so in this analysis the mentioned value was used only. It is possible that if a port applies the no special fee system, the port receives indirect fees from sewage reception with other fees such as general waste fee and covers a part of the wastewater treatment costs. In this analysis the port is assumed to cover the costs because no information about the indirect fees were available.

Climate impact

As was estimated above, the consumption of electricity for heating the pipes is approximately 15,120 kWh. To assess the amount of greenhouse gas emissions (in CO_2-equivivalent kg) due to the electricity consumption, the electricity consumption was multiplied by the average climate impact from one unit produced electricity, which is in Finland 210 CO_2-eqv kg/MWh (Hippinen & Suomi, 2012, pp. 7 - 8).

5.4 Results

Beginning from the environmental impacts, the estimated nutrient load reductions gained from the reception of sewage from ships in the Port of Helsinki are approximately 21,000 kg of nitrogen and 3,000 kg of phosphorus annually. Reduction covers about 1% of BSAP targets for Finland (HELCOM, 2014b). This is a remarkable amount on a country level for a single water protection action. As was mentioned previously, it is not clear in which part of the sea the sewage dumping is avoided and thus it is not clear in which part of the sea the reductions have the highest impact. However, it is likely that the Gulf of Finland gains the most benefit from the avoided sewage dumping, because the vessels visiting the Port of Helsinki travel inside or through Gulf of Finland.

The annual costs and benefits calculated with the best guess values during the assumed lifespan (until 2040) are presented in Figure 17 (in the BSAP scenario) and in Figure 18 (BASELINE scenario). Please note that the only differences between these two figures are the different eutrophication reduction benefits and the scale of the y-axis. As in the previous cases of Luotsinmäki and Liepaja WWTPs, the eutrophication reduction benefits are in the BASELINE scenario notably higher than in the BSAP scenario due to higher marginal benefit of nutrient load reduction. Figure 17 and Figure 18 show that the investment costs in 1999–2013 of port reception facilities (PRF) and the wastewater treatment costs are the largest cost sources. Operating and maintenance costs and climate cost from electricity heating of PRF are very small (electricity costs are included in operating and maintenance costs). In the analysis, the wastewater reception was assumed to begin from 2007, because the data was available since that year. During the first years, the amount of received wastewater increased (as was seen in Figure 16) until it achieved the assumed maximum amount of wastewater. Although the amount of received wastewater remained the same, the annual present value cost and benefits decrease in future due to discounting.

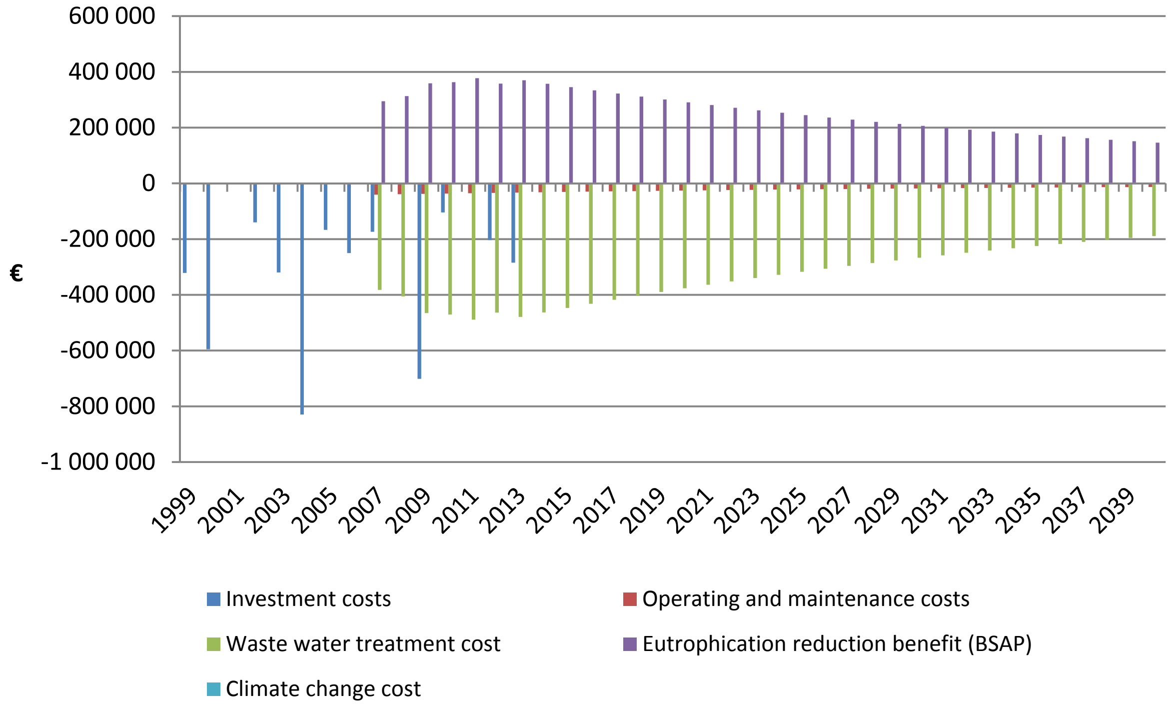


Figure 17. Annual present value costs and benefits in the Port of Helsinki case in the BSAP scenario

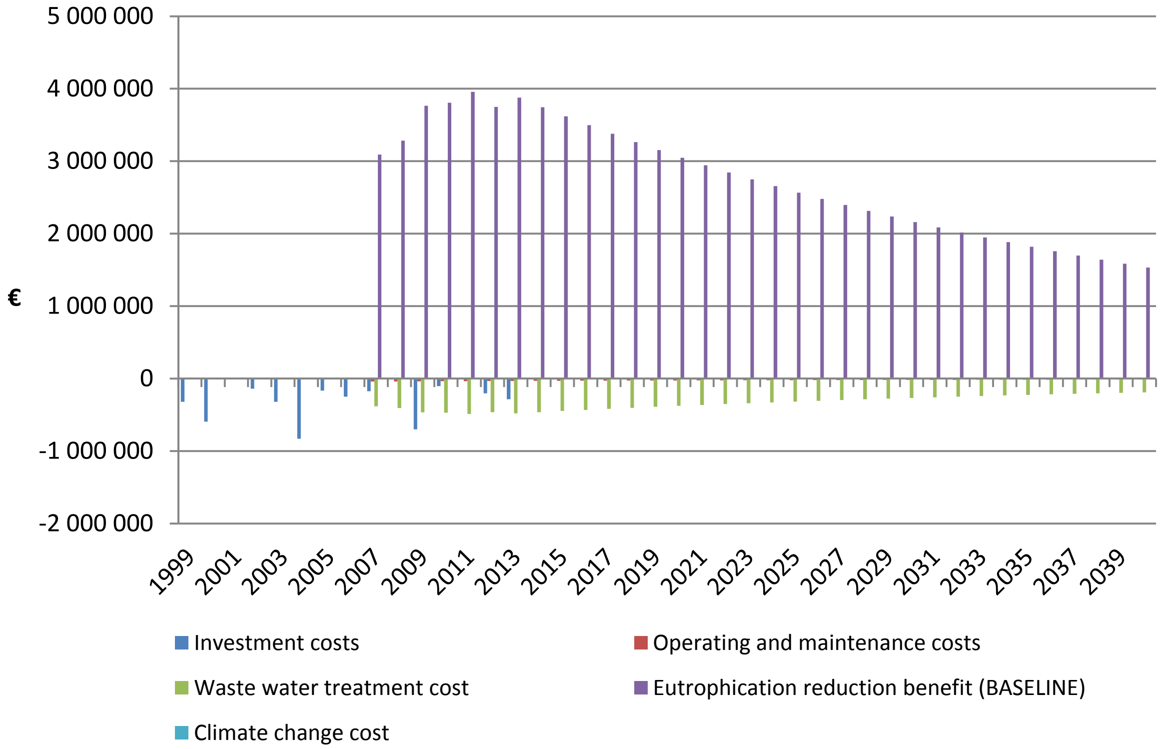


Figure 18. Annual present value costs and benefits in the Port of Helsinki case in the BASELINE scenario

The annual net present values were obtained by summing up annual costs and benefits. Annual net present values until 2040 for both the BSAP and BASELINE scenarios are presented in Figure 19. In the BSAP scenario, the annual net present values remain negative during the whole lifespan. In the BASELINE scenario, the annual net present values turn to positive already in the first year when wastewater reception was assumed to begin, and they are relatively large compared to the negative net present values during the investment years.

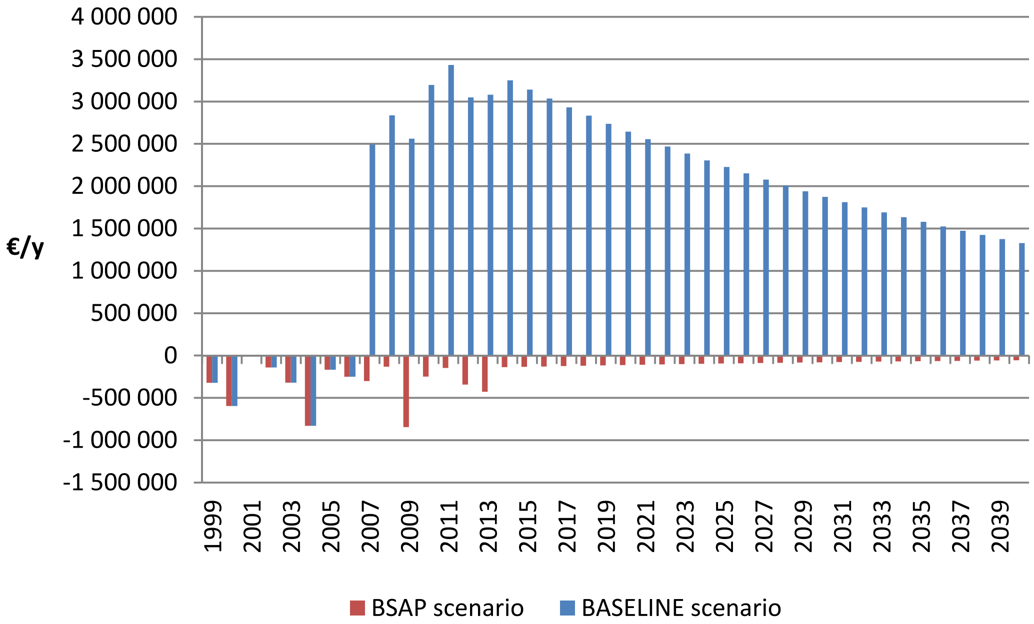


Figure 19. Annual net present values in the Port of Helsinki case in the BSAP and BASELINE scenarios

Then, the annual net present values are summed up together to obtain the total net present values (NPVs). With the best guess values, for the BSAP scenario the NPV is approximately –7.5 million euros and negative, but for the BASELINE scenario approximately 76.2 million euros and positive, while the B/C-ratios are respectively 0.54 and 5.66. The situation seems to be similar as in the case of Luotsinmäki WWTP: the sign of NPV depends on the scenario how the general level the Baltic Sea protection develops in the future. To get more information about the results and to analyse how other variables affect the NPVs or how probable it is that NPVs are positive and negative, the sensitivity analysis was performed.

The variables that were taken into account in the sensitivity analysis and their best guess, minimum and maximum values are listed in Table 13. For example, operating and maintenance costs were assumed to be 10% lower or higher in the future than the best guess value. The heating of pipes was assumed to be used 2 to 6 months per year, instead of the best guess value of 4 months. The minimum values of nitrogen (N) and phosphorus (P) concentrations of wastewater are nutrient concentrations of the grey water and the maximum values are nutrient concentrations of the black water received from ships. Wastewater fees and electricity price were assumed to be 50% lower or higher in the future.

In partial sensitivity analysis, NPV was calculated by changing the value of a factor per time from best guess value to a minimum or maximum value and it was checked how the obtained NPV differed from the NPV calculated with best guess values. Table 13 shows the results of partial sensitivity analysis both for BSAP and BASELINE scenarios. For example, discount rate, length of the lifespan, wastewater treatment cost and the variables that are related to the sewage have a relatively great impact on the NPV. Some of these have relatively larger impact on NPV in the BASELINE scenario (discount rate, lifespan N-related variables and amount of sewage) and this is due to the large estimated nitrogen load reduction (on average 21 tons N per year) and the weight of future benefits. The change in wastewater treatment cost causes the highest relative change in the NPV in the BSAP scenario, which can be explained by the large weight of this cost source and with the scale differences to the BASELINE scenario. None of the factors are able to turn the sign of NPV.

Table 13. Partial sensitivity analysis of the Port of Helsinki case: variables and their minimum, maximum and best guess values and their relative impact on NPVs in the BSAP and BASELINE scenarios

				BSAP scenario		BASELINE scenario	
Variable	**Min value**	**Best guess value**	**Max value**	**Change (Min value)***	**Change (Max value)***	**Change (Min value)****	**Change (Max value)****
Discount rate	0.01	0.035	0.06	0.65%	–7.21%	23.63%	–15.04%
Operating and maintenance costs in the future, €/y	–27,551	–30,612	–33,673	0.73%	–0.73%	0.07%	–0.07%
Social cost of carbon, €/CO_2-ton	7.2	23.9	43.9	0.01%	–0.02%	0.00%	0.00%
Marginal climate impact, kg CO_2/ MWh	189	210	231	0.00%	0.00%	0.00%	0.00%
Energy consumption in the future, kWh/y	7,560	15,120	22,680	0.22%	–0.22%	0.02%	–0.02%
Electricity price in the future, €/kWh	0.04	0.08	0.12	0.21%	–0.21%	0.02%	–0.02%
Discharged wastewater in the future m^3/y	300,000	350,000	400,000	2.89%	–2.89%	–11.74%	11.74%
N-reduction rate in WWTP, %	80	90	95	–2.89%	1.45%	–4.87%	2.44%
P-reduction rate in WWTP, %	90	95	98	–4.79%	2.88%	–4.09%	2.45%
N concentration in wastewater, g/m^3	60	67	130	–2.72%	24.47%	–4.58%	41.21%
P concentration in wastewater, g/m^3	9	9.5	14	–4.79%	43.15%	–4.09%	36.78%
Wastewater treatment cost, €/m^3	0.66	1.32	1.98	54.98%	–54.98%	5.44%	–5.44%
Lifespan, until year	2030	2040	2050	8.77%	–6.22%	–20.47%	14.51%

* Relative change in NPV compared to best guess NPV in the BSAP scenario (approx. –7.5 million euros)
** Relative change in NPV compared to best guess NPV in the BASELINE scenario (approx. 76.2 million euros)

In Monte Carlo sensitivity analysis, all of the variables can get any value between minimum and maximum factors at the same time (see Chapter 2). All variables listed in Table 13, except discount rate and the length of the lifespan, were included in the simulation. The Monte Carlo simulation results are presented in Figure 20 for both the BSAP and BASELINE scenarios with the best guess lifespan (until 2040) and the discount rate (3.5%). In the BASELINE scenario, all NPVs were positive, but in the BSAP scenario, 99% of NPVs were negative. The variance of NPV for the BASELINE scenario is larger than for the BSAP scenario, because the uncertainty related to the amount of nutrient reductions get more weight from higher marginal benefit in BASELINE scenario. The Monte Carlo simulation was performed also for different lifespans and discount rates, and these results are presented in Appendix III. All NPVs in the BASELINE scenario are positive in all analysed lengths of lifespan. The probability that NPV is positive in the BSAP scenario increases slightly if the lifespan is longer or the discount rate smaller, but the NPV remains still negative.

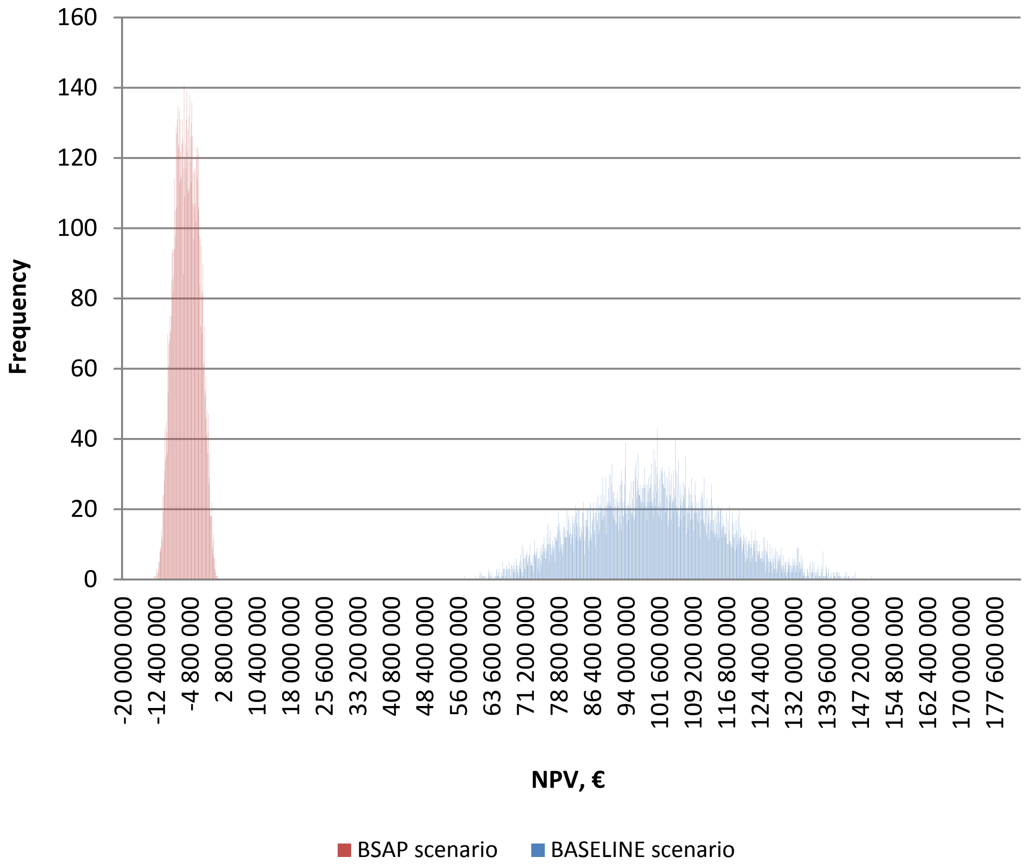


Figure 20. Distribution of NPVs in Monte Carlo sensitivity analysis in case the Port of Helsinki case in the BSAP and BASELINE scenarios (lifespan until 2040).

The development of the total NPV in time calculated with the best guess, worst case and best case values is presented in Figure 21 for both the BSAP and BASELINE scenarios. In the BSAP scenario, the sign of best case NPV turns positive in 2024 but the best guess and worst case NPVs are declining in time and remain negative despite the length of the lifespan. In the BASELINE scenario, all development paths of NPV are increasing and the sign turns positive around 2007–2008 in all cases.

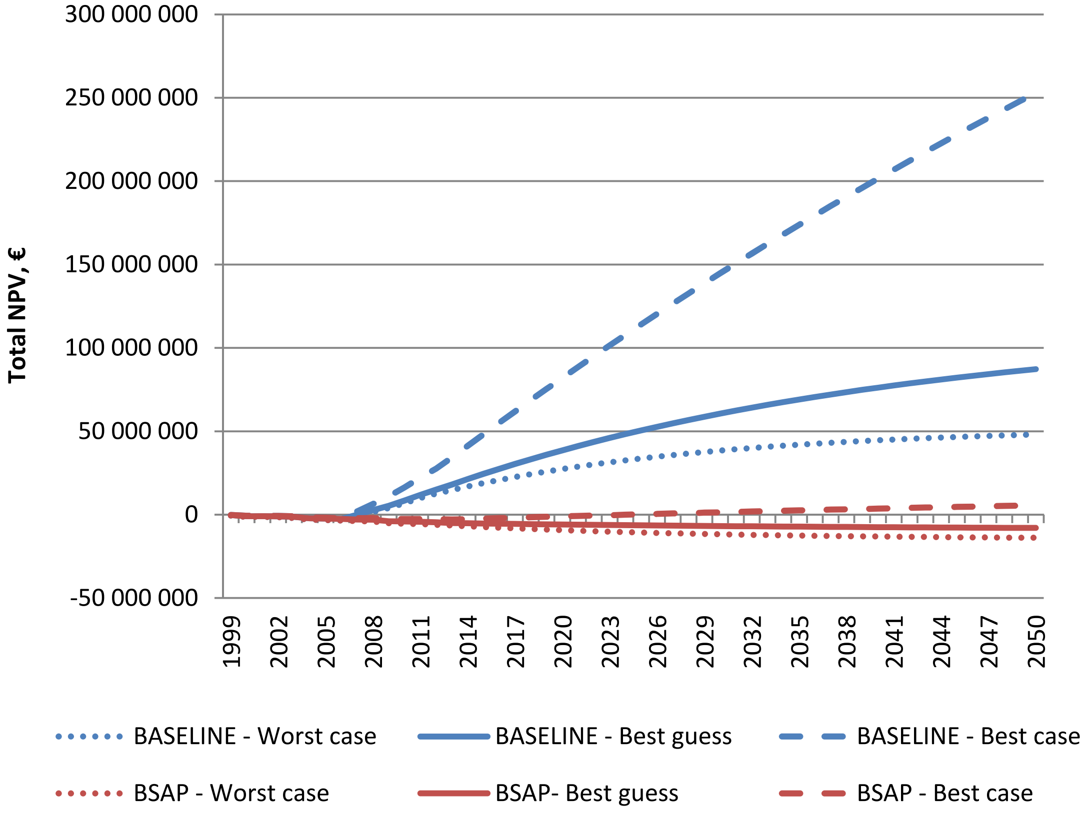


Figure 21. Development of total net present values in the Port of Helsinki case: best guess, minimum (worst case) and maximum (best case) NPVs in the BSAP and BASELINE scenarios

5.5 Discussion

The case study of the Port of Helsinki provided an overview on how large are the costs of implementing port reception facilities (PRF) and how large nutrient reductions can be obtained when passenger ships discharge their sewage water in port instead of dumping in the sea. For example, the estimated nutrient reduction loads to the Baltic Sea were 21,000 kg of nitrogen and 3,000 kg of phosphorus annually. These amounts cover 1% of the Baltic Sea Action Plan (BSAP) for Finland, which is a remarkable amount from a single measure.

The sign of net present value (NPV) of the case measure of the Port of Helsinki depends strictly on how the level of the Baltic Sea protection develops in the future. If actors around the Baltic Sea are not making additional actions to reduce nutrient loads and the state of the sea will remain poor in the future as in the BASELINE scenario, nutrient reductions are very valuable, and the total benefits of receiving sewage from ships clearly exceed the total costs from it (NPV 76.2 M€, B/C-ratio 5.66). If the BSAP targets will be achieved, the total benefits of improved state of the water are higher, but the marginal benefit gained from one reduced unit of nutrient would be lower. Thus, in the BSAP scenario the benefits from measure of the Port of Helsinki would not cover its costs (NPV –7.5 M€, B/C-ratio 0.54). The results can be interpreted so that currently the net benefits are positive since additional actions to reduce nutrient loads are not yet made. If the amount of nutrient load reductions to the Baltic Sea increases to the BSAP targets level, the marginal benefit value will decrease and the net benefits turn negative. If BSAP targets are achieved, cost-efficient ways to implement PRF in ports should be considered.

However, the calculated net benefits in case study of the Port of Helsinki are probably underestimates, because the marginal benefit estimates do not cover the benefits of improved coastal water quality and also other positive impacts were not included in the analysis. The results should be interpreted with caution also because many assumptions were made and some data were lacking. For example, the nutrient reductions were estimated from 2007 although the first pipes were installed already in 1990. Only part of the potential impacts were included in the analysis, and it is possible that some impacts were not identified. Also the numbers of ships visiting the Port of Helsinki and the number of ships discharging sewage in port were not compared, and thus it is hard to say how large is the share of received sewage from all the generated sewage from the passenger ships.

Currently the ports around the Baltic Sea are facing upgrading their PRFs because the dumping of untreated sewage to the sea may be prohibited in the future. The most efficient treatment of sewage would be achieved in an onshore plant, but the total costs of a PRF system for a port may be rather high. Would there be possibilities that PRF could be implemented with higher net benefits? In the Port of Helsinki case, the investment costs and wastewater treatment costs were the largest cost categories in the analysis, and the Baltic Sea benefit the largest benefit category. When building up new quays and installing the port reception facilities there, the investment costs would be lower than installing them to existing quays. Investment costs would be lower also if the WWTP is very close to the port and a shorter sewage pipe would be needed. The eutrophication reduction benefit would be higher if the amounts of received wastewater would be higher, and ships should be encouraged to discharge their sewage in the ports with a no special fee (NSF) system. Also the cost-efficiency of wastewater treatment should be on a high level.

Meanwhile the ships consider whether to invest in a treatment plant on the ship or not. The countries around the Baltic Sea may apply the NSF system in different ways, and achieving a common system should be discussed more, for example about what characteristics of sewage are included in NSF. NSF should be applied in a way that provides no incentive for ships to discharge their sewage to the sea, or treat the sewage on ship. (Clean Baltic Sea Shipping, 2013, pp. 75-76.) What would be the optimal level of indirect fee to be charged from ships in order to encourage ships to prefer discharging the sewage at ports and to cover wastewater treatment costs for port should also be studied.

Photo: Eila Palojärvi, City of Lahti

Natural stormwater management

Stormwater management is becoming more and more important in urban environments. As perception increases and extreme weather conditions become more frequent in the future due to climate change, amounts of stormwater (e.g. rain water and melted water) from impermeable surfaces increase. It may cause flooding and on an area of combined sewerage system sewage overflows. In urban environments, the stormwater can leach solid matter, nutrients, hazardous substances and trash from roads and other unclean surfaces and carry them to water systems in which these may cause eutrophication and harm ecosystems. Natural stormwater management methods aim to take into account both quality and quantity of stormwater: it collects the stormwater, delays flow rates and purifies the unclean water. They can also provide recreational values for citizens and increase biodiversity in urban nature. Examples of natural stormwater management methods are wetlands, biofiltration swales, creeks, ponds and dams, to mention a few. A case study of stormwater management comes from Lahti, where a wetland was constructed couple of years ago to manage the stormwaters of a residential area.

6 Case: constructed urban wetland in Lahti, Finland

During 2008–2011, a large stormwater wetland was built up in a new urban habitat area in Karisto, Lahti to gather the stormwater from the area into an open system, to retain and purify the water before flowing into Lake Kymijärvi and to provide recreational benefits for the local people. The wetland of Kivipuro consists of a large sedimentation pond and a wetland area, in which a meandering creek collects stormwater from the habitat area. This wetland represents an example of the natural stormwater solutions that can be applied in urban planning.

6.1 Background

The City of Lahti is located inland approximately 100 kilometres north of the City of Helsinki and it has approximately 100,000 citizens. Karisto is a relatively new habitat area of Lahti situated on the coast of Lake Kymijärvi, east of Lahti city centre. Lahti Regional Environmental Services took part in the Baltic Sea Challenge in 2008 and stormwater management actions were one of the themes in their Baltic Sea Challenge Action Plan (City of Lahti, 2008).

Karisto was the first residential area in Lahti where natural stormwater management was applied in urban planning. The motives for natural storm water management in Karisto were adaption to climate change, reducing eutrophication of Lake Kymijärvi, providing recreational opportunities for the residents in the area and increasing biodiversity. Lahti is also an important area concerning ground water generation, and stormwater is regarded as an important resource for it.

The wetland of Kivipuro consists of a sedimentation pond and a wetland area which together retain and purify the water before it flows into Lake Kymijärvi. The wetland can be seen in Picture 3. Two meandering creeks collect the storm waters from the residential area located south of the wetland. Water deepness is varying within this wetland area, to sediment the solid matter and to retain the water flowing for purification, as well as to provide habitat for various plant and animal species and increase biodiversity. (City of Lahti & Jaakko Pöyry Infra, 2005; Lahti Region Environmental Services & Pöyry, 2006.) The wetland area is also utilised in pedagogical purposes by the local kindergarten and school, and to increase citizens' knowledge on natural stormwater management (Picture 4).

Picture 3. Air photo from Karisto, Lahti (City of Lahti): the stormwater management system of Kivipuro is located below right, and its catchment area is located south of the wetland.

Picture 4. Info board of natural stormwater management located next to the Kivipuro wetland (Photo by Taru Hämäläinen, 2014)

6.2 Identification of the impacts

In general, natural storm water management methods prevent problems related to the quantity and quality of stormwater and can provide recreational and ecological benefits (Table 14). There is potential for several cost savings that natural stormwater management can provide: for example, prevention of stormwater floods and overflows from combined drainage system decreases flood damages costs. Cost savings come also from avoided construction of drainage systems and maintenance work for dwells. Also the need for snow transportation decreases when the melting water of snow is managed on the initial site. If stormwater was initially led to a combined sewerage system and treated in a wastewater treatment plant, shifting to natural stormwater management reduces also costs of wastewater treatment, because it reduces the amount of wastewater to purify and the risk for process failures in sewage pumping stations and plants. On the other hand, natural stormwater management is not cost-free: an open drainage system for stormwater brings costs from construction and maintenance and it increases land requirement both in private and public areas. (City of Vantaa, 2009, p. 29.; Lahti Region Environmental Services, 2010, p. 19 & 35)

Natural stormwater management methods, e.g. wetlands and meandering creeks, can bring greenery, aesthetics and biodiversity to an urban environment and thus provide recreational benefits for people. Also the improved state of local water systems provide improved opportunities for recreational activities, when stormwater is purified and emissions ending up in water systems is avoided. Green infrastructure in urban environments can also improve air quality. If combined sewerage is applied in the area, a shift to natural stormwater management decreases overflows in the sewerage network and pump stations and thus decreases health risks related to sewage.

In addition, natural stormwater management provides ecological benefits. Natural stormwater management can increase biodiversity by providing habitats for natural vegetation and wild animals, like wetland birds. In addition to biodiversity and improved state of local water systems and their ecosystems, natural stormwater management improves hydrological balance: retention of stormwater prevents the groundwater level from falling as well as environment and vegetation drying in constructed areas.

Table 14. Potential positive and negative impacts of natural stormwater systems in general. In the case of the Kivipuro wetland, impacts that were included in the cost-benefit analysis are marked with a grey background.

Positive impacts	**Negative impacts**
Avoided flood damages	Planning and construction costs
Avoided costs related to problems if sewerage system is combined: overflow floods and problems in pump stations and wastewater treatment plant due to high flow rates	Maintenance costs
Avoided health risk related to overflows of combined sewerage system	Opportunity cost of required land

The table continues at the next page.

Table 14 Continues

Positive impacts	Negative impacts
Avoided construction and maintenance of stormwater dwells and pipes	
Reduced transportation of snow	
Reduced erosion	
Recreational benefits	
Improved air quality	
Improved state of water systems due to reduced emissions of solid matter and nutrients that cause eutrophication	
Improved state of ecosystems due to reduced emissions of harmful substances and trash	
Increased biodiversity	
Improved hydrological balance	

Possible impacts related to the Kivipuro wetland are similar than in Table 14 above. As was mentioned previously, stormwater management in Karisto aims to provide recreational values, purify the stormwater, which reduces eutrophication, increase biodiversity and promote ground water generation. The wetlands and open drainage system may provide cost savings from avoided installation of storm water dwells and pipes. The opportunity cost of land is also a potential cost, because open drainage systems require a bit more land than pipes. However, on the site where wetland was built up the ground is very soft and likely it would not be utilised in residential construction.

Because the new residential area of Karisto was planned to be dense, there was no space for snow piles and reduced transportation of snow was not relevant in this case. In addition, the stormwater system was built up in a new area, and impacts related to combined sewerage system were not relevant either.

6.3 Material and model

Identifying the potential impacts showed that the wetland in Karisto can provide several benefits, including ecological benefits that are very challenging to measure or monetise. The cost-benefit analysis of the Kivipuro wetland in Karisto could cover only part of the potential impacts. In addition to investment and maintenance costs of wetland, there was data available to measure recreational values for residents and benefits from reduction of nutrient emissions. Costs and cost savings related to constructing open drainage system instead of pipes and dwells were not included because this kind of assessment data was not available.

Although the wetland is constructed and maintained by humans, it is also a natural ecosystem and would last also independent of human actions. But how long there will be residents accessing the recreational benefits is another question. Because Karisto is a relatively new area, it was assumed that the wetland will stand as it is now for a time period of 50 years.

Investment and maintenance costs

The total cost of construction of the Kivipuro wetland during 2008–2011 was approximately 360,000 euros and planning 20,000 euros. The construction included earth construction work for two sedimentation ponds, construction of the ditches and footpaths and planting the wetland vegetation. The maintenance costs were 5,000 euros and 8,000 euros in 2012 and 2013, respectively. Annual maintenance depends on e.g. the growth of the vegetation and erosion and sedimentation of solid matter. The ditches had to be cleared every 1–2 years, and the large ponds every 5–10 years. The cost of removing sludge from the ponds was assumed to be 1 euro per m^2.

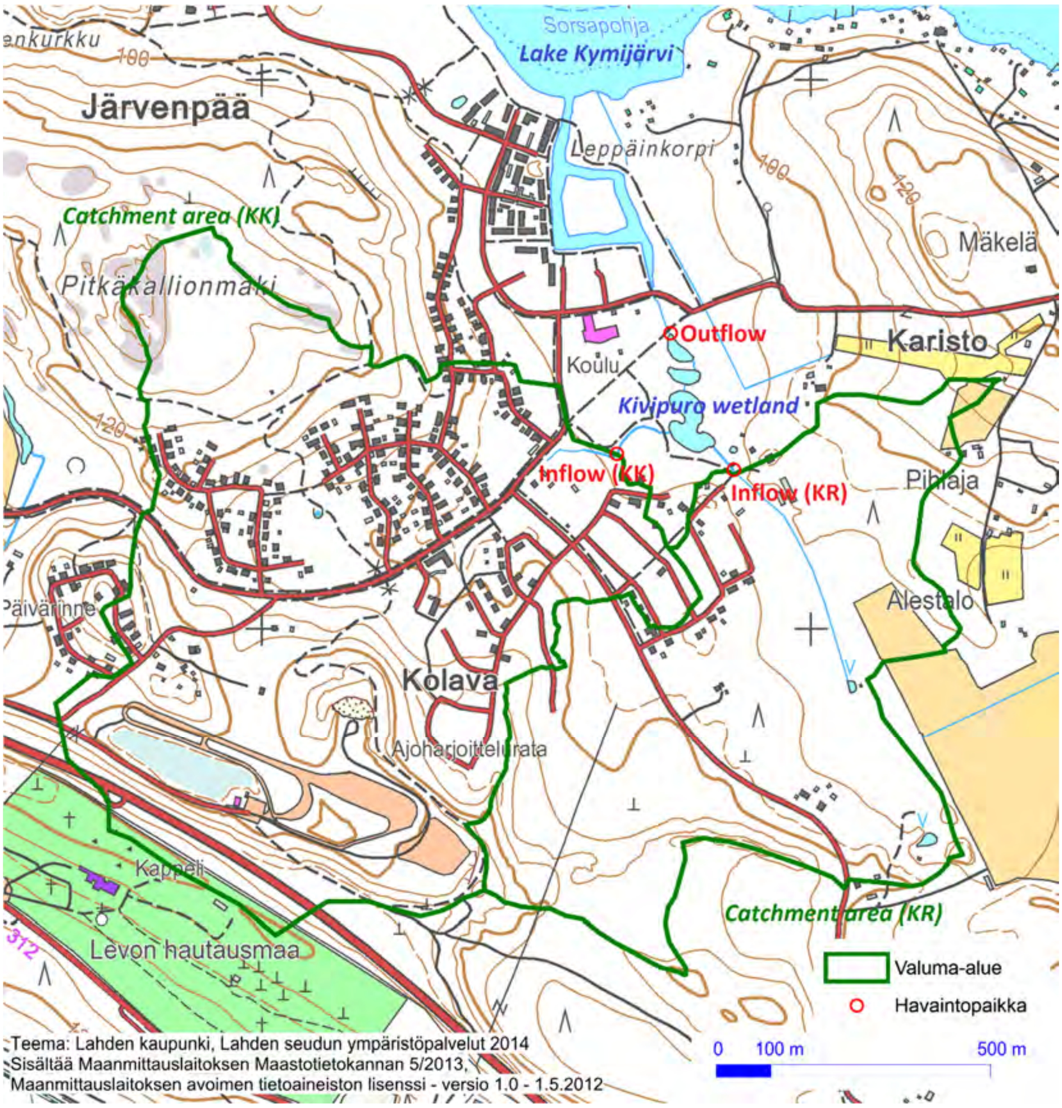
Nutrient load reductions

To calculate the total nutrient load reduction for every year, data for stormwater quality and quantity was needed. In the case of Lahti there are eight sets of stormwater samples available which have been taken in spring and/or autumn during the years 2009–2013. Each set includes samples of in and outflowing water. The available data set includes total nitrogen and total phosphorus concentrations (µg/l) as well as flow rate (l/s). Data are presented in Table 15. Stormwater enters to the Kivipuro wetland from two creeks at Karistonkatu side and Kivelänraitti side (Picture 5).

Table 15. Stormwater nitrogen and phosphorus concentrations and flow rates of Kivipuro wetland (data from Lahti Region Environmental Services)

	Inflow from Karistonkatu side			Inflow from Kivelänraitti side			Outflow		
Date	**Total N µg/l**	**Total P µg/l**	**Flow rate l/s**	**Total N µg/l**	**Total P µg/l**	**Flow rate l/s**	**Total N µg/l**	**Total P µg/l**	**Flow rate l/s**
6.10.2009	1400	23	42.5	1200	180	8	660	47	40
15.4.2010	2100	58	0	1300	70	0	1500	57	44
9.11.2010*							2100	35	4
19.4.2011*	3100	49		1200	68	4.6	1800	68	72
22.9.2011*	3100	23	0	1600	600		520	29	4.3
26.4.2012	1500	53	33.3	1300	87	5.4	1300	54	42
17.10.2012	1800	45	9.04	1500	140	2.55	1400	62	40
23.4.2013	1700	27	0	1700	87	22.5	1600	70	8.4

*On 9.11.2010 there is data only for the outflow of Kivipuro wetland because the rest of the streams were frozen. Also many of the flow rate values are zero, and for an unknown reason also four flow rate values are missing.



Picture 5. Catchment areas (green line) and sample points (red dots) of Kivipuro wetland. Inflow from Karistonkatu side is abbreviated (KK) and from Kivelänraitti side (KR) (modified from map provided by Mira Kuparinen & Lahti Region Environmental Services, 2014).

There is a large variation in the nutrient concentrations and flow rates of stormwater, as seen in the results (Table 15). The measures may be affected by varying weather conditions and street construction in the catchment area. Outflow rates may be affected by a small weir, which is used to control the water level in the wetland. In addition, the phosphorus concentration measure taken from inflowing water at Kivelänraitti side on 22.9.2011 is exceptionally high, and it looks like an error. The data can provide only rough estimates for the nutrient flows, because the number of samples are low, variation is high and the samples are taken in spring and autumn. More reliable nutrient flow estimation would require continuous measuring of volumes and nutrient concentrations in water, also measures in summer during the growth season, when circumstances for absorbing nutrients by plants are the best.

However, in this case there was no alternative data for nutrient concentrations, values from the sample data were regarded as best guess. Flow rates were calculated from a model. The nutrient load estimation required some assumptions.

Firstly, it was assumed that the spring samples represent melting snow and rainwater, the precipitation of the November–April period, and the autumn samples represent rainwater of the May–October period. It was also assumed that the wetland system is closed: the inflowing water volume equals outflowing volume and the inflowing nutrient load equals the sum of outflowing nutrient load and nutrients bind by wetland. Because the water may remain in the wetland for days or weeks, the measures from inflowing and outflowing water at the same date are not directly comparable. Thus, the average concentrations of nutrients in inflows at Karistonkatu side and Kivelänraitti side and outflow were used. To calculate the water volume flowing through the wetland system, equation 1.4 was used:

$$Q = C * i * A, \qquad (1.4)$$

where Q is the stormwater volume (m^3 per time unit), C is a runoff factor, that depends of the share of impermeable surfaces in the area, i is the intensity of precipitation (m per time unit) and A is the size of catchment area (m^2) (Jutila & Kesäniemi, 2006, p. 13). Runoff factor is for residential area on flat terrain between 0.05–0.15 (Melanen et al., 1982 according to Jutila & Kesäniemi, 2006, p. 13). The water volume was calculated for every half year period by using average perception in May–October and November–April periods from 2000–2014 perception data (from Lahti Region Environmental Services). The catchment area of the Karistonkatu side of Kivipuro wetland is 84.5 ha and the Kivelänraitti side 53.5 ha. Estimated water volume flowing through the wetland is likely an underestimate, because groundwater exudes to the creeks and increases the water volume. However, the volume of exuded groundwater to the creeks has not been assessed. The total nutrient load for every half year period was estimated then by multiplying nutrient concentrations and stormwater volumes.

When the nutrient load is estimated, the second step is to assess which part remains in Lake Kymijärvi and which part ends up in the Baltic Sea. Lake Kymijärvi is located inland, and the water collected from its catchment area flows through several lakes to the river Kymijoki, which discharges to the Gulf of Finland. The share of nutrients that end up in the Baltic Sea was calculated by estimates by Huttunen, Vehviläinen, and Huttunen (2013) who have estimated the transportation of nutrients from lake catchment areas of Finland to the Baltic Sea by using the WSFS-Vemala-model. According to their estimates, 12.75% of phosphorus and 45.19% of nitrogen ends up in the Baltic Sea from the lake Kymijärvi catchment area (Huttunen et al., 2013, p. 89). The benefits of nutrient load reduction into the Baltic Sea were calculated in the way that was explained in Chapter 2.

The rest of the nutrients are assumed to remain in lake Kymijärvi, other lakes and river Kymijoki, but the question is, how large are the benefits gained from nutrient load reduction to these water systems? Another question is, for example in the case of Kymijärvi, how large nutrient reduction should be made to have an impact on the state of this water system? Currently the ecological state of lake Kymijärvi is satisfactory, and to achieve a good ecological status, the phosphorus concentration of the lake should decrease by 35% and nitrogen concentration by 20% (Häme ELY Centre, 2010, p. 93 & 100), but there is no exact information on how much the load should be reduced to improve the state of lake. Without this kind of data it was not possible to estimate how large an impact the nutrient reduction gained from Kivipuro wetland has on the state of Lake Kymijärvi – or the next water courses.

To calculate annual benefits of reduced nutrient load into Lake Kymijärvi there should also be estimates for willingness to pay for improved state of water. Willingness to pay (WTP) estimates for some lakes in Finland does exist, for example it is 12–34 €/y per household for neighbouring lake Vesijärvi (Lehtoranta, 2013). Although there is no benefit valuation study made for Lake Kymijärvi, a benefit transfer method could be applied, where existing WTP-value for improved state of a lake is transferred to represent the WTP for improving the state of another lake. To use the benefit transfer method, there should be information about the characters of both lakes and the population living in the surrounding areas, and how large nutrient load reduction is needed to achieve the certain state. In the case of Kymijärvi, the last mentioned condition is restrictive, because we are lacking this data. Thus the benefits from a single measure (as a stormwater wetland is) to improve the state of lake Kymijärvi for people who have access to use ecosystem services provided by lake Kymijärvi was not possible to estimate in this study. The benefits from the improved state of other lakes or river Kymijoki were not possible to estimate either.

Benefits from wetland ecosystem services

The benefit transfer method could be applied to also estimate the benefit of the wetland ecosystem services. As was opened above, existing willingness to pay estimates for wetland services could be applied if the wetlands are comparable in scale, wetland functions, and socio-economic background of citizens living nearby the wetland. There is currently under construction a wetland park in Nummela, a town located about 40 kilometres from Helsinki to the north-west. The wetland park project is a part of Life+ Urban Oases project (University of Helsinki, 2014). The wetland has similarities with the Kivipuro wetland: Nummela wetland will handle the storm waters collected from the residential area, purify them before entering Lake Enäjärvi, and provide recreational and pedagogical services for residents. There was conducted a small contingent valuation (CV) study of resident’s WTP for environmental services provided by Nummela wetland as a course assignment in the University of Helsinki. According to the results, 70% of 61 respondents were WTP for recreational opportunities, median annual WTP was 20.00 €/househould and mean WTP 30.90 €/household, and mentioned activities related to the wetland were e.g. walking and jogging, spending time with children and enjoying nature (Rekola, 2014). Because the CV study was conducted as a student assignment, the data or analyses beyond the results were not available and thus there is uncertainty related to the results and the comparability of the populations. Although the use of benefit transfer method would require more detailed data, the median WTP (20 €/y per household) is taken as a best guess of WTP for recreational opportunities of similar wetlands.

The total willingness to pay for Kivipuro wetland was calculated by multiplying the median WTP by number of those households who probably gain benefit from the wetland. Because the Kivipuro wetland is a part of a park area located in the residential area, it was assumed that all residents in Karisto are able to gain benefit from the wetland. In 2013, there were about 1,600 residents living in the Karisto area (City of Lahti, 2014). The number of residents in Karisto has been predicted to grow to 3,700–3,800 residents in 2025 (Mero, 2013) and to 7,000–10,000 residents in near decades (Ilveskorpi, Päivänen, Murole, Vanhanen, & Airas, 2007). These numbers were used to predict the annual number of citizens and households (Appendix IV): in the analysis it was assumed that the number of residents will grow according to rate 5.0% (range 4.4–5.8% in the sensitivity analysis). The number of households was calculated from the number of residents by using household size information from a resident survey made in Karisto (City of Lahti; Land Use Department, 2009).

6.4 Results

Since many assumptions were made and available data was restricted, the results should be indicated with care, although they give an overview of costs and benefits of stormwater wetland. At first, amounts of nitrogen and phosphorus flowing in and out the Kivipuro wetland was estimated using average nutrient concentrations from existing sample data and quantified amounts of stormwater. According to the estimation, total inflowing amounts were higher than outflowing amounts, so it seems that wetland is able to retain nutrients: annual estimated amount of nitrogen was 61 kg per year (52 kg per summer–autumn period) and phosphorus 2 kg per year (2 kg per summer–autumn period) (Table 16). Estimation indicates that about a third of inflowing nutrients is stored in the wetland. Sample data did not include measurements of solid matter, which could show the sedimented particle phosphorus.

Table 16. Estimated annual amounts of inflowing and outflowing nutrients and retention of the nutrients by the Kivipuro wetland

	Nitrogen, kg/y	**Phosphorus, kg/y**
Inflow, Karistonkatu side (KK)	111	2
Inflow, Kivelänraitti side (KR)	47	4
Outflow	97	4
Amounts of nutrients retained by the wetland	**61**	**2**
Nutrient retention efficiency	38%	33%

These nutrients were assumed to be avoided flowing in Lake Kymijärvi, and further in other lakes, river Kymijärvi and in the Baltic Sea. It was not possible to measure or monetise the impact on local waters, but benefits of nutrient reductions to the Baltic Sea were included as well as recreational benefits of wetland for residents living in Karisto. Figure 22 and Figure 23 show the estimated annual costs and benefits during the assumed lifespan of the wetland in BSAP and BASELINE scenarios. The recreational benefit is the largest benefit category and the investment costs (cut in the figures). In both scenarios, the Baltic Sea benefits are rather small.

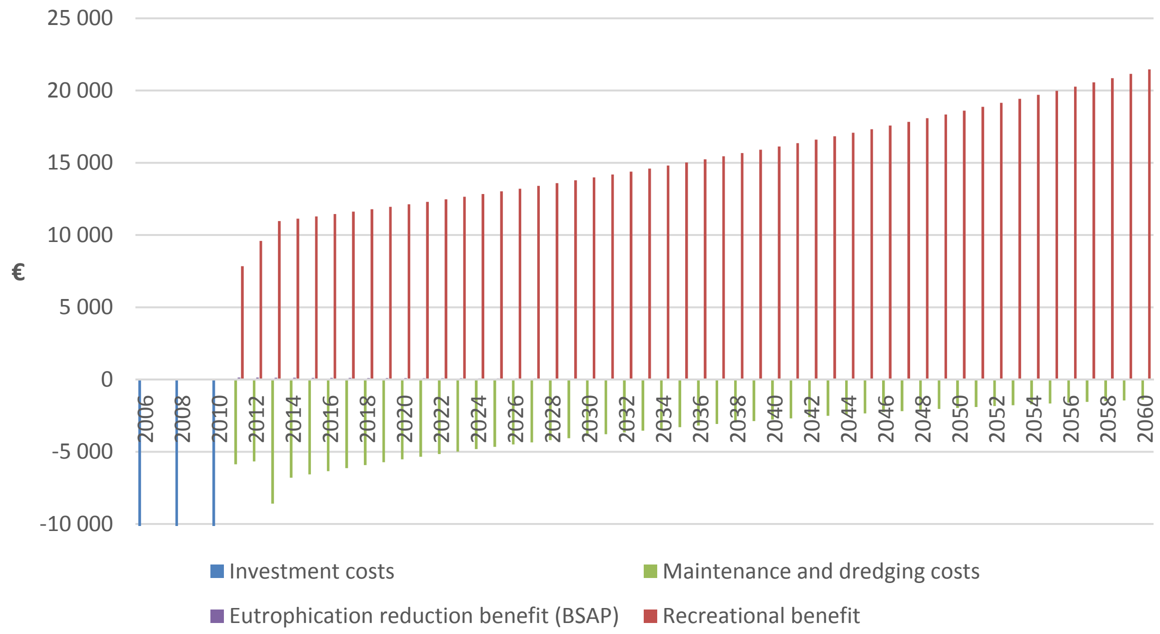


Figure 22. Annual costs and benefits in present values in the Kivipuro wetland case in the BSAP scenario. The present value of investment costs is about 0.5 million euros. Investment cost pillars are cut to illustrate the scale of other pillars.

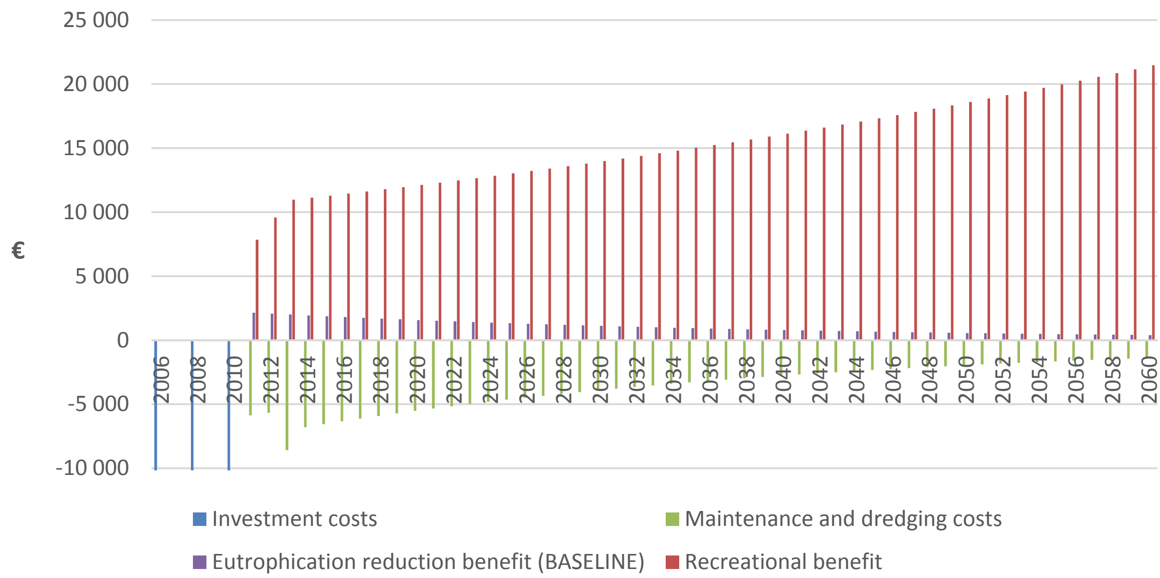


Figure 23. Annual costs and benefits in present values in the Kivipuro wetland case in the BASELINE scenario. The present value of investment costs is about 0.5 million euros. Investment cost pillars are cut to illustrate the scale of other pillars.

The net present value of Kivipuro wetland calculated with best guess values were 83,000 € in the BSAP scenario and 132,000 € in the BASELINE scenario. B/C-ratios were respectively 1.12 and 1.19. Figure 24 shows how the total net present value is divided in the assumed lifespan. The annual net present values, sums of annual costs and benefits, are first negative due to large investment costs, but after construction they are positive because the wetland provides recreational opportunities, which are valued higher than the maintenance costs. The annual net present value grows due to the assumption that the number of households benefiting from the wetland will increase in future.

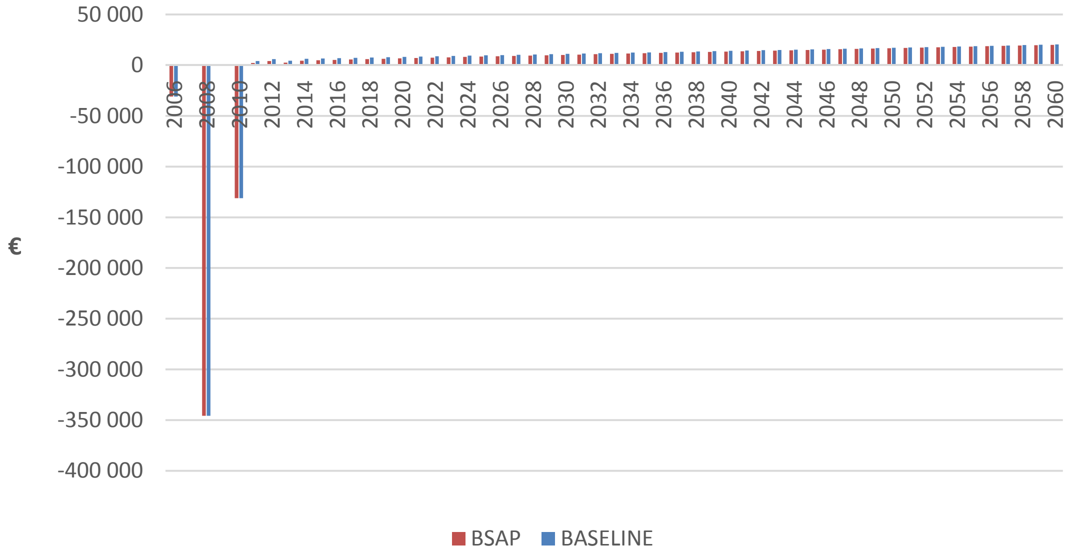


Figure 24. Annual net present values in the Kivipuro wetland case in the BSAP and BASELINE scenarios calculated with the best guess values

In partial sensitivity analysis, the impact of each variable on the NPV were studied by changing the value of one variable at a time. The minimum and maximum values for nutrient concentrations and precipitation were sums or differences of average values and standard deviations. In addition, it was guessed that dredging costs could be 30% lower or higher than the best guess, and WTP of wetland be 50% lower or higher than median WTP per household. According to the results (Table 17), chosen values of the discount rate, the growth rate of number of residents in Karisto, the WTP estimate for wetland and the assumed lifespan have significant impact on the best guess NPV and turn the sign of the NPV to negative. The scale is large due to the long lifespan of wetland. Other variables had relatively small impacts, especially in the BSAP scenario.

Table 17. Partial sensitivity analysis of the Kivipuro wetland case: variables and their minimum, maximum and best guess values and their relative impact on NPVs in the BSAP and BASELINE scenarios

Variable	Minimum value	Best guess value	Maximum value	BSAP scenario		BASELINE scenario	
				Change (Min value)*	Change (Max value)*	Change (Min value)**	Change (Max value)**
Discount rate	0.01	0.035	0.06	832.12%	–412.65%	542.83%	–270.79%
Maintenance costs, €	–5000	–6500	–8000	42.94%	–42.94%	27.03%	–27.14%
Dredging cost, €	–1540	–2200	–2860	2.86%	–2.86%	1.80%	–1.81%
Dredging frequency, in every *n* year	5	7.5	10	–4.77%	2.38%	–3.00%	1.51%
Precipitation W, mm/half year	172	238	304	–0.12%	0.12%	–1.38%	1.39%
Precipitation S, mm/half year	295	386	476	–0.83%	0.83%	–8.10%	8.14%
KK-W Inflowing N concentration, kg/m^3	0.001388	0.002100	0.002812	–0.79%	0.79%	–8.48%	8.51%
KK-S Inflowing N concentration, kg/m^3	0.001211	0.002100	0.002989	–1.60%	1.60%	–17.15%	17.22%
KR-W Inflowing N concentration, kg/m^3	0.001153	0.001375	0.001597	–0.16%	0.16%	–1.67%	1.68%
KR-S Inflowing N concentration, kg/m^3	0.001225	0.001433	0.001641	–0.24%	0.24%	–2.54%	2.55%
W Outflowing N concentration, kg/m^3	0.001342	0.001550	0.001758	0.38%	–0.38%	4.05%	–4.07%
S Outflowing N concentration, kg/m^3	0.000387	0.000860	0.001333	1.39%	–1.39%	14.90%	–14.96%
KK-W Inflowing P concentration, kg/m^3	0.000033	0.000047	0.000060	–0.10%	0.10%	–0.54%	0.55%
KK-S Inflowing P concentration, kg/m^3	0.000018	0.000030	0.000043	–0.15%	0.15%	–0.82%	0.82%
KR-W Inflowing P concentration, kg/m^3	0.000068	0.000078	0.000088	–0.05%	0.05%	–0.26%	0.26%
KR-S Inflowing P concentration, kg/m^3	0.000132	0.000160	0.000188	–0.21%	0.21%	–1.15%	1.16%
W Outflowing P concentration, kg/m^3	0.000054	0.000062	0.000070	0.09%	–0.09%	0.52%	–0.52%
S Outflowing P concentration, kg/m^3	0.000029	0.000046	0.000063	0.32%	–0.32%	1.74%	–1.75%
Runoff factor	0.05	0.1	0.15	–2.00%	2.00%	–19.79%	19.87%
Annual growth of number of households	1.044	1.050	1.058	–125.24%	205.97%	–78.82%	130.16%
WTP for wetland per households, €/y	10	20	30	–464.16%	464.16%	–292.13%	293.32%
Lifespan, until year	2050	2060	2070	–223.91%	266.91%		

* Relative change in NPV compared to best guess NPV in BSAP scenario (approx. 83,000 euros)
** Relative change in NPV compared to best guess NPV in BASELINE scenario (approx. 132,000 euros)

In Monte Carlo simulation uncertainty related to all variables as in partial sensitivity analysis except discount rate and lifespan are taken into account at the same time. As a result, Monte Carlo distribution is similarly shaped in both scenarios and the probability estimate that NPV is positive is 63% in the BSAP scenario and 69% in the BASELINE scenario (Figure 25). The higher the discount rate and the shorter the lifespan, the smaller the probability of positive NPV is (Appendix IV). Monte Carlo analysis indicates that NPV is more likely positive than negative, but the wetland requires a long life span.

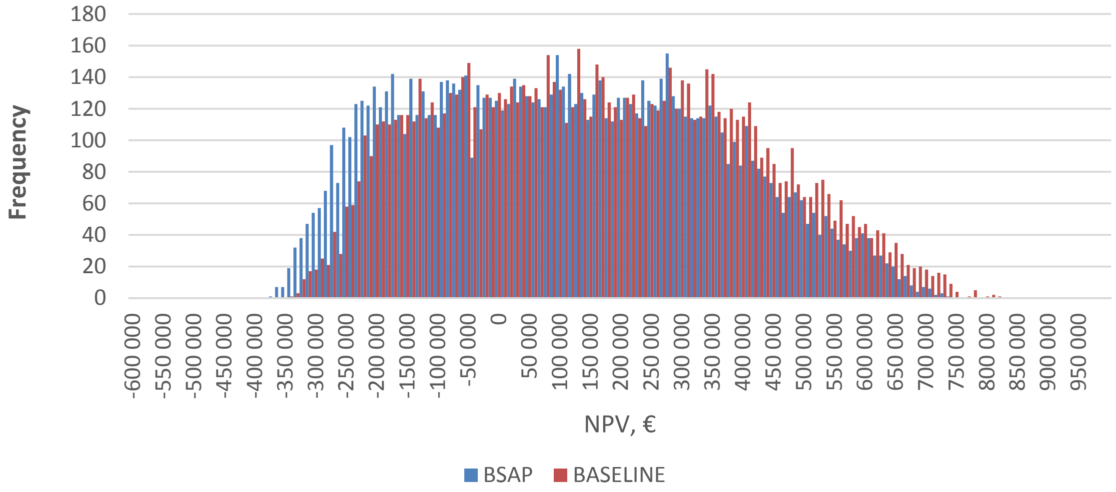


Figure 25. Distribution of NPVs in Monte Carlo sensitivity analysis in the Kivipuro wetland case in the BSAP and BASELINE scenarios (with discount rate 3.5% and lifespan until 2060)

When looking at the development of NPV in time, in all scenarios (worst case, best guess and best case; BSAP and BASELINE) the NPV is increasing in time (Figure 26). However, in worst case scenarios the NPV remains negative until 2070. In best guess scenarios the wetland pays itself back in 2050–2060, and in best case scenario already in 2030–2040. The worst and best case scenarios are calculated with extreme values (see partial sensitivity analysis) and are thus not likely, but show the boundaries in which the NPV probably is.

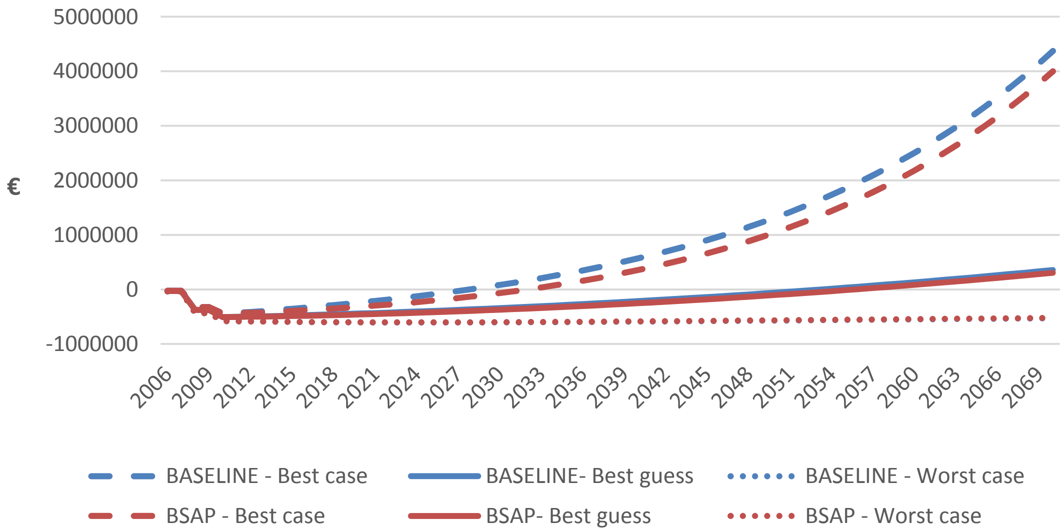


Figure 26. Development of total net present values in the Kivipuro wetland case: best guess, worst case (minimum) and best case (maximum) NPVs in the BSAP and BASELINE scenarios.

6.5 Discussion

The identification of the impacts showed that a wetland as a natural stormwater management method can provide several benefits which can be economical, social or ecological. These benefits are not accessed if stormwater management is realised with a conventional underground pipe system. Another important remark was that local water protection actions implemented inland may have very wide impact. In the case of the Kymijärvi catchment area, the water flows through several lakes to the river Kymijoki, which discharges to the Baltic Sea. If the state of all these water systems will improve, there is a remarkable number of citizens using these water systems who will benefit from healthier local waters. On the other hand, the stormwater wetland provides ecosystem services that have very local impact, and mainly the people living in the area are able to gain benefits from them.

According to the cost-benefit analysis (CBA) results, the overall benefits gained from the Kivipuro stormwater wetland seemed to exceed the overall costs, but it depends on how much the residents value the wetland and how the Karisto area will develop in the future. However, the CBA could cover only a part of the potential impacts and measuring these impacts was rather challenging. The results should be interpreted with caution, because a lot of assumptions were made and the available data was restricted. For example, because the sample data did not include measures taken during the best growth season or from so-called first flush events, the amount of nutrient retained by the wetland may be higher than estimated. In addition, the benefit from reduced nutrient loads was able to be monetised only for the Baltic Sea part. Costs savings from an underground stormwater network which could be remarkable were not included either.

Although the CBA case study of Kivipuro stormwater wetland provided only rough estimates, it gave an overview of what should be take into account when considering stormwater management and water protection. Because the natural stormwater management is a long-term investment, it will also provide benefits long in the future. The long lifespan also makes performing a CBA of natural stormwater management challenging, because the impacts should be estimated and monetised far to the future. In addition, climate change will increase the uncertainty even more. However, the case study taught that more research concerning natural stormwater management and more information of the costs and measured benefits are needed, in order to find the most efficient methods to manage quality and quantity of stormwater. The most important question that remained open was, how large would be the benefits from a natural stormwater management system compared to the conventional, underground pipe system.

Photo: City of Helsinki Media Bank / Kimmo Brandt / Compic-Photos Oy

Agriculture

Agriculture is currently the major source of nutrient load from anthropogenic and diffuse sources to the Baltic Sea. Within agriculture the main sources of nutrient loads are manure from livestock production and chemical fertilisers. Large nutrient reductions are required also in agriculture in order to achieve the Baltic Sea Action Plan (BSAP) targets. (HELCOM, 2011, pp. 89-91.)

Although agricultural activities are usually related to private sector, they can be also related to actors within the public sector, such as municipalities that own agricultural land. Thus also municipalities have opportunities to influence water protection in agriculture. Measures that municipalities can apply to decrease nutrient leaching from fields are, for example, providing advice and guidance in agricultural water protection and encouraging local farmers to apply good practises such as reduced fertilisation, direct sowing, buffer zones, catch crops, crop rotation, grasslands and wetlands (Baltic Deal project, 2012; Launto-Tiuttu et al., 2014; Leppänen et al., 2012). For example, the City of Turku owns agricultural land and leases it to local farmers with the requirement of establishing extra wide buffer zones on fields by the rivers in the area. This will be the next case study.

7 Case: buffer zones by the river, Turku, Finland

The City of Turku owns agricultural land and leases it to local farmers. As a landowner, the city can influence water protection of the local agriculture. The city included in 2005 a special condition of establishing extra wide buffer zones in land lease contracts. Buffer zones are at least 15-metre on average wide vegetated zones established between a field and a water course to reduce the surface runoff of nutrients and soil erosion (Kulmala, 2012; TEHO Plus, 2012). This case differs a lot from other cases in this cost-benefit analysis study, because the role of a private actor, a farmer, is pivotal. As the city is the landowner, its decisions have influence on the farmer's profitability.

7.1 Background

The City of Turku is located in the south-west of Finland. The city has about 180,000 citizens and it is the sixth largest city in Finland. The River Aurajoki flows through the city and discharges to the Archipelago Sea. The City of Turku is one of the largest agricultural landowners in Finland: it owns 2000 ha arable land and leases 1600 ha of it to local farmers.

The City of Turku included the special condition in land lease contracts in 2005. According to this condition, farmers should establish buffer zones on fields by the river Aurajoki or by its tributaries depending on the slope, location and size of the field. The farmers have the possibility to apply for a special agri-environmental subsidy from the EU for the establishment and management of the buffer zones. The motive for the special condition in lease contracts was that the city considered its duty to show a good example as a large landowner and to promote water protection activities in the local agriculture. Agriculture-related water protection work led by the city began already in the mid-90s and it has been promoted and developed further later by the Baltic Sea Challenge initiative made by the Cities of Turku and Helsinki in 2007.

Nowadays there are approximately three kilometres of buffer zones in length by the river Aurajoki and other rivers in the Turku area. The buffer zones are 100 m wide at the widest. In practice, the location and the width of buffer zones are usually decided by the city but sometimes together with the farmer. To get special agri-environmental subsidy rights from the EU, the buffer zone should be established in a place where the risk for nutrient leach and erosion as well as the impact to the local water system are high. In addition, a plan on how to establish and maintain the buffer zone is required for a 5 or 10-year period, and the use of fertilisers and chemical protectants is prohibited in the buffer zone. (Agengy of rural affairs MaVi, 2012.)

The City of Turku introduced two farmers who had suitable fields for this case study. The focus here was put on two case fields, one from each farmer. One of the fields is located by the river Aurajoki, about 10 kilometres from the Baltic Sea coastline. It has been a rental field for the present farmer since 2000 and the 85-metre-wide buffer zone was established in 2006. Already before the establishment, a narrower 15–20 m wide buffer zone had been implemented. The wider buffer zone was established by sowing a seed mix of timothy grass, meadow fescue and red clover. The grass has been harvested by the cattle keeper 1–2 times per year for silaging and cut when needed. On the field area above the zone there has been cultivated wheat and rape. The field can be seen in Picture 6.

Picture 6. The case field by the river Aurajoki (modified from City of Turku The Real Estate and Measurement Authority, 2014)

The other field is located about 10 kilometres from the coastline by the narrower river Vähäjoki, which discharges to the river Aurajoki close to the field. The field by the river Vähäjoki has been under barley, wheat and rape cultivation during recent years. The 10-metre-wide buffer zone was established in spring 2013 by sowing grass seed mix and rolling. The seeds did not germinate properly due to drought, so new sowing was required in spring 2014. Annual maintenance will consist of cutting the vegetation when needed. The field can be seen in Picture 7.

Picture 7. The case field by the river Vähäjoki (modified from City of Turku The Real Estate and Measurement Authority, 2014)

7.2 Identification of the impacts

Establishing buffer zones has many impacts on the farmer's profitability but it provides also environmental benefits for society (Table 18). When arable land is turned into a buffer zone, it is excluded from the cultivation area. This may cause opportunity costs from loss in total crop income and total cultivation subsidies, but on the other hand it also reduces the total cost of cultivation. The buffer zone produces additional costs from the establishment and the annual maintenance. However, the farmer has an opportunity to get a special subsidy from the EU to cover additional and opportunity costs caused by the buffer zones. If the rent price per hectare of the buffer area is lower than the cultivation area, then the buffer zone reduces the total rent costs as well, but for the landowner, the city, this means a loss of rent income. All of these impacts were included in the analysis. In addition, a clear benefit for the farmer is also that the buffer zone may facilitate and enhance the cultivation, for example, because the buffer zone provides more space for large machines and protects the crop from spreading weed (Ylinen, 2012).

Table 18. Potential positive and negative impacts related to buffer zones on rental fields. Private impacts refer to the farmer and public impacts to the city and society. The ones marked with a grey background were included in the analysis.

	Positive impacts	**Negative impacts**
Private	Right to apply special agri-environmental subsidy from the EU	Establishment and maintenance costs of buffer zone
	Reduced cultivation costs	Reduced crop incomes
	Reduced rent costs	
	Income from grass	
	Buffer zone facilitates and enhances cultivation (e.g. more space for large machines)	
Public	Reduced erosion and nutrient runoff	Reduced rent incomes
	Reduced emissions from protectants	
	Increased biodiversity	
	Recreational benefits if urban agriculture	

The buffer zones provide also many environmental benefits. The main function of the buffer zone is to reduce erosion and surface runoff of nutrients from the field to the water system, but at the same time buffer zones prevent herbicides and pesticides leaching from the field. If a special agri-environmental subsidy is received, it is also prohibited to use fertilisers or protectants on the buffer zone area, which also reduces the nutrient load and protectant emissions to the water system. The buffer zone may also increase biodiversity, if it is vegetated by meadow plants for instance. The decrease in nutrient reduction was estimated in the analysis, but other environmental impacts were not included due to lack of data.

7.3 Material and model

The impacts from establishing buffer zones were found by comparing situations with and without the buffer zones. Below is explained in more detail how impacts on farmer's revenues and the nutrient retention of buffer zones were estimated.

In Turku, lease contracts for fields are usually made for 5–6 years at a time. Always when the lease contract ends the need for a buffer zone is checked and it is assessed how the land use will continue. For this reason it is difficult to predict if the cultivation will continue in case fields and if the buffer zones will remain in the land area in the next lease period. Thus, it is assumed that the lifespan in this case begins from the moment when the buffer zones were established and ends at that moment when the present lease contract expires. In the Aurajoki case, the present lease contract will expire in 2015, and in the Vähäjoki case, in 2017.

Farmers' costs and benefits

In this case study two fields were studied. In the case field by the river Aurajoki (Aurajoki case) the total field area is 27.82 ha and the buffer zone area is 7.0 ha. Because in this case field the narrower buffer zone did exist before establishing the wider buffer zone, this 3.0 ha land area was excluded from the analysis, and thus the analysed areas were 24.82 ha and 4.0 ha respectively. In the case field by the river Vähäjoki (Vähäjoki case) the total area is 8.81 ha and the share of the buffer zone 1.66 ha. The annual income and cost values are listed in the following Table 19:

Table 19. Values that are used in the analysis of two fields with buffer zones (in 2014 values)

	Case field by the river Aurajoki	Case field by the river Vähäjoki
Cultivation income, €/ha/y	770	636
Cultivation subsidy, €/ha/y	564	525
Cultivation costs, €/ha/y	515	220
Rent of cultivated land, €/ha/y	420	320
Buffer zone subsidy, €/ha/y	765	585
Buffer zone establishment, €/ha/y		200
Buffer zone maintenance costs, €/ha/y	155	200
Rent of buffer zone land, €/ha/y	290	320

In Table 19, the values (in 2014 values) for the Aurajoki case are average annual values based on values from the years 2006–2013 and the values for the Vähäjoki case are based on values from the year 2013. In the Aurajoki case, the establishment costs are included in the maintenance costs. In the Vähäjoki case, the farmer did not have the possibility to apply for the EU subsidy for buffer zone for the first year, 2013, because the establishing was done after the application time. Beginning from year 2014 it was estimated that the annual amount of subsidy is 585 euros per hectare of buffer zone. The buffer zone was actually established in this case from the farmer's own initiative, but the city would support the action by lowering the buffer zone rent if the farmer applies for the special agri-environmental subsidy. In the analysis, the rent of the buffer zone was assumed to remain at the same level, because there were no estimates on how much the rent would be lowered.

Nutrient load reductions

The annual reductions in nutrient runoff in the case of the buffer zones were estimated by using runoff functions from an article written by Lankoski, Ollikainen, and Uusitalo (2006, pp. 202‑204). Runoffs were calculated for nitrogen (N), particle phosphorus (PP) and dissolved reactive phosphorus (DRP). The runoffs depend on the width of the buffer zone and fertiliser use, as well as nutrient specific factors, like soil P status and rate of the soil erosion. (Lankoski et al., 2006.)

Tilling practice related parameter values for erosion, experimental surface runoff and nutrient runoffs that were substituted in the runoff functions were values from nutrient runoff experiments made in Southern Finland by the river Aurajoki (Lankoski et al., 2006, p. 205; Puustinen et al., 2010, p. 309). The field where experiments were carried out is the same field that is analysed in this study. The current tilling practice on the field by the river Vähäjoki is direct sowing. On the field by the river Aurajoki it has been normal ploughing until 2010 and shallow stubble tillage since

2011. The parameter values for buffer zone size, soil phosphorus and fertiliser use originated from case data. The values are listed in the following Table 20:

Table 20. Parameter values for nutrient runoff assessment in agricultural buffer zone cases

	Case field by the river Aurajoki	**Case field by the river Vähäjoki**
Total land area, ha	24.82	8.81
Buffer zone land area, ha	3.96	1.66
Share of buffer zone, %	0.25	0.19
Tilling practice related N runoff, kg/(ha*y)	9	9
N fertilisation, kg/ha	140	100
Tilling practice related surface runoff, mm/y	234	233
Soil P,	21	19
Erosion kg/ha	1420	620
Tilling practice related DRP run-off kg/(ha*y)	0.68	2.02
Tilling practice related PP runoff kg/(ha*y)	2.68	1.13
P fertilisation coefficient	0.06	0

The results of the cost-benefit analyses of the two case fields are discussed next. The results of the two fields are reported separately and then compared in the discussion.

7.4 Results: The field by the river Aurajoki

The buffer zone by the river Aurajoki reduced estimated runoffs per hectare for both nitrogen and phosphorus (Figure 27 and Figure 28). From 2011, the tillage practice changed from normal ploughing to shallow stubble tillage which also reduced estimated runoffs. The nitrogen runoff was estimated to reduce by 69%, in normal ploughing phase by 12.3 kg/ha/y (and in shallow stubble tillage phase by 7.3 kg/ha/y (69%)). Phosphorus runoff was estimated to reduce respectively by 2.8 and 1.4 kg/ha/y (52% and 48%). Estimated phosphorus runoff reduction was mainly a result of reduction in particle phosphorus runoff (96–98% share of the total P runoff). When talking about the whole field, estimated nitrogen runoff reductions were 305.5 kg/y normal ploughing phase and 175.1 kg/y in shallow stubble tillage phase, and estimated phosphorus reductions 69.6 kg/y and 34.8 kg/y respectively.

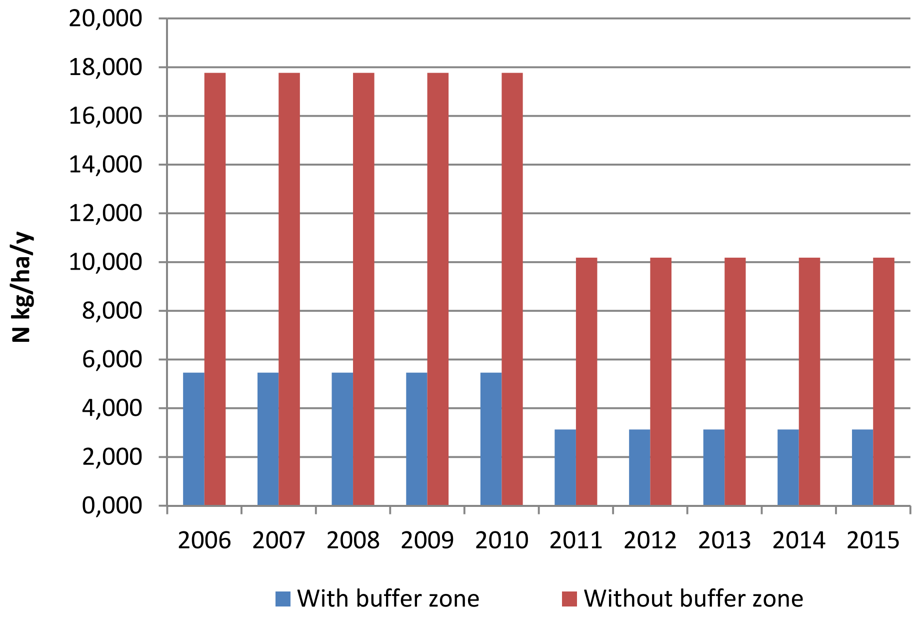


Figure 27. Nitrogen runoffs (kg/ha/y) with and without buffer zone in the case field by the river Aurajoki.

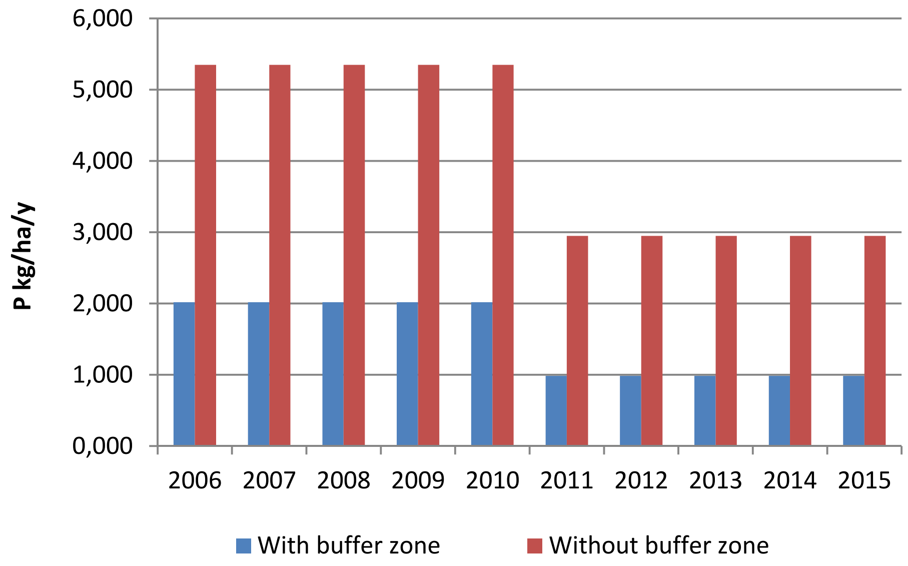


Figure 28. Phosphorus runoffs (kg/ha/y) with and without buffer zone in the case field by the river Aurajoki

According to the estimates, the buffer zone seem to be an efficient way of preventing both nitrogen and phosphorus leaching from fields to the river Aurajoki and further to the Baltic Sea. Although nutrient reductions from a single field are rather small, the reductions are multiplied if buffer zones are applied widely in the area. Then reduced erosion may improve the visibility of river water and thus provide very local impacts. The reduced nutrient load may provide both local and wider impacts by decreasing eutrophication in the coastal waters near the river mouth of the river Aurajoki and in the Baltic Sea.

The cost-benefit analysis of the buffer zone included many cost and benefit categories, as can be seen from Figure 29 (BSAP scenario) and Figure 30 (BASELINE scenario) (values are for the whole field area). For farmer, the buffer zones provide cost savings but also some loss of income and additional costs. For the landowner, the City of Turku, reduced rent price for buffer zones causes some losses in rent incomes, but it equals the savings in rent costs for the farmer. Due to reduced nutrient runoff, buffer zones also provide the Baltic Sea eutrophication reduction benefit which is high compared to other categories especially during the years when normal ploughing was applied (2006–2010) in the cultivation. The difference in the eutrophication benefit in the BSAP and BASELINE scenarios is large. In the BASELINE scenario, this benefit is annually significantly larger than other benefits and costs (Figure 30).

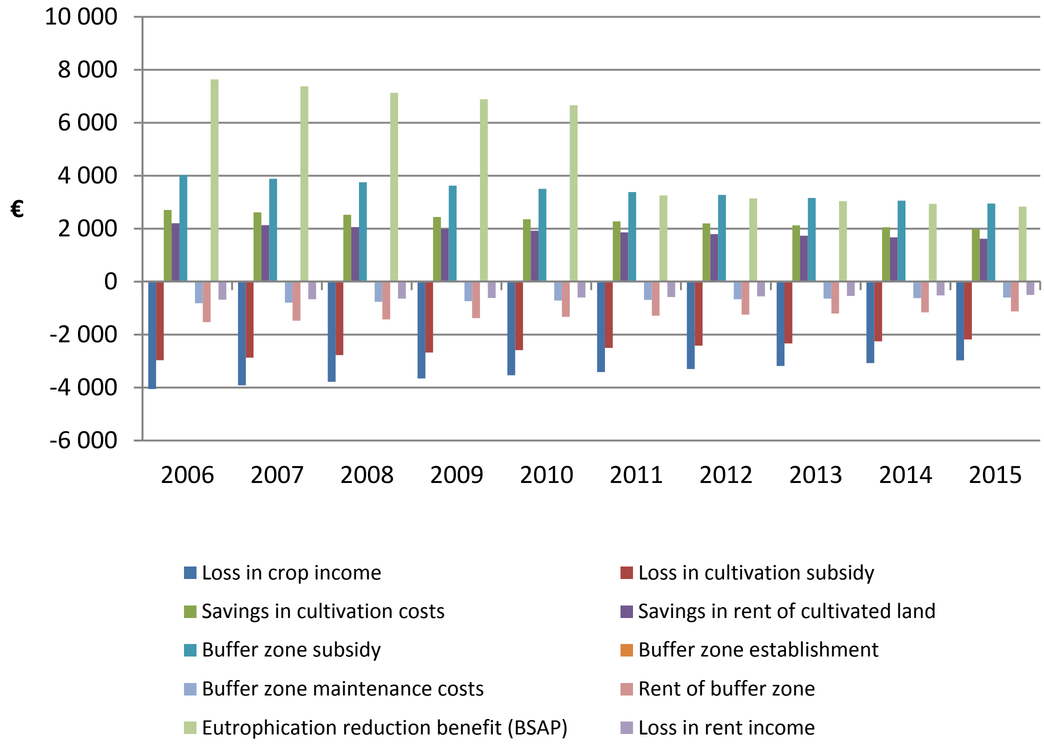


Figure 29. Annual benefits and costs in present values in the case field by the river Aurajoki in the BSAP scenario

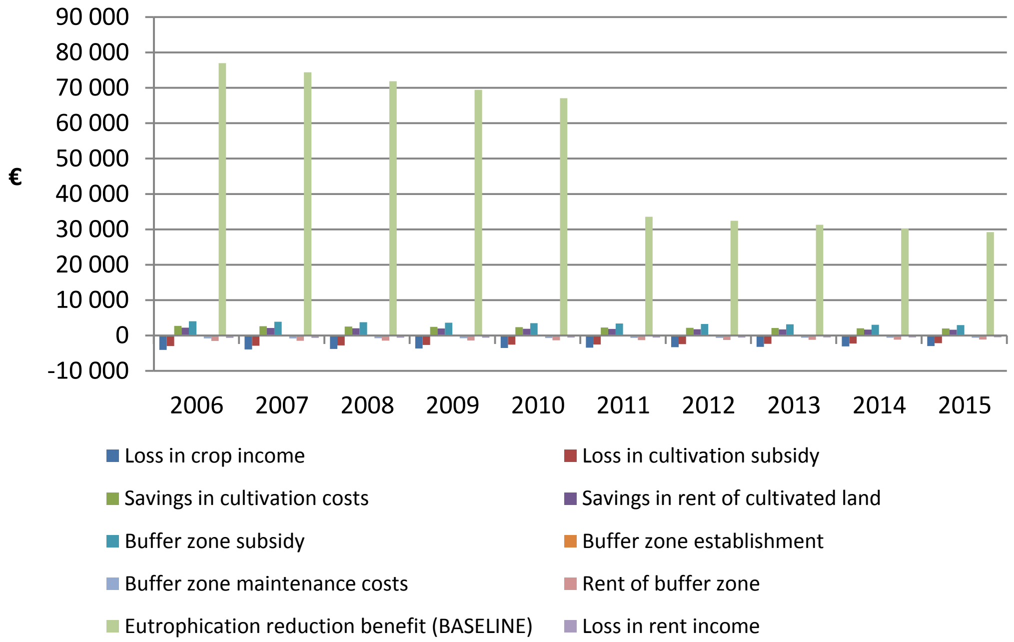


Figure 30. Annual benefits and costs in present values in the case field by the river Aurajoki in the BASELINE scenario

The sums of annual benefits and costs, the annual net present values, for both BSAP and BASELINE scenarios, are presented in Figure 31. The annual net present values are positive in both scenarios, but in the BASELINE scenario clearly higher. Due to the change in the tilling practice, the annual net present values are significantly lower from 2011.

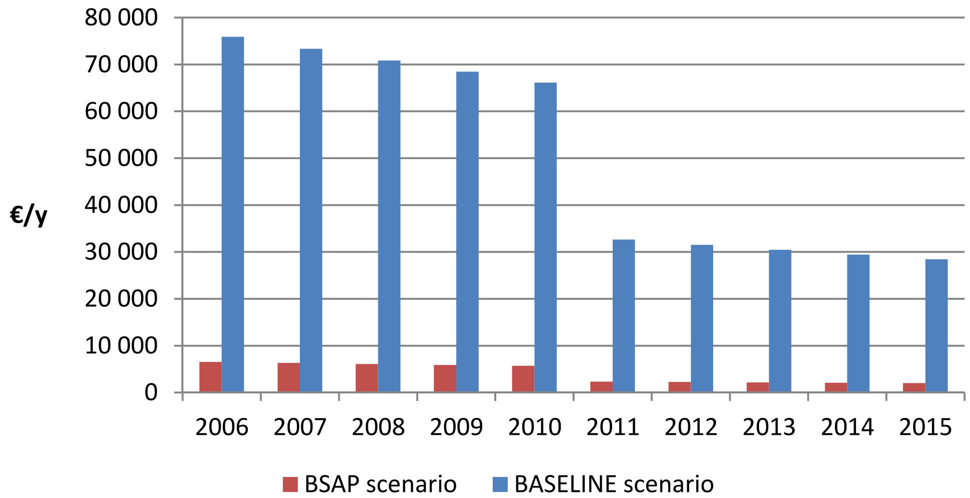


Figure 31. Annual net present values in the case field by the river Aurajoki in the BSAP and BASELINE scenarios calculated with the best guess values

When the annual net present values are summed up together, we obtain the net present values (NPV), which are approximately 41,000 € in the BSAP scenario and 507,000 € in the BASELINE scenario. The B/C-ratios were 1.48 and 6.87 respectively. Although NPVs in both scenarios calculated with the best guess values are positive, their sign may be sensitive to the assumptions. Especially the nutrient runoff is important to analyse in the sensitivity analysis, because it is based on estimation, not to the exact measurements. The variables and their values that were analysed in sensitivity analysis are listed in Table 21. The variables related to farmer's profits were assumed to have values that are 10% lower or higher, and nitrogen runoff factor was assumed to be 50% lower or higher. Minimum and maximum values for runoff parameter were estimates from runoff experiments (Puustinen et al., 2010).

Table also presents the results from the partial sensitivity analysis. The particle phosphorus (PP) runoff factor and erosion factor have the largest impact to the NPV, especially in the BSAP scenario. The discount rate has also a rather significant impact. The variables that are related to the revenues of the farmer change the NPV only slightly, but the changes (10%) were also rather small. The relative changes look larger in the BSAP scenario because the best guess NPV is smaller. None of the variables turn the sign of NPV to negative.

Table 21. Partial sensitivity analysis of the Aurajoki case: variables and their minimum, maximum and best guess values and their relative impact on NPVs in the BSAP and BASELINE scenarios

				BSAP scenario		**BASELINE scenario**	
Variable	**Min value**	**Best guess value**	**Max value**	**Change (Min value)***	**Change (Max value)***	**Change (Min value)****	**Change (Max value)****
Discount rate	0.01	0.035	0.06	–10.79%	12.23%	–10.37%	11.74%
Crop revenues in future %	90	100	110	1.46%	–1.46%	0.12%	–0.12%
Annual work and material costs in future, %	90	100	110	–0.68%	0.68%	–0.06%	0.06%
Subsidies in future, %	90	100	110	–0.38%	0.38%	–0.03%	0.03%
Surface runoff factor (NP), mm/y	172	234	315	–0.40%	0.52%	–0.27%	0.36%
Surface runoff factor (ST), mm/y	168	213	315	–0.29%	0.65%	–0.20%	0.44%
Erosion factor (NP), kg/(ha*y)	980	2100	4640	–41.02%	93.03%	–28.03%	63.57%
Erosion factor (ST), kg/(ha*y)	650	1420	2930	–17.15%	33.64%	–11.72%	22.98%
PP runoff factor (NP), kg/(ha*y)	1.57	3.71	9.56	–44.36%	121.28%	–30.31%	82.87%
PP runoff factor (ST), kg/(ha*y)	1.05	2.68	5.56	–19.24%	33.99%	–13.15%	23.23%
DRP runoff factor (NP), kg/(ha*y)	0.43	0.58	0.98	–0.39%	1.04%	–0.27%	0.71%
DRP runoff factor (ST), kg/(ha*y)	0.47	0.68	0.98	–0.42%	0.60%	–0.29%	0.41%
N runoff factor (NP), kg/(ha*y)	7.85	15.7	23.55	–3.85%	3.85%	–8.68%	8.68%
N runoff factor (ST), kg/(ha*y)	4.5	9	13.5	–1.86%	1.86%	–4.19%	4.19%

* Relative change in NPV compared to best guess NPV in BSAP scenario (approx. 41,000 euros)
** Relative change in NPV compared to best guess NPV in BASELINE scenario (approx. 507,000 euros)

The NPV distributions for the BSAP and BASELINE scenarios, resulting from the Monte Carlo simulation (see Chapter 2), are slightly skewed on the left (Figure 32). Especially NPV distribution in the BASELINE scenario has a clear right tail. These findings can be explained with the results from partial sensitivity analysis: for example, the maximum values for erosion factor and PP runoff factor increase the NPV very much in the relative sense. All of the NPV values in the Monte Carlo simulation were positive in both scenarios. The minimum NPV (worst case) in the BSAP scenario was approximately 700 euros, rather close to the zero but still positive. The highest NPVs in the BSAP scenario and the lowest NPVs in the BASELINE scenario are about the same scale. Monte Carlo simulation results with 1% and 6% discount rates will found from Appendix V.

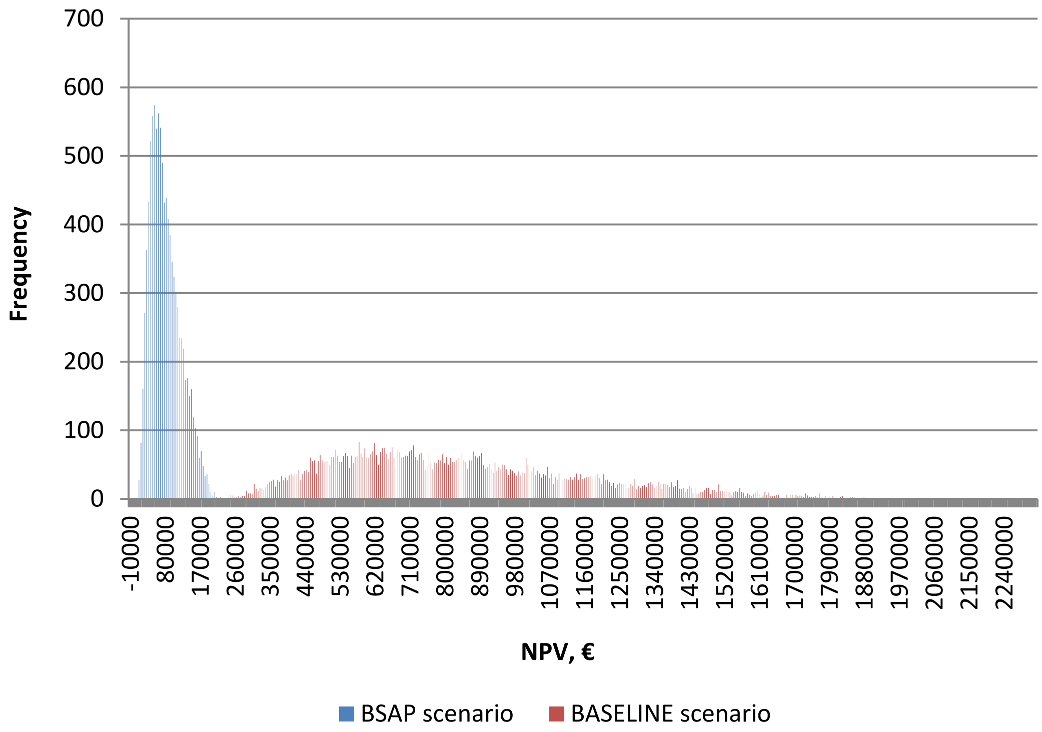


Figure 32 Net present values in the Monte Carlo sensitivity analysis of the case field by the river Aurajoki (discount rate 3.5%)

Finally, the development of the NPV in the time until 2015 (the year when the present contract will expire) is presented in Figure 33. Also the NPV in the worst and best case scenarios (with the min/max-values that either decreased of increased the NPV in the partial sensitivity analysis) are presented in the figure. The NPVs are positive from the beginning and increase in time. If the lease contract would continue for one or more 5-year periods, the NPVs would be even higher.

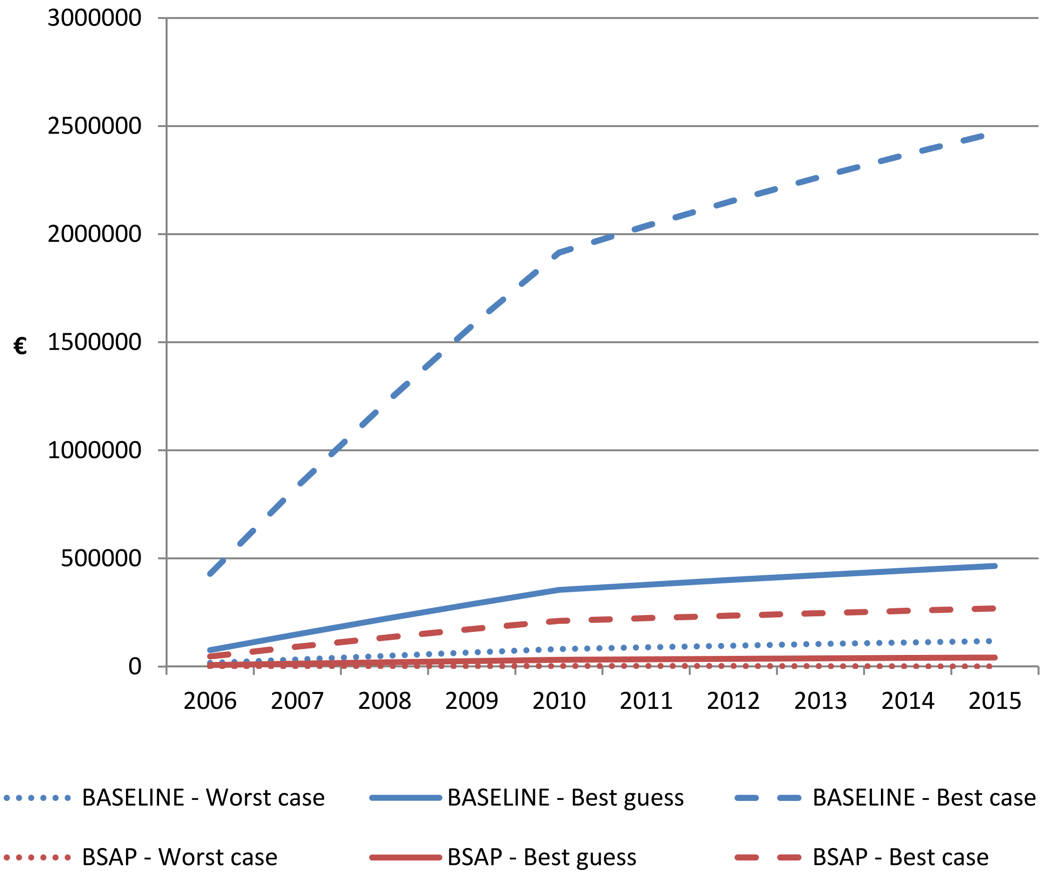


Figure 33. Development of the total NPV in time during the leasing period concerning the case field by the river Aurajoki.

7.5 Results: The field by the river Vähäjoki

The reductions in nutrient runoffs were estimated by a model, in which runoff factors based on the experiments performed in the Aurajoki field (see page 83) and the characters of the Vähäjoki field (the width of the buffer zone, soil P concentration) were applied. The tilling practice applied in the Vähäjoki field is direct sowing, so runoff factor values related to direct sowing were used in the estimation. The estimated annual nutrient runoffs (kg/h) with and without buffer zones are presented in Figure 34 (nitrogen) and Figure 35 (phosphorus). The estimated nitrogen runoff reduction was 6.7 kg/ha/y (75% reduction compared to runoff without buffer zone) and the phosphorus reduction 0.5 kg/ha/y (21% reduction). Reductions per hectare are smaller than in the Aurajoki case, which can be explained by the relatively narrower buffer zone and different tilling practice, which gives the smaller nutrient runoff per hectare even without the buffer zone. The share of particle phosphorus (PP) reduction of total P runoff reduction was smaller (55%) than in the Aurajoki field, because the direct sowing reduces erosion, which is correlated to PP runoff. The estimated nutrient reductions concerning the whole field area 60 kg/y nitrogen and 4 kg/y phosphorus.

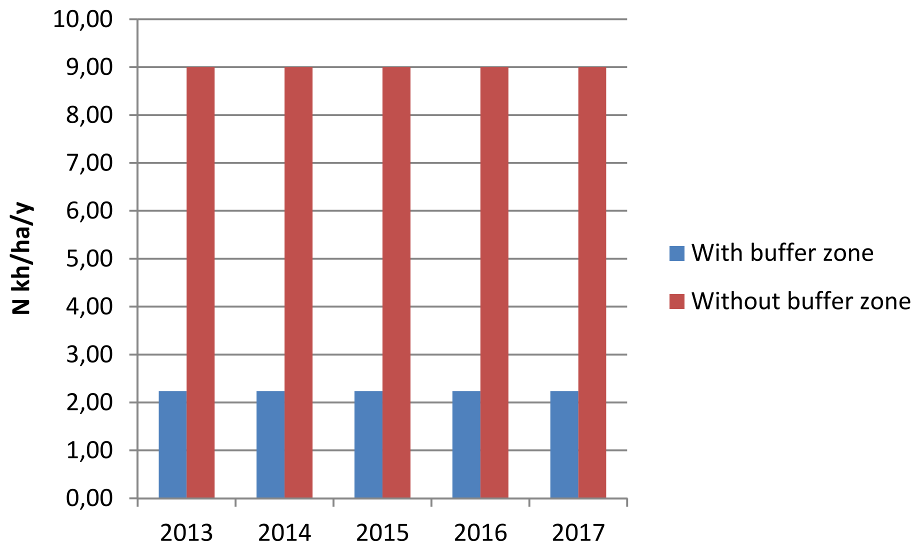


Figure 34. Estimated annual nitrogen runoff (kg/ha) with and without buffer zone in the case field by the river Vähäjoki

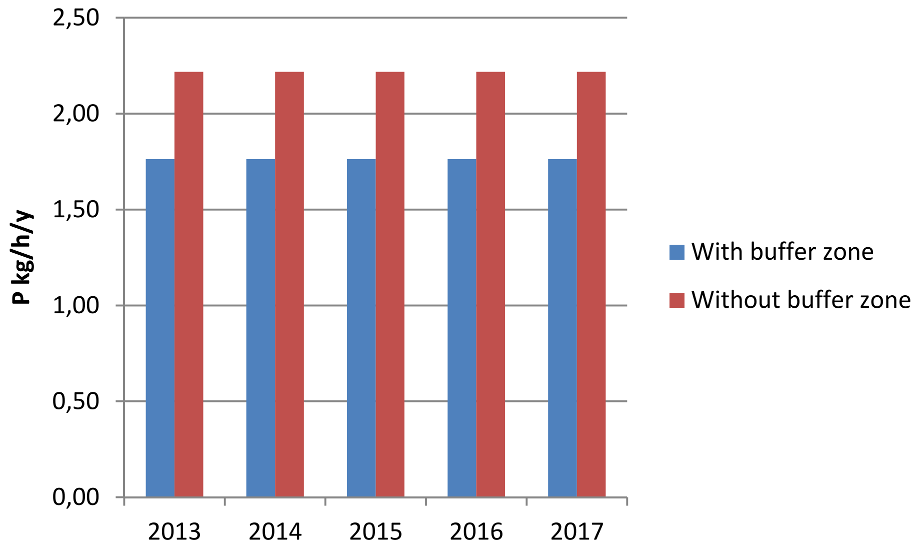


Figure 35. Estimated annual phosphorus runoff (kg/ha) with and without buffer zone in the case field by the river Vähäjoki

According to the estimate, the buffer zone seems to be an efficient way to prevent especially nitrogen leaching to the river Vähäjoki and further to river Aurajoki and to the Baltic Sea. Estimation showed also that direct sowing is another efficient way to reduce nutrient leaching, especially particle phosphorus. As was discussed previously in the Aurajoki case, although nutrient reductions from a single field are rather small, the reductions are multiplied if buffer zones are applied widely in the area. Then they provide both local and wider impacts by decreasing eutrophication in the coastal waters near the river mouth of the river Aurajoki and in the Baltic Sea.

The annual costs and benefits during the present contract period are presented in present values in Figure 36 (BSAP) and Figure 37 (BASELINE). The values are calculated for the whole field area. The eutrophication reduction benefit is relatively high in the BASELINE scenario, but not significant in the BSAP scenario if compared to other costs and benefits. The opportunity costs, losses in crop income and cultivation subsidy, are the largest cost sources, while the buffer zone subsidy is the largest benefit group. Because the establishment of buffer zone vegetation failed in the first year, it was done again in the next year. The rent of the buffer zone equals the rent of cultivated land, and did not provide rent cost savings for farmer or income losses for the city (see page 81). These benefits and costs are not included in the figures, because they were not changed.

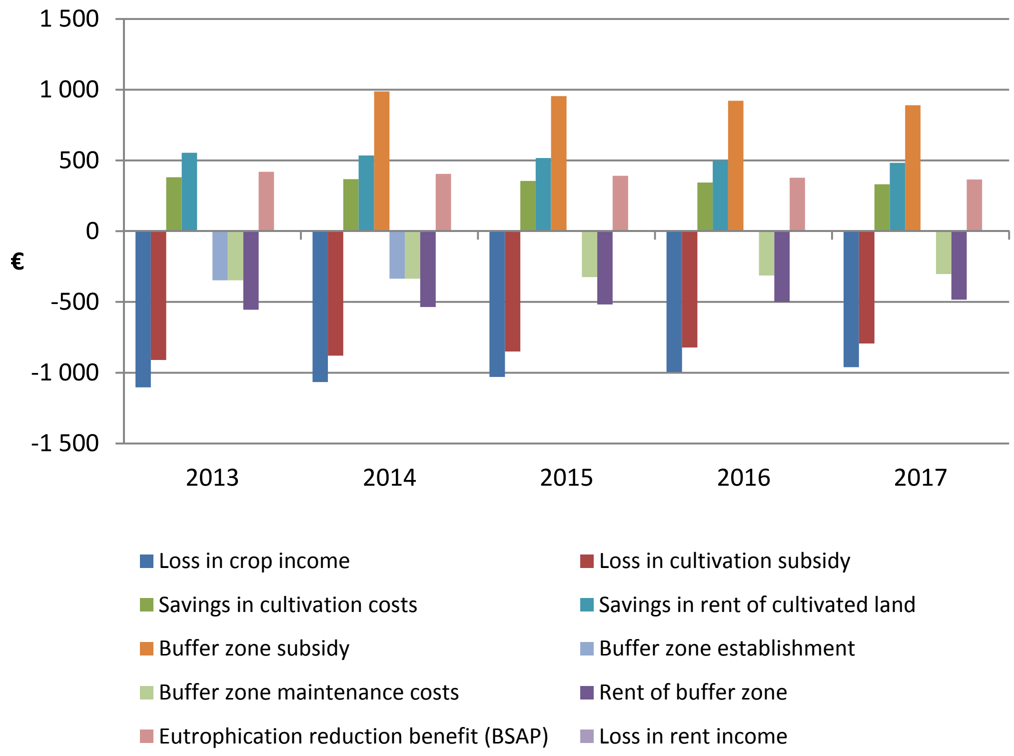


Figure 36. The annual costs and benefits during the present lease contract period in present values in the BSAP scenario in the case of the Vähäjoki field

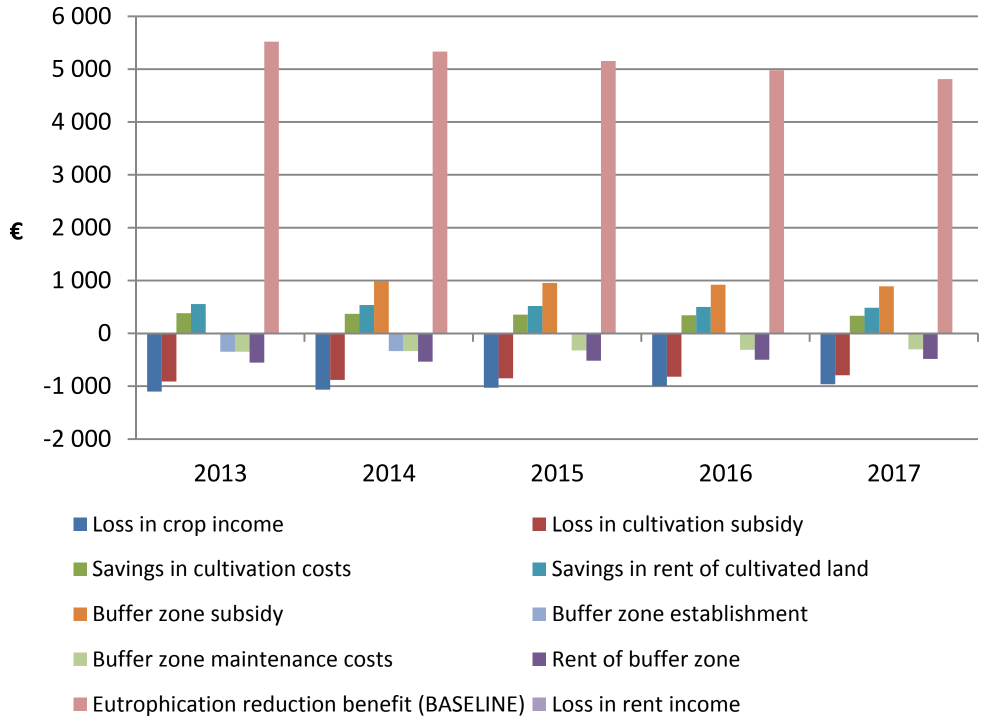


Figure 37. The annual costs and benefits during the present lease contract period in present values in the BASELINE scenario in the case of the Vähäjoki field

The annual net present values (sums of annual costs and benefits) of the whole field area during the present contract period in the BSAP and BASELINE scenarios are presented in Figure 38. The annual net present value (NPV) is smaller in both scenarios in the first year than in the next years, because the buffer zone subsidy was not received during the first year. The annual NPV is negative in the BSAP scenario and positive in the BASELINE scenario, and this is due to the large eutrophication benefits in the BASELINE scenario.

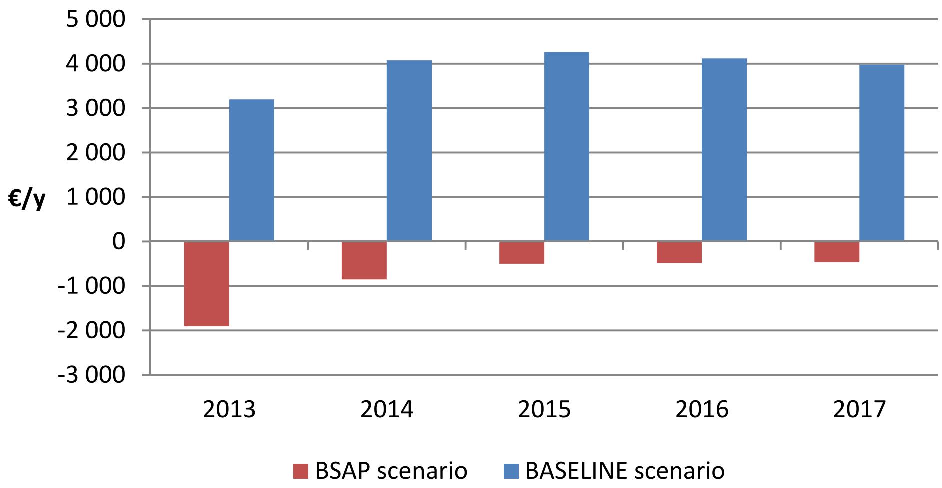


Figure 38. The annual net present values for the whole field area during the present lease contract period in the BSAP and BASELINE scenarios in the case of the Vähäjoki field

The estimated net present value during the whole contract period was –4200 € and negative in the BSAP scenario and 19,600 € and positive in the BASELINE scenario. The B/C-ratios were 0.34 and 4.10 respectively. The results were analysed further in sensitivity analysis.

The variables and their values that were included in the sensitivity analyses are listed in Table 22. The crop revenues, annual work and maintenance costs and subsidies were assessed to be 10% lower or higher in the future. Minimum and maximum for runoff and erosion factors were picked up from literature (Puustinen et al., 2010) except the N runoff factor, which was assumed to be 50% lower and higher. In addition, it was checked how possible reduction in buffer zone rent would impact on the NPVs. In the case field of Aurajoki, the rent of buffer zone was about 30% lower than the rent of the cultivated area. A similar reduction in rent was included in the sensitivity analysis of case Vähäjoki. Rent reduction and discount rate were analysed separately in the Monte Carlo analysis.

Table 22. Partial sensitivity analysis of the Vähäjoki case: variables and their minimum, maximum and best guess values and their relative impact on NPVs in the BSAP and BASELINE scenarios

				BSAP scenario		**BASELINE scenario**	
Variable	**Min value**	**Best guess value**	**Max value**	**Change (Min value)***	**Change (Max value)***	**Change (Min value)****	**Change (Max value)****
Discount rate	0.01	0.035	0.06	–0.62%	0.49%	2.74%	–2.50%
Crop revenues in future, %	90	100	110	9.62%	–9.62%	2.06%	–2.06%
Annual work and material costs in the future, %	90	100	110	–0.30%	0.30%	–0.06%	0.06%
Subsidies in the future, %	90	100	110	–0.98%	0.98%	–0.21%	0.21%
Surface runoff factor (DS), mm/y	200	233	256	–2.25%	1.56%	–4.03%	2.81%
Erosion factor (DS), kg/(ha*y)	430	620	950	–5.86%	10.17%	–10.50%	18.24%
PP runoff factor (DS), kg/(ha*y)	0.76	1.13	1.78	–6.26%	11.00%	–11.22%	19.71%
DRP runoff factor (DS), kg/(ha*y)	0.73	2.02	3.5	–10.12%	11.61%	–18.15%	20.82%
N runoff factor (DS), kg/(ha*y)	4.5	9	13.5	–5.82%	5.82%	–34.38%	34.38%
Reduction in buffer zone rent (%)	*30*	-	-	*–20.00%*	-	*4.09%*	-

* Relative change in NPV compared to best guess NPV in the BSAP scenario (approx. –4,200 euros)
** Relative change in NPV compared to best guess NPV in the BASELINE scenario (approx. 19,600 euros)

According to the partial sensitivity analysis results in Table 22, the NPVs in both the BSAP and BASELINE scenarios are a bit sensitive to erosion and phosphorus related factors, especially to their maximum values. In the BSAP scenario also the crop revenues and reduction in the buffer zone rent have the largest impact on the NPV, and in the BASELINE scenario N runoff factor has the largest impact. None of the variables turn the sign of NPV in either scenario.

The signs of NPV remained the same also in the Monte Carlo analysis: all NPVs in the BSAP scenario were negative and all NPVs in the BASELINE scenario positive (Figure 39). The variance is much larger in the BASELINE scenario than in the BSAP scenario, but not skewed as in the case field of Aurajoki (Figure 32), which is due to relatively smaller reductions in nutrient loads and smaller range of minimum and maximum of the runoff factor. If the rent is assumed to be 30% lower in the future, the sign of all NPVs will remain the same in the both scenarios. Monte Carlo simulation results with 1% and 6% discount rates will found from Appendix VI.

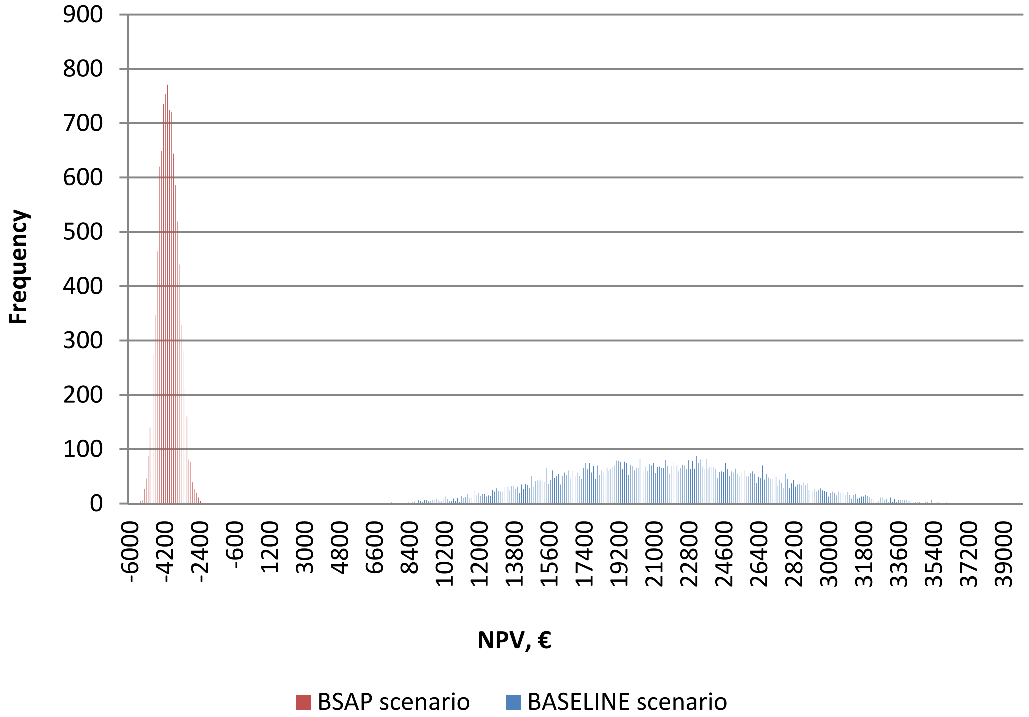


Figure 39. Net present values in the Monte Carlo sensitivity analysis of the case field by the river Vähäjoki (discount rate 3.5 %)

Figure 40 shows how NPV behaves if the lease contract would continue for one or more 5-year periods and shows differences between the BSAP and BASELINE scenarios with best and worst cases and best guess assumptions. All NPV development lines in the BASELINE scenario are increasing, while all NPV lines in BSAP scenario are decreasing. When assuming that rent of the buffer zone is the same as it is for the cultivated land, the NPV in the BSAP scenario will be negative despite the length of the rent contract. If the rent price of the buffer zone is lowered by 30%, then the best case NPV would turn to positive after 20 years. Only with very optimistic assumptions could the NPV also in the BSAP scenario be positive.

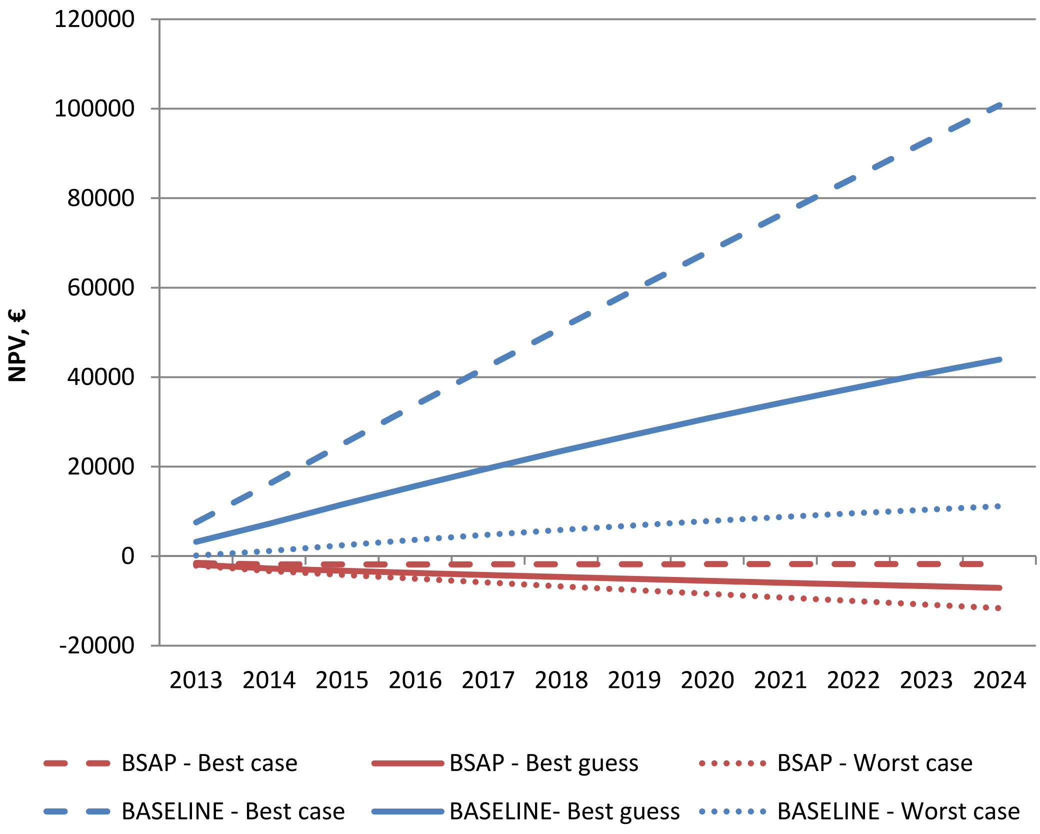


Figure 40. Development of the NPV in time if the leasing continues for several 5-year periods after the present contract expires in 2017.

7.6 Discussion

The case study of buffer zones in the rental fields of the City of Turku brought up how the city as a landowner can influence water protection in local agriculture but also how it influences a farmer's profitability. The case study included two case fields by the river Aurajoki and the river Vähäjoki.

The nutrient reductions were estimated by a model and it gave a rough estimate for the reduced nutrients. The model included factors such as applied tilling practice, soil phosphorus status and width of the buffer zone of the case fields and runoff factors based on runoff experiments made in the case field by the river Aurajoki (Puustinen et al., 2010). According to the estimate, the buffer zones reduced nitrogen leaching by 69–75% and 22–52% phosphorus leaching from fields to the river. The reduced amounts of nitrogen were 6.7–12.3 kg/ha/y and phosphorus 0.5–1.4 kg/ha/y, and together buffer zones on these two fields reduce 235–366 kg/y nitrogen and 39–74 kg/y phosphorus, depending on the tilling practice and width of the buffer zone (the tilling practice was changed in 2011 in the Aurajoki case). Although nutrient reductions from these two single fields are rather small, the reductions are multiplied if buffer zones are applied widely in the area. Then reduced erosion may improve the visibility of river water and thus provide very local impacts. The reduced nutrient load may provide both local and wider impacts by decreasing eutrophication in the coastal waters near the river mouth of the river Aurajoki and in the Baltic Sea.

The net present value (NPV) in the case field of the river Aurajoki was positive in both the BSAP and BASELINE scenarios (BSAP: NPV 41,000€, B/C-ratio 1.48; BASELINE: NPV 507,000 €, B/C-ratio 6.87), while in the case field by the river Vähäjoki the sign dependend on the scenario (BSAP: NPV –4,000, B/C-ratio 0.34; BASELINE: NPV 20,000, B/C-ratio 4.10). The net present values were smaller in the Vähäjoki case for many reasons, and the most important of them are related to the estimated nutrient load: the buffer zone was narrower, and the applied tillage practice was direct sowing, which also reduces nutrient leaching efficiently and the change in nutrient leaching due to the buffer zone was relatively smaller than in the Aurajoki case. In addition, the costs and benefits for the farmer were different in the two cases. The uncertainty related to nutrient load estimated in the Vähäjoki case is higher than in the Aurajoki case, because the field is different. For example, due to the higher slope of the Vähäjoki field the runoff would be higher than in the Aurajoki field, and it would increase the estimated nutrient leaching. The lifespan in the Aurajoki case was notably longer, which also explains the difference in NPVs.

The results should be interpreted with caution, because the nutrient reduction was estimated by a model which did not take into account e.g. cultivated crops or varying weather conditions, and they had a large influence on NPVs. Although it is hard to draw straight conclusions from the results, buffer zones can be regarded as a potential measure to reduce nutrient load from agriculture. If they are applied widely within the same area, the total nutrient reductions may be remarkable. In addition, the buffer zones may provide many environmental benefits and enhance and facilitate cultivation, which could not be included in the analysis.

8 Conclusions and discussion

The current ecological state of the Baltic Sea is alarming due to severe eutrophication, which threatens marine life and the benefits that the sea can provide for humans. The main reason for eutrophication is the excess nutrient load caused by human activities which calls for urgent and radical nutrient load reductions in the entire Baltic Sea catchment area. While nutrient reductions in practice should be done on the local level by cities, municipalities and other local organisation, the impact is wider affecting the state of both local waters and the Baltic Sea.

The aim of this study was to assess the role of cities and municipalities in saving the Baltic Sea. The following questions were considered:

- Which and how large impacts can be related to municipal water protection measures?
- How are municipal water protection measures affecting the state of the local water systems or the state of the Baltic Sea?
- How large are the environmental benefits gained compared to the costs of these measures?
- Are the measures worthwhile from the perspective of social welfare?

These questions were studied by using the cost-benefit analysis (CBA) method in which all relevant impacts from the whole lifespan of a project are identified, quantified, turned into monetary values and summed up into a net present value (NPV) measuring the increment in social welfare. The CBA was performed for five case measures implemented by cities and municipalities:

- Centralising of wastewater treatment in Luotsinmäki WWTP in Pori (Finland)
- An aerator investment in Liepaja WWTP (Latvia)
- Reception of sewage waters from ships in the Port of Helsinki without special fee (Finland)
- A constructed urban wetland in Lahti (Finland)
- Agricultural buffer zones in Turku (Finland).

These differing case studies were chosen to provide information on overall impacts, monetised environmental benefits, costs and net benefits of varying municipal water protection measures.

8.1 Summary of the results and conclusions

The study gave valuable information on different water protection measures implemented by municipalities around the Baltic Sea (Table 23). **Firstly**, each case study provided an overview of which positive and negative impacts are potentially related to the studied measure. Identification of the impacts showed that in addition to the nutrient reductions to the local water systems and the Baltic Sea, water protection measures can provide also various other positive impacts, which can be local or global. The positive local impacts are, for example, energy cost savings due to reduced energy consumption (wastewater treatment), flood protection and improved recreational opportunities (natural stormwater management) and increased biodiversity (natural stormwater management, agriculture), while the global impacts due to decreased energy consumption and decreased climate emissions comprise avoided social costs of climate change. The case studies further showed that water protection actions are usually connected also to other subjects of environmental protection, such as climate change mitigation and adaption, air and noise protection, flood protection etc.

Table 23. Key findings of the cost-benefit analysis study

1. The study provides an overview of positive and negative impacts potentially related to the studied measures - In addition to nutrient reductions, water protection measures can provide various other positive impacts, especially on the local level - Water protection measures are usually connected also to other subjects of environmental protection, such as climate change mitigation and adaption.
2. The study estimated the nutrient load reductions provided by the case measures - Investments in wastewater treatment and PRF can provide large nutrient reductions which are significant even at the Baltic Sea level - Natural water protection measures related to stormwater management and agriculture can efficiently reduce nutrient loads, and multiple similar measures implemented within the same area may provide significant nutrient reductions
3. The study considered impacts of the measures on the state of both the local water systems and the Baltic Sea. - Nutrient reductions within the Baltic Sea catchment area seem to have an impact both on local waters and the Baltic Sea. The water quality improvement may, however, become apparent in delay.
4. The study estimated the environmental benefits in monetary terms - When the state of the Baltic Sea is poor, the nutrient reductions are very valuable - Natural stormwater management may provide significant recreational benefits in urban areas
5. The study compared the environmental benefits and costs of implementation and studied the potential of water protection measures increasing social welfare. - All case measures provide substantial positive net benefits, suggesting that all of them are worthwhile to be implemented today, if no additional actions are made and the state of the sea remains poor in the future. - If the Baltic Sea Action Plan targets will be achieved, the nutrient reductions of some of the case measures seem not to bring enough benefits to exceed their costs, because the state of the sea is assumed to be at a good level in the future. Additional nutrient reductions become less valuable while the state of the sea improves. - Due to the difficulty of predicting the protection of the Baltic Sea in the future, the quantitative net benefits are likely to be found between the net benefits estimated in the two scenarios above. However, net benefits of case measures are probably higher than given by the results of this study, because there are very many potential impacts that were not possible to include in the analysis, such as, for example, benefits of improved state of local waters

Secondly, the study estimated the nutrient load reductions provided by the case measures. The summary of these results is presented in Table 24. The investments in Luotsinmäki WWTP and the PRF of the Port of Helsinki were very substantial and provided large nutrient reductions but also a smaller investment in a WWTP can notably reduce nutrient loads, as shown by the case of Liepaja WWTP. The nutrient load reductions proved to be notable compared to country-level targets of the Baltic Sea Action Plan (BSAP). Also the natural water protection measures, i.e. the stormwater wetlands and agricultural buffer zones, appeared to retain nutrients rather efficiently although to a smaller amount. However, these kinds of water protection measures are of high importance, since there may be several of them within the same area accumulating the effects.

Thirdly, the study discussed their impacts on the state of local waters and the Baltic Sea. The water protection measures of Luotsinmäki WWTP and the buffer zones in Turku were implemented by the river, and thus they impact on the state of the river water locally and the sea near to the river mouth, in addition to the impact on the state of the Bothnian Sea basin. Considering the measures of Liepaja WWTP and the Port of Helsinki, the nutrient reductions were directly targeted to the sea (Baltic Proper and Gulf of Finland sea basins), but effects may also be seen on coastal waters. In the case of the stormwater wetland in Lahti, the nutrient reductions were targeted to Lake Kymijärvi, but because the water flows through many lakes and water courses to the Gulf of Finland, it may have a wider impact on several water systems. This study was not able to measure the effect of the measures on the water quality of local waters or the sea, because the cases were rather recently implemented and detection of changes usually requires long-term monitoring data and good knowledge of the considered water system. Water quality improvements, in particular, become apparent in delay, because the recovery of the water ecosystems takes time.

Table 24 Estimated nitrogen and phosphorus reductions (kg/y) gained from different water protection measures and estimated monetary benefits (€/y) gained from the nutrient reductions (kg/y) to the Baltic Sea

Case study	Average nitrogen reduction, kg/y	Average phosphorus reduction, kg/y	Benefits from nutrient reductions to the Baltic Sea in the BSAP scenario, €/y	Benefits from nutrient reductions to the Baltic Sea in the BASELINE scenario, €/y
Luotsinmäki WWTP	127,500	31,000	2,572,000	25,635,000
Liepaja WWTP	18,000	1,000	107,000	1,477,000
Port of Helsinki	21,000	3,000	343,000	3,619,000
Stormwater wetland in Lahti	61	2	400	5,400
Buffer zones in Turku (Aurajoki)	306; 175* (12; 7* kg/ha)	70; 35* (3; 2* kg/ha)	5,800; 3,000*	58,700; 30,400*
Buffer zones in Turku (Vähäjoki)	60 (7 kg/ha)	4 (1 kg/ha)	400	5,300

* Normal ploughing; shallow stubble tillage (tilling practice was changed in 2011)

Fourthly, the study estimated the environmental benefits in monetary terms. For example, the benefits from the nutrient load reductions to the Baltic Sea were estimated by using marginal benefit estimates for nitrogen and phosphorus from Ahlvik and Ahtiainen (2014). The marginal benefit is a monetary estimate of the benefit from one kg of reduced nitrogen or phosphorus load to the sea gained by the citizens living around the sea. The marginal benefit is based on people's willingness to pay (WTP) for an improved state of the Baltic Sea. Ahlvik and Ahtiainen (2014) estimated the marginal benefits in two scenarios:

1. The BSAP scenario: The level of the Baltic Sea protection in the future follows the Baltic Sea Action Plan targets set by HELCOM
2. The BASELINE scenario: The current level of water protection is maintained, but no additional actions are made in the future.

The marginal benefits depend strongly on the scenario of the future nutrient reduction development (BSAP or BASELINE). If no additional actions are made in the future as assumed in the BASELINE scenario, the state of the sea will remain poor and the benefits from additional nutrient reductions are very valuable. In the BSAP scenario, the state of the sea improves, and the benefit from additional reductions becomes lower accordingly – however, the total benefits from a better state of the sea would be remarkably higher than without nutrient reduction actions. The estimated marginal benefit further depends on the sea basin where the nutrient reductions are carried out and the nutrient in question, because e.g. the sensitivity of sea basins differs and the estimated WTPs differ by country. It should further be noted that the marginal benefit estimates in the BSAP scenario are likely underestimates, because they do not cover the benefits gained from an improved state of the local waters. (Ahlvik & Ahtiainen, 2014.)

It turned out that in all case studies except the case study of Lahti, the nutrient reductions to the Baltic Sea bring relatively large monetary social benefits, but the scenario of how the Baltic Sea protection develops in the future significantly influences the amount (Table 24). The Baltic Sea protection is currently at the BASELINE level, and if the level remains the same in the future, the BASELINE scenario will be realised. If the level of protection increases in the future, the future scenario shifts closer to the BSAP scenario. To achieve BSAP targets, ambitious nutrient reductions and general willingness of saving the sea are required and many obstacles need to be solved before that. Although it is hard to predict the future, the future scenario will be somewhere between these two scenarios. Thus, the monetary benefits gained from the measures are within the range of benefits in the BSAP and the BASELINE scenarios in Table 24. In the case study of the stormwater wetland in Lahti, the estimated monetary benefits from ecosystem services were the biggest benefit category. In addition to these benefits, nutrient reductions implemented within the Baltic Sea catchment area have an impact on the state of local waters providing benefits for people using them. The number of people gaining benefits may be notable especially when measures to reduce nutrient loads are implemented inland, because these may impact every water system and course along the way to the sea.

Fifthly, the study aimed to compare the environmental benefits and costs of implementation and to show if the water protection measures have potential to increase social welfare. This potential was measured by two economic performance indicators: net present value (NPV) in which the benefits and costs during the expected lifespan of a measure are discounted and summed up, and benefit-cost-ratio (B/C) which compares total benefits and total costs in present values. If NPV is positive and B/C is over 1, the measure provides more benefits than costs, and thus this project is worthwhile from society's point of view. A sensitivity analysis was also performed to study the uncertainty related to the results.

The cost-benefit analysis of each case included all relevant impacts of the measure that were possible to measure and monetise. The CBA case studies resulted in net present values (NPV) and B/C-ratios that are summed in Table 25. The results of the cost-benefit analyses showed that in the BASELINE scenario, all the case measures gave positive NPVs and B/C-ratios over 1, suggesting that all of them are worthwhile to be implemented today, when the state of the sea is still poor. In the BSAP scenario, the NPV is negative and B/C ratio less than 1 in the cases of Luotsinmäki WWTP, the Port of Helsinki, and the buffer zone by the river Vähäjoki. If the BSAP scenario will be realised and the state of the sea will be good in the future, the nutrient reductions of the measures do not bring enough additional benefits to exceed their costs. In the case of Liepaja WWTP, the NPVs were positive and the B/C-ratio over 1 in both scenarios due to large nutrient reductions and electricity cost savings. In the case of Lahti, the scenario has a rather small influence on the results, because the benefits mainly resulted from large benefits from wetland ecosystem services. In this case, the net benefits are likely to be positive. However, the NPVs and B/C-ratios will probably be between the BSAP and BASELINE values because the future development of the protection of the sea is difficult to predict as mentioned above. It should also be noted that many of the potential positive impacts were not included in the analysis, e.g. the benefits of an improved state of local waters, and the net benefits are probably higher than estimated.

NPV range, standard deviation and probability of positive NPV case by case with expected lifespans

	BSAP scenario		BASELINE scenario		**Major benefit (+) and cost (−) categories**
	Best guess NPV	**(B/C)**	**Best guess NPV**	**(B/C)**	
	Min. NPV*	Max. NPV*	Min. NPV*	Max. NPV*	
	P(NPV>0)**		P(NPV>0)**		
Luotsinmäki WWTP: centralising of wastewater treatment	**-40 301 000**	**0.64**	**120,698,000**	**2.07**	**+** Nutrient reductions to the Baltic Sea, − Investment costs
	-54,256,000	*-21,893,000*	*69,533,000*	*173,144,000*	
	0.0000		1.0000		
Liepaja WWTP: aerator investment	**2,058,000**	**4.65**	**18,561,000**	**33.92**	**+** Nutrient reductions to the Baltic Sea, electricity cost savings **−** Investment costs
	1,626,000	*2,826,000*	*12,632,000*	*26,370,000*	
	1.0000		1.0000		
PRF in Port of Helsinki: reception of sewage from ships	**-7,534,000**	**0.54**	**76,182,000**	**5.66**	**+** Nutrient reductions to the Baltic Sea **−** Investment costs, wastewater treatment costs
	-12,708,000	*2,201,000*	*57,856,000*	*154,179,000*	
	0.0121		1.0000		
Stormwater wetland in Lahti	**83,000**	**1.12**	**132,000**	**1.19**	**+** Ecosystem services of wetland **−** Investment costs, maintenance costs
	-377,000	*747,000*	*-356,000*	*808,000*	
	0.6286		0.6877		
Buffer zones in Turku (by river Aurajoki)	**41,000**	**1.48**	**507 000**	**6.87**	+ Nutrient reductions to the Baltic Sea, increased revenues of farmer
	7,000	*225,923*	*214,000*	*1,987,000*	
	1.0000		1.0000		
Buffer zones in Turku (by river Vähäjoki)	**-4,000**	**0.34**	**20,000**	**4.10**	+ Nutrient reductions to the Baltic Sea **−** Decreased revenues of farmer
	-6,000	*-2,000*	*7,000*	*38,000*	
	0.0000		1.0000		

* Range from minimum NPV and maximum NPV, obtained in the Monte Carlo sensitivity analysis
** Probability that NPV is positive, obtained in the Monte Carlo sensitivity analysis performed by 10,000 iterations

The Table 25 shows results from the Monte Carlo sensitivity analysis, which revealed that the uncertainty is higher in the BASELINE scenario than in the BSAP scenario (larger ranges between minimum and maximum NPVs). In the Monte Carlo sensitivity analysis, all known uncertainties are taken into account, and in the BASELINE scenario a higher marginal benefit estimate gives more weight to the uncertainties of parameter values related to the nutrient reduction estimation. In addition to Monte Carlo, also partial sensitivity analysis and worst-best case analyses were performed. These sensitivity analyses showed that, in general, the longer the lifespan, the larger are the net benefits but also the higher is also the uncertainty. In the cases of the Port of Helsinki and the buffer zone by the river Vähäjoki, the NPV were positive in the BSAP scenario when using very optimistic assumptions. The sensitivity analyses also showed that the NPV in the case of Lahti is very sensitive to many of the variables, although the NPVs seem likely to be positive.

As a general conclusion of the case studies, the benefits gained from water protection can exceed the related costs, and thus the measures are able to increase social welfare. Keeping the importance of local impacts in mind is fundamental in social welfare. Keeping the importance of local impacts in mind is fundamental in decision-making concerning the water protection, even at the Baltic Sea level. The case studies also showed that there are many kinds of benefits related to the water protection, and these are often connected to other fields of environmental protection. Different kinds of water protection actions around the Baltic Sea are needed: the protection of the Baltic Sea should be seen as an entirety and every single measure is an important part of it. The study also showed how cost-benefit analysis can be performed at a municipal level for single water protection measures, and found out which kind of information would be required in order to perform a cost-benefit analysis and to support implementing of water protection measures in municipalities.

8.2 Discussion

In general, the study can be regarded as successful because it answered the questions set up in the beginning, and showed that a cost-benefit analysis can be a valuable and useful tool to be applied also at the municipality level. The study provided a lot of valuable and useful information on different water protection measures implemented by cities and municipalities on a local level. The five studied case measures formed a diverse set of municipal water protection actions within the themes of wastewater treatment, marine traffic, stormwater management and agriculture. The case measures included both large and small-scale investments, implemented in different parts of the Baltic Sea region both in coastal and inland cities. In each case study, potential impacts related to the measures were identified, and also measured and monetised if possible. These case studies provided information on lifespan impacts, monetised environmental benefits, costs of implementation and the net benefits of different water protection measures.

However, in all cases there were impacts that were not included in the analyses due to lack of possibility to measure or monetise them. Some of these impacts are local, for example effects of the water quality of local water systems and the image value for the local actor. These impacts may be very valuable from a decision-making point of view and essential to remark. The estimated total benefits gained from water protection actions were likely underestimates in most of the cases, because many positive impacts were not possible to be included in the analyses, as exemplified and mentioned above. There may also be positive or negative impacts that were not identified in the study. The difficulties of including all impacts derived from lack of data: data was not existing or reacquiring too much time, work or multidisciplinary special expertise.

Although a comprehensive sensitivity analysis was performed, the obtained quantitative results should be regarded as rough estimates. Many assumptions had to be made and usually best guess or average values were used in the estimations because the available data were restricted. The municipalities were voluntarily involved in the study, and provided their expertise and help in collecting the material with their own possibilities. To get more accurate results in the analysis would have required the use of detailed and explicit data for the analysis. Collecting these data requires a good overview of the existing long-term data related to the water protection measure, and also time and understanding to extract and compile all of it to a form which can be sent to the analyst.

Uncertainty is related to the results also because case studies have long time spans and future impacts had to be predicted. As was seen in the sensitivity analyses, the longer the lifespan, the wider the variance of net present values. The development of the state of the Baltic Sea in the future was also one of the key factors causing uncertainty in the results: in some of the cases the sign of net present value was dependent on the future development. It is hard to say how probable it is that the nutrient reduction targets described in the BSAP and the good state of the sea will be achieved in a certain time period. This depends on every actor in the Baltic Sea catchment area. In some cases, the net benefits were negative in the BSAP scenario, but positive in the BASELINE scenario. These case measures are recommendable today, because they are already implemented and the work for aiming for better state of the sea is in the beginning, meaning that nutrient reductions are currently very valuable. However, if these measures should be implemented as a part cost-efficient set of measures in order to achieve the BSAP targets described in the BalticSTERN report (BalticSTERN, 2013) is a larger question, which should be discussed in another study.

When interpreting the results, it is also very important to remember that the studied case measures are not comparable with each other since they are very different single examples from different themes. Thus, it is not advisable to generalise the results of a case study to represent the affordability of the whole theme of water protection or say that some measure is better than another. It is not advisable either to conclude that focus in water protection should be put to one theme rather than to the other, because one measure may provide various kinds of benefits that are not achievable from another measure.

9 Recommendations

As the last step in the cost-benefit analysis, the authors give recommendations to support decision-making, usually on whether the studied measure should be implemented or not. This cost-benefit analysis study consisted of five case studies of different water protection actions that are already implemented. The recommendations result from the conclusions, lessons learned during the analysis and the information provided by the case studies. Recommendations are directed to civil servants and decision-makers especially at a local level around the Baltic Sea, but also other levels and stakeholders.

1. Use the provided information and the lessons learned of this study to support implementation of water protection work at the local level.

The study showed that the role of local actors in improving the state of local waters and the Baltic Sea is crucial, and thus implementing new water protection measures at the local level is recommendable. New measures to protect your local waters can be implemented also with smaller investments. These measures have especially local impacts, but they affect also the state of the common sea. The study provides information on the implementation of differing municipal water protection measures and their lifespan impacts, monetised environmental benefits, costs of implementation and the net benefits. All this information and lessons learned can be valuable when defining alternative solutions, designing new measures and implementing them at the local level. With some reservation, you can reflect your own actions to the studied case measures.

2. Implement different kinds of water protection measures and, when possible, prefer measures having connection to other fields of environmental protection in order to get multiple benefits.

The case studies represented examples from four themes showing how diverse water protection can be although they are only a small part of all possible measures and themes. They also showed that many kinds of benefits are usually related to the water protection and that the measures are often connected to the other fields of environmental protection. Thus, all kinds of water protection work around the Baltic Sea is needed: protection of the Baltic Sea should be seen as entirety within which every single measure is an important part. When planning your water protection work, prefer diverse measures that provide multiple benefits and, when possible, connect water protection to other fields of environmental protection, such as climate change mitigation and adaption, biodiversity protection etc.

3. Use cost-benefit analysis as a tool for choosing among potential measures to be implemented or to improve cost-efficiency of already implemented measures.

The study introduces the cost-benefit analysis method and how to apply it in municipal water protection work. It showed that the CBA can be very a valuable tool to support decision-making, because it provides help to understand the worth of water protection. The CBA can be conducted before or after implementing a measure. Conducting it beforehand, it gives information for decision-making, concerning which one of the alternatives would be the most efficient and provide the largest net benefits. Analysing the long-term benefits and costs of different alternatives may lead to substantial cost savings. In this study, the CBA was conducted for measures that were already implemented, to provide lessons learned. This kind of *ex post* CBA will provide knowledge on different measure and ideas how to implement similar measures more efficiently with smaller costs or larger benefits. Because the CBA is a rather heavy tool, it is recommendable mainly to larger investments. However, lighter versions of CBA and similar tools exist, such as a qualitative CBA and a cost-effectiveness analysis.

4. Put more effort in water protection research and data compilation.

The study revealed a need for more sufficient data compiling at the local level, because the lack of data was probably the biggest hindrance in conducting the prevailing cost-benefits analysis. If the possible impacts are not possible to assess, these are difficult to take into account in decision making. Especially more comprehensive long-term monitoring of the state of local water ecosystems and water quality would be important, as well as estimating the environmental benefits of ecosystem services in monetary values. In case of stormwater management, there is need for information on the quality and quantity of stormwaters and estimates for the costs savings and ecological benefits that natural stormwater management can provide. The information should be easily accessible and understandable, in order to be easily utilised in municipalities. Municipalities should compile cost and other data in an easily extractable form.

5. Utilise the existing networks, for example the Baltic Sea Challenge, for sharing ideas, experiences and best practices regarding water protection to get support for your own work.

The study showed that municipalities in the Baltic Sea region have implemented differing water protection actions and a lot of information already exists. Hence, local actors are not alone with their water protection work. The Baltic Sea Challenge is an international network for saving the Baltic Sea, with focus on concrete action at the local level. The network provides support for water protection work, networking opportunities as well as possibilities to exchange ideas, experiences, best practices and information concerning the water protection measures at a local level. You can also find partners for collaboration on water protection work.

References

Agengy of rural affairs MaVi. (2012). Suojavyöhykkeen perustaminen ja hoito – Ympäristötuen erityistukisopimus.

Ahlvik, L., & Ahtiainen, H. (2014). Marginal benefits of reducing nutrient loads to the Baltic Sea. Helsinki: MTT Agrifood Research Finland & City of Helsinki, EU Life+ project CITYWATER - Benchmarking water protection in cities.

Ahlvik, L., Ekholm, P., Hyytiäinen, K., & Pitkänen, H. (2014). An economic-ecological model to evaluate impacts of nutrient abatement in the Baltic Sea. Environmental Modelling & Software, 55, 164‐175.

Ahtiainen, H., Artell, J., & Czajkowski, M. (2014). Benefits of meeting nutrient reduction targets for the Baltic Sea – a contingent valuation study in the nine coastal states. Journal of Environmental Economics and Policy. doi: 10.1080/21606544.2014.901923

Ahtiainen, H., Hasselström, L., Artell, J., Angeli, D., Czajkowski, M., Meyerhoff, J., Alemu, M., Dahlbo, K., Fleming-Lehtinen, V., Hasler, B., Hyytiäinen, K., Karloseva, A., Khaleeva, Y., Maar, M., Martinsen, L., Nommann, T., Oskolokaite, I., Pakalniete, K., Semeniene, D., Smart, J. & Söderqvist, T. (2012). Benefits of meeting the Baltic Sea nutrient reduction targets–Combining ecological modelling and contingent valuation in the nine littoral states MTT Discussion Papers 1/2012: MTT Agrifood Research Finland.

Alahuhta, J. (2008). Selkämeren rannikkovesien tila, vesikasvillisuus ja kuormitus - Rehevöitymistarkastelu Lounais-Suomen ympäristökeskuksen raportteja (Vol. 9). Turku: Lounais-Suomen ympäristökeskus.

Baltic Deal project. (2012). Best agricultural practices around the Baltic Sea: Baltic Deal - a flagship project of the EUBSR.

BalticSTERN. (2013). The Baltic Sea - Our Common Treasure. Economics of saving the Sea. Swedish Agency for Marine and Water Management, Report 2013:4.

Bank of Finland. (2011). Valuuttojen keskikurssit 2011 Retrieved 26.3.2014, from http://www.suomenpankki.fi/fi/tilastot/valuuttakurssit/Documents/VK2011.pdf

Boardman, A., Greenberg, D., Vining, A., & Weimer, D. (2013). Cost-benefit analysis. Concepts and practice. (International ed of 4th revised ed ed.). Harlow: Pearson Education Limited.

City of Helsinki. (2014). Map service of City of Helsinki Retrieved 3.11.2014, from http://kartta.hel.fi/Default.aspx

City of Lahti. (2008). Lahden seudun toimenpideohjelma Itämerihaasteeseen. Lahti: Retrieved from http://www.itamerihaaste.net/files/76/Lahden_seudun_ympáristolautakunta.pdf.

City of Lahti. (2014). Väkiluku ja ikärakenne alueittain 1990, 1995, 2000 -. http://www4.lahti.fi/verkkotilastointi/

City of Lahti, & Jaakko Pöyry Infra. (2005). Kariston Purolaakso - virkistysalueiden yleissuunnittelu.

City of Lahti; Land Use Department. (2009). KARISTON ASUKASKYSELY 2009 Loppuraportti (Final report of Karisto citizen survey).

City of Liepaja. (2013), from http://www.liepaja.lv/page/22

City of Pori, & AIRIX Ympäristö Oy Turku. (2011). Vesihuollon kehittämissuunnitelma.

City of Turku The Real Estate and Measurement Authority (Cartographer). (2014). City of Turku map service. Retrieved from http://opaskartta.turku.fi/IMS/en/Map

City of Vantaa. (2009). Hulevesiohjelma (Storm water program) Kuntek 2/2009, Retrieved from https://www.vantaa.fi/instancedata/prime_product_julkaisu/vantaa/embeds/vantaawwwstructure/65801_Hulevesiohjelma_nettiin.pdf

Clean Baltic Sea Shipping. (2013). CLEANSHIP Final Report. In J. Madjidian, S. Björk, A. Nilsson & T. Halén (Eds.).

European Commission. (2008). Guide to cost-benefit analysis of investment projects. Structural Funds, Cohesion Fund and Instrument for Pre-Accession: European Commission Directorate General Regional Policy.

Finnish Environment Institute. (2013). Jätevedenpuhdistamoiden kuormitustiedot (Emission data of waste water treatment plants), from http://wwwp2.ymparisto.fi/Scripts/OivaVahti/PutsariDefault.asp

Hanley, N., Shogren, J., & White, B. (2007). Environmental economics in theory and practice. Basinstoke: Palgrave Macmillan.

HELCOM. (2007). HELCOM Recommendation 28E/5: Municipal wastewater treatment, from http://www.helcom.fi/Recommendations/en_GB/rec28E_5/

HELCOM. (2011). The Fifth Baltic Sea Pollution Load Compilation (PLC-5) Baltic Sea Environment Proceedings No. 128.

HELCOM. (2013). Review of the Fifth Baltic Sea Pollution Load Compilation for the 2013 HELCOM Ministerial Meeting Baltic Sea Environment Proceedings No. 141.

HELCOM. (2014a). 2013 HELCOM overview on port reception facilities for sewage in the Baltic Sea area and related trends in passenger traffic HELCOM 35-2014.

HELCOM. (2014b). Baltic Sea Action Plan - Targets Retrieved 26.3.2014, from http://helcom.fi/baltic-sea-action-plan/nutrient-reduction-scheme/targets/

HELCOM. (2014c). Baltic Sea data and map service. Retrieved 4.9.2014 http://maps.helcom.fi/website/mapservice/index.html

HELCOM. (2014d). Eutrophication status of the Baltic Sea 2007-2011 - A concise thematic assessment Baltic Sea Environment Proceedings No. 143.

Hippinen, I., & Suomi, U. (2012). Yhteenvetojen CO_2-päästöjen laskentaohjeistus sekä käytettävät CO_2-päästökertoimet: Motiva Oy.

HM Treasury. (2003). The green book: Appraisal and Evaluation in Central Government Retrieved from https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/220541/green_book_complete.pdf

HSY. (2013). Jätevedenpuhdistus pääkaupunkiseudulla 2012: Viikinmäen ja Suomenojan puhdistamot. Helsinki.

Huttunen, M., Vehviläinen, B., & Huttunen, I. (2013). Typen, fosforin ja kiintoaineksen pidättyminen vesistöissä– WSFS- Vemala-mallin arvio SUOMEN YMPÄRISTÖKESKUKSEN RAPORTTEJA 5 | 2013: Suomen ympäristökeskus (SYKE), Vesikeskus.

Hyytiäinen, K., & Ahlvik, L. (2014) Prospects for cost-efficient water protection in the Baltic Sea. Discussion Papers n:o 67. Helsinki: University of Helsinki, Department of Economics and Management.

Häme ELY Centre. (2010). Hämeen vesienhoidon toimenpideohjelma vuoteen 2015.

Ilveskorpi, L., Päivänen, J., Murole, P., Vanhanen, T., & Airas, P. (2007). Tiiviin ja matalan asuinalueen suunnittelu ja toteutus – esimerkkinä Lahden Karisto SUOMEN YMPÄRISTÖ 17. Helsinki.

International Energy Agency. (2014). Latvia: Electricity and heat for 2011. Retrieved 26.3.2014 http://www.iea.org/statistics/statisticssearch/report/?country=LATVIA&product=ElectricityandHeat&year=2011

International Maritime Organization. (2011). Special Area Provisions and the Designation of the Baltic Sea as a Special Area under MARPOL Annex IV.

Jutila, H., & Kesäniemi, O. (2006). Katumajärven hulevesikuormitus ja sen vähentäminen Hämeenlinnan seudullisen ympäristötoimen julkaisuja 4: Hämeenlinnan seudullinen ympäristötoimi JÄRKI-hanke.

Kollin, M. (2012). Jätevesiraportti: Port of Helsinki.

Kulmala, A. (2012). Buffer zones, from http://www.balticdeal.eu/measure/buffer-zones/

Lahti Region Environmental Services. (2010). Hulevesiohjelma (Storm water program) Retrieved from http://www.lahti.fi/www/images.nsf/files/7A259953034EF30CC2257A7D003E9226/$file/Hulevesiohjelma_lopullinen.pdf

Lahti Region Environmental Services, & Pöyry. (2006). Kariston Purolaakso - Mustaojan hulevesikosteikkojen toteutussuunnittelu.

Lankoski, J., Ollikainen, M., & Uusitalo, P. (2006). No-till technology: benefits to farmers and the environment? Theoretical analysis and application to Finnish agriculture. European Review of Agricultural Economics 33(2), 193–221.

Latvijas statistika. (2014). Consumer price index, 2010=100. Retrieved 4.7.2014 http://www.csb.gov.lv/en/statistikas-temas/consumer-prices-key-indicators-30504.html

Launto-Tiuttu, A., Heikkinen, J., Koskinen, J., Lankinen, E., Lundström, E., Puustinen, S., Röytiö, J., Vartiainen, E., Wilander, S. & Yli-Heikkilä, K. (2014). Targeted measures bring the greatest benefits for environmental protection in agriculture - Final report of the TEHO Plus project (2011-2014) Publication of the TEHO Plus project (Vol. 9).

Lehtoranta, V. (2013). Vesienhoidon arvo Vesijärvelle SUOMEN YMPÄRISTÖ 10 | 2013: Suomen ympäristökeskus, Vesikeskus.

Leppänen, J., Nevalainen, L., Rosqvist, K., & Sopanen, S. (2012). Action for a Healthier Sea! - Handbook for Voluntary Baltic Sea Protection in Cities and Municipalities

Mero, P. (2013). Lahden väestöennuste 2013: City of Lahti.

Moomaw, W., Burgherr, P., Heath, G., Lenzen, M., Nyboer, J., & Verbruggen, A. (2011). Annex II: Methodology. In O. Edenhofer, R. Pichs-Madruga, Y. Sokona, K. Seyboth, P. Matschoss, S. Kadner, T. Zwickel, P. Eickemeier, G. Hansen, S. Schlömer & C. v. Stechow (Eds.), IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation. United Kingdom and New York, USA: Cambridge University Press.

Mykrä, M. (2011). Keskitetyn jätevesien puhdistuksen vaikutus Kokemäenjokeen ja Porin edustan merialueelle johdettavan vesistökuormituksen määrään.

Official Statistics of Finland (OSF). (2014). Consumer price index, Appendix table 5. Consumer Price Index 2005=100. Retrieved 14.7.2014, from Statistics Finland http://www.tilastokeskus.fi/til/khi/2014/06/khi_2014_06_2014-07-14_tau_005_en.html

OpenStreetMap contributors (Cartographer). (2014). OpenStreetMap. Retrieved from http://www.openstreetmap.org/

Porin Vesi. (2013). Vuosikertomus (Annual report).

Port of Helsinki. (2014). Annual report 2013 Retrieved from http://www.portofhelsinki.fi/instancedata/prime_product_julkaisu/helsinginsatama/embeds/helsinginsatamawwwstructure/16598_Helsa_Vsk_2013_resume_WEB.pdf

Project on Urban Reduction of Eutrophication (PURE), & Union of the Baltic Cities (UBC) Environment Commission. (2012). Good practices in sludge management.

Puustinen, M., Turtola, E., Kukkonen, M., Koskiaho, J., Linjama, J., Niinioja, R., & Tattari, S. (2010). VIHMA—A tool for allocation of measures to control erosion and nutrient loading from Finnish agricultural catchments. Agriculture, Ecosystems and Environment, 138, 306-317.

Sarvala, M., & Sarvala, J. (2005). Miten voit, Selkämeri? Merialueen tila Satakunnan ja Vakka-Suomen rannikolla Ympäristön tila Lounais-Suomessa. Turku: Lounais-Suomen ympäristökeskus.

SEPA. (2008). Ecosystem services provided by the Baltic Sea and Skagerrak SWEDISH ENVIRONMENTAL PROTECTION AGENCY Report 5873.

Söderqvist, T., Ahtiainen, H., Artell, J., Czajkowski, M., Hasler, B., Hasselström, L., Huhtala, A., Källstrøm, M., Khaleeva, J., Martinsen, L., Meyerhoff, J., Nõmmann, T., Oskolokaite, I., Rastrigina, O., Semeniene, D., Soutukorva, Å., Tuhkanen, H., Vanags, A. & Volchkova, N. (2010). BalticSurvey – a study in the Baltic Sea countries of public attitudes and use of the sea SWEDISH ENVIRONMENTAL PROTECTION AGENCY Report 6348.

TEHO Plus. (2012). Pientareet, suojakaistat ja suojavyöhykkeet Retrieved 4.11.2014, from http://www.ymparisto.fi/download/noname/%7B0A0582EC-5FD8-427F-9236-69674E7DD046%7D/91499

The Baltic Sea Challenge. (2014). Itämerihaasteen toimenpidepankki. Retrieved 18.3.2014 http://www.itamerihaaste.net/toimenpidepankki

The Baltic Sea Portal. (2014), from http://www.itameriportaali.fi/en_GB/

Tol, R. S. J. (2011). The Social Cost of Carbon. Annual Review of Resource Economics, 3(1), 419-443.

University of Helsinki. (2014). Urban Oases: Shaping a Sustainable Future through Environmentally Functional Landscape Features, from http://www.helsinki.fi/urbanoases/Nummela/Prototypes/index_proto.html

US EPA. (2013, 26.11.2013). The Social Cost of Carbon Retrieved 15.12.2014, from http://www.epa.gov/climatechange/EPAactivities/economics/scc.html

Westerberg, V., Bonde, A., Mäensivu, M., & Mäkinen, M. (2014). Vesien tila hyväksi yhdessä: Ehdotus Kokemäenjoen-Saaristomeren-Selkämeren vesienhoitoalueen vesienhoitosuunnitelmaksi vuosiksi 2016–2021.

Ylinen, E. (2012). Talous ylös, ravinteet alas (seminar presentation).

Appendix

Appendix I: Luotsinmäki WWTP case

Appendix I-A. Monte Carlo sensitivity analysis results in the BSAP scenario: average NPVs and minimum and maximum NPVs with different lengths of lifespan (in euros)

BSAP		Discount rate	Minimum	0.01	Best guess	0.035	Maximum	0.06
Lifespan			**Best guess NPV**	**Best guess B/C**	**Best guess NPV**	**Best guess B/C**	**Best guess NPV**	**Best guess B/C**
			*Min. NPV**	*Max. NPV**	*Min. NPV**	*Max. NPV**	*Min. NPV**	*Max. NPV**
			P(NPV>0)**		P(NPV>0)**		P(NPV>0)**	
Minimum	**Best guess NPV**	**Best guess B/C**	**–35,804,078**	**0.64**	**–42,032,227**	**0.57**	**–48,573,830**	**0.51**
20	*Min. NPV**	*Max. NPV**	*–43,834,625*	*–27,253,832*	*–49,029,511*	*–34,770,475*	*–54,622,094*	*–42,246,475*
	P(NPV>0)**		0.000		0.000		0.000	
Best guess	**Best guess NPV**	**Best guess B/C**	**–32,887,738**	**0.74**	**–40,301,333**	**–0.64**	**–47,528,714**	**0.56**
30	*Min. NPV**	*Max. NPV**	*–44,569,360*	*–20,964,970*	*–54,256,016*	*–21,893,037*	*–55,020,978*	*–40,137,137*
	P(NPV>0)**		0.000		0.000		0.000	
Maximum	**Best guess NPV**	**Best guess B/C**	**–30,200,611**	**0.80**	**–39,052,161**	**0.68**	**–46,934,490**	**0.58**
40	*Min. NPV**	*Max. NPV**	*–45,264,851*	*–14,914,427*	*–49,670,035*	*–27,928,492*	*–55,054,930*	*–38,758,556*
	P(NPV>0)**		0.000		0.000		0.000	

* Range from minimum NPV and maximum NPV, obtained in the Monte Carlo sensitivity analysis

** Probability that NPV is positive, obtained in the Monte Carlo sensitivity analysis performed by 10,000 iterations

Appendix I-B. Monte Carlo sensitivity analysis results in the BASELINE scenario: average NPVs and minimum and maximum NPVs with different lengths of lifespan (in euros)

BASELINE		Discount rate	Minimum	0.01	Best guess	0.035	Maximum	0.06
Lifespan			**Best guess NPV**	**Best guess B/C**	**Best guess NPV**	**Best guess B/C**	**Best guess NPV**	**Best guess B/C**
			*Min. NPV**	*Max. NPV**	*Min. NPV**	*Max. NPV**	*Min. NPV**	*Max. NPV**
			P(NPV>0)**		P(NPV>0)**		P(NPV>0)**	
Minimum	**Best guess NPV**	**Best guess B/C**	**107,197,005**	**2.07**	**83,708,046**	**1.85**	**64,552,846**	**1.65**
20	*Min. NPV**	*Max. NPV**	*63,709,367*	*154,667,522*	*46,803,358*	*123,238,255*	*33,391,986*	*98,325,361*
	P(NPV>0)**		1.000		1.000		1.000	
Best guess	**Best guess NPV**	**Best guess B/C**	**169,511,151**	**2.35**	**120,698,359**	**2.07**	**86,891,085**	**1.81**
30	*Min. NPV**	*Max. NPV**	*102,387,139*	*237,457,349*	*69,533,417*	*173,144,030*	*47,955,840*	*128,917,756*
	P(NPV>0)**		1.000		1.000		1.000	
Maximum	**Best guess NPV**	**Best guess B/C**	**226,543,661**	**2.53**	**147,214,198**	**2.19**	**99,505,879**	**1.88**
40	*Min. NPV**	*Max. NPV**	*139,949,809*	*318,286,263*	*87,956,823*	*211,835,912*	*56,064,436*	*146,068,543*
	P(NPV>0)**		1.000		1.000		1.000	

* Range from minimum NPV and maximum NPV, obtained in the Monte Carlo sensitivity analysis

** Probability that NPV is positive, obtained in the Monte Carlo sensitivity analysis performed by 10,000 iterations

Appendix II: Liepaja WWTP case

Appendix II-A. Monte Carlo sensitivity analysis results in the BSAP scenario: average NPVs and minimum and maximum NPVs with different lengths of lifespan (in euros)

BSAP		Discount rate	Minimum	0.01	Best guess	0.035	Maximum	0.06
Lifespan			**Best guess NPV**	**Best guess B/C**	**Best guess NPV**	**Best guess B/C**	**Best guess NPV**	**Best guess B/C**
			*Min. NPV**	*Max. NPV**	*Min. NPV**	*Max. NPV**	*Min. NPV**	*Max. NPV**
			P(NPV>0)**		P(NPV>0)**		P(NPV>0)**	
Minimum	**Best guess NPV**	**Best guess B/C**	**1,464,204**	**3.93**	**1,347,696**	**3.42**	**1,237,603**	**3.00**
10	*Min. NPV**	*Max. NPV**	*1,162,025*	*1,995,154*	*1,085,925*	*1,862,376*	*982,002*	*1,693,793*
	P(NPV>0)**		1.000		1.000		1.000	
Best guess	**Best guess NPV**	**Best guess B/C**	**2,348,452**	**5.61**	**2,058,050**	**4.65**	**1,811,912**	**3.90**
15	*Min. NPV**	*Max. NPV**	*1,881,612*	*3,204,188*	*1,626,355*	*2,826,021*	*1,433,565*	*2,542,421*
	P(NPV>0)**		1.000		1.000		1.000	
Maximum	**Best guess NPV**	**Best guess B/C**	**3,189,873**	**7.16**	**2,656,207**	**5.66**	**2,241,107**	**4.57**
20	*Min. NPV**	*Max. NPV**	*2,483,653*	*4,402,132*	*2,133,268*	*3,665,882*	*1,787,857*	*3,,110,836*
	P(NPV>0)**		1.000		1.000		1.000	

* Range from minimum NPV and maximum NPV, obtained in the Monte Carlo sensitivity analysis

** Probability that NPV is positive, obtained in the Monte Carlo sensitivity analysis performed by 10,000 iterations

Appendix II-B. Monte Carlo sensitivity analysis results in the BASELINE scenario: average NPVs and minimum and maximum NPVs with different lengths of lifespan (in euros)

BASELINE		Discount rate	Minimum	0.01	Best guess	0.035	Maximum	0.06
Lifespan			**Best guess NPV**	**Best guess B/C**	**Best guess NPV**	**Best guess B/C**	**Best guess NPV**	**Best guess B/C**
			*Min. NPV**	*Max. NPV**	*Min. NPV**	*Max. NPV**	*Min. NPV**	*Max. NPV**
			P(NPV>0)**		P(NPV>0)**		P(NPV>0)**	
Minimum	**Best guess NPV**	**Best guess B/C**	**13,782,138**	**28.54**	**13,264,618**	**24.84**	**12,828,330**	**21.76**
10	*Min. NPV**	*Max. NPV**	*9,705,546*	*19,148,493*	*9,399,189*	*18,460,718*	*9,158,951*	*17,794,103*
	P(NPV>0)**		1.000		1.000		1.000	
Best guess	**Best guess NPV**	**Best guess B/C**	**20,374,713**	**40.99**	**18,560,707**	**33.92**	**17,110,121**	**28.43**
15	*Min. NPV**	*Max. NPV**	*13,902,623*	*29,403,044*	*12,715,589*	*26,312,232*	*11,857,526*	*24,108,976*
	P(NPV>0)**		1.000		1.000		1.000	
Maximum	**Best guess NPV**	**Best guess B/C**	**26,647,412**	**52.43**	**23,019,930**	**41.40**	**20,309,761**	**33.33**
20	*Min. NPV**	*Max. NPV**	*17,568,815*	*38,705,386*	*15,371,069*	*32,955,901*	*13,832,565*	*28,882,645*
	P(NPV>0)**		1.000		1.000		1.000	

* Range from minimum NPV and maximum NPV, obtained in the Monte Carlo sensitivity analysis

** Probability that NPV is positive, obtained in the Monte Carlo sensitivity analysis performed by 10,000 iterations

1.1
Appendix III: Port of Helsinki case

Appendix III-A. Monte Carlo sensitivity analysis results in the BSAP scenario: average NPVs and minimum and maximum NPVs with different lengths of lifespan (in euros)

BSAP		Discount rate	Minimum	0.01	Best guess	0.035	Maximum	0.06
Lifespan			**Best guess NPV**	**Best guess B/C**	**Best guess NPV**	**Best guess B/C**	**Best guess NPV**	**Best guess B/C**
			Min. NPV*	Max. NPV*	Min. NPV*	Max. NPV*	Min. NPV*	Max. NPV*
			P(NPV>0)**		P(NPV>0)**		P(NPV>0)**	
Minimum	**Best guess NPV**	**Best guess B/C**	**–6,371,905**	**0.55**	**–6,873,040**	**0.51**	**–7,677,576**	**0.46**
2030	Min. NPV*	Max. NPV*	*–10,701,211*	*2,091,836*	*–10,410,628*	*199,697*	*–10,887,041*	*–1,162,040*
	P(NPV>0)**		0.0176		0.0003		0.0000	
Best guess	**Best guess NPV**	**Best guess B/C**	**–7,484,803**	**0.59**	**–7,533,867**	**0.54**	**–8,076,763**	**0,.9**
2040	Min. NPV*	Max. NPV*	*–14,369,042*	*4,551,152*	*–12,707,600*	*2,200,961*	*–12,083,606*	*–224,348*
	P(NPV>0)**		0.0861		0.0121		0.0000	
Maximum	**Best guess NPV**	**Best guess B/C**	**–8,492,295**	**0.61**	**–8,002,340**	**0.56**	**–8,299,667**	**0.50**
2050	Min. NPV*	Max. NPV*	*–17,353,359*	*6,240,661*	*–13,949,133*	*3,017,995*	*–13,091,660*	*133,213*
	P(NPV>0)**		0.1451		0.0316		0.0001	

* Range from minimum NPV and maximum NPV, obtained in the Monte Carlo sensitivity analysis

** Probability that NPV is positive, obtained in the Monte Carlo sensitivity analysis performed by 10,000 iterations

Appendix III-B. Monte Carlo sensitivity analysis results in the BASELINE scenario: average NPVs and minimum and maximum NPVs with different lengths of lifespan (in euros)

BASELINE		Discount rate	Minimum	0,01	Best guess	0,035	Maximum	0,06
Lifespan			**Best guess NPV**	**Best guess B/C**	**Best guess NPV**	**Best guess B/C**	**Best guess NPV**	**Best guess B/C**
			Min. NPV*	Max. NPV*	Min. NPV*	Max. NPV*	Min. NPV*	Max. NPV*
			P(NPV>0)**		P(NPV>0)**		P(NPV>0)**	
Minimum	**Best guess NPV**	**Best guess B/C**	**67,924,561**	**5,78**	**60,590,433**	**5,33**	**55,307,366**	**4,86**
2030	Min. NPV*	Max. NPV*	*52,996,702*	*134,922,813*	*47,485,881*	*118,094,235*	*43,688,978*	*110,297,440*
	P(NPV>0)**		1,000		1,000		1,000	
Best guess	**Best guess NPV**	**Best guess B/C**	**94,181,766**	**6,17**	**76,181,692**	**5,66**	**64,725,607**	**5,11**
2040	Min. NPV*	Max. NPV*	*70,376,482*	*190,534,702*	*57,855,899*	*154,178,908*	*51,042,443*	*126,172,808*
	P(NPV>0)**		1,000		1,000		1,000	
Maximum	**Best guess NPV**	**Best guess B/C**	**117,952,072**	**6,41**	**87,234,628**	**5,84**	**69,984,704**	**5,23**
2050	Min. NPV*	Max. NPV*	*90,290,101*	*233,972,095*	*65,799,362*	*170,930,041*	*51,428,022*	*139,342,444*
	P(NPV>0)**		1,000		1,000		1,000	

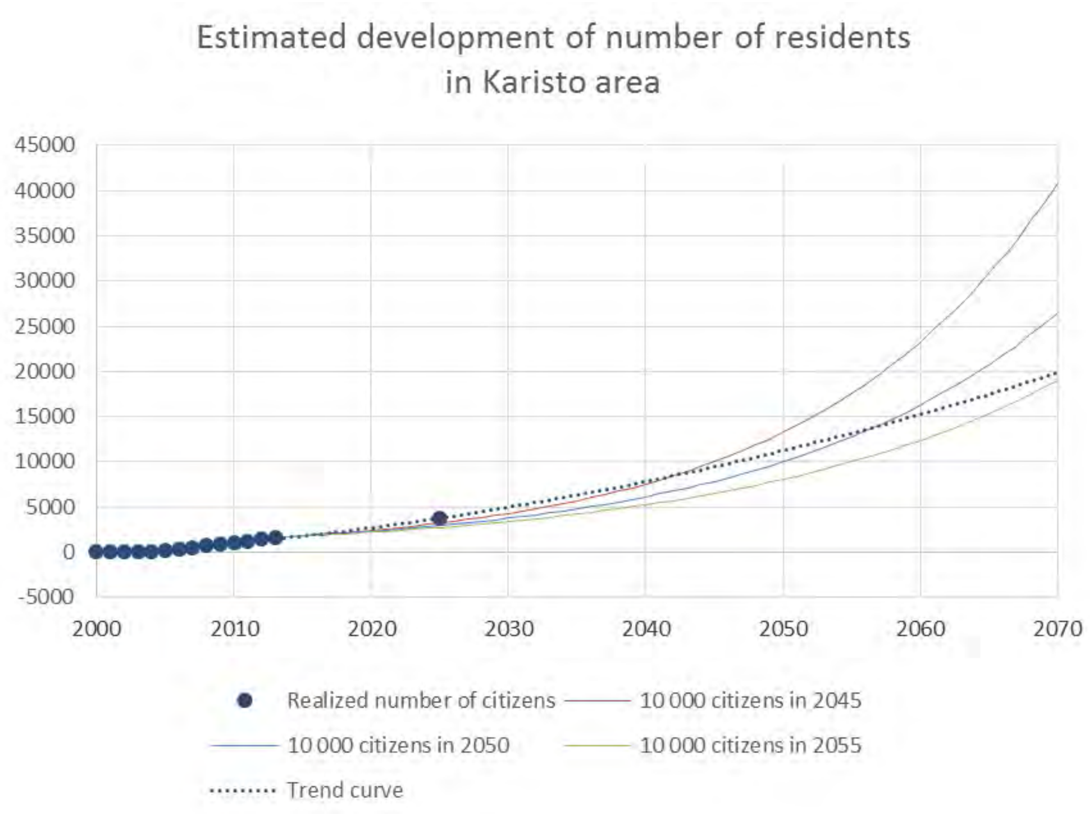
* Range from minimum NPV and maximum NPV, obtained in the Monte Carlo sensitivity analysis

** Probability that NPV is positive, obtained in the Monte Carlo sensitivity analysis performed by 10 000 iterations

Appendix IV: Lahti stormwater wetland case

Appendix IV-A. The development of number of residents in the Karisto area

	Annual growth rate, %	3,700 residents in year	7,000 residents in year	10,000 residents in year
Minimum	4.38	2032	2047	2055
Best guess	4.99	2030	2043	2050
Maximum	5.79	2027	2039	2045



Appendix IV-B. Monte Carlo sensitivity analysis results in the BSAP scenario: average NPVs and minimum and maximum NPVs with different lengths of lifespan (in euros)

		Discount rate	Minimum	0.01	Best guess	0.035	Maximum	0.06
Lifespan			**Best guess NPV**	**Best guess B/C**	**Best guess NPV**	**Best guess B/C**	**Best guess NPV**	**Best guess B/C**
			Min. NPV*	Max. NPV*	Min. NPV*	Max. NPV*	Min. NPV*	Max. NPV*
			P(NPV>0)**		P(NPV>0)**		P(NPV>0)**	
Minimum	**Best guess NPV**	**Best guess B/C**	**257.131**	**1.38**	**–102,581**	**0.85**	**–327,575**	**0.54**
2050	Min. NPV*	Max. NPV*	–295,503	985,687	–440,381	347,726	–548,714	–47,085
	P(NPV>0)**		0.795		0.340		0.000	
Best guess	**Best guess NPV**	**Best guess B/C**	**771,651**	**2.07**	**82,784**	**1.12**	**–258,821**	**0.64**
2060	Min. NPV*	Max. NPV*	–138,273	2,101,813	–376,792	747,319	–526,387	103,786
	P(NPV>0)**		0.988		0.629		0.035	
Maximum	**Best guess NPV**	**Best guess B/C**	**1,554,600**	**3.05**	**303,747**	**1.43**	**–194,243**	**0.73**
2070	Min. NPV*	Max. NPV*	154,247	3,889,741	–310,053	1,234,041	–504,270	247,448
	P(NPV>0)**		1.000		0.820		0.159	

* Range from minimum NPV and maximum NPV, obtained in the Monte Carlo sensitivity analysis

** Probability that NPV is positive, obtained in the Monte Carlo sensitivity analysis performed by 10 000 iterations

Appendix IV-C. Monte Carlo sensitivity analysis results in the BASELINE scenario: average NPVs and minimum and maximum NPVs with different lengths of lifespan (in euros)

BASELINE		Discount rate	Minimum	0.01	Best guess	0.035	Maximum	0.06
Lifespan			**Best guess NPV**	**Best guess B/C**	**Best guess NPV**	**Best guess B/C**	**Best guess NPV**	**Best guess B/C**
			Min. NPV*	Max. NPV*	Min. NPV*	Max. NPV*	Min. NPV*	Max. NPV*
			P(NPV>0)**		P(NPV>0)**		P(NPV>0)**	
Minimum	**Best guess NPV**	**Best guess B/C**	**319,012**	**1.47**	**–58,200**	**0.91**	**–293,172**	**0.59**
2050	Min. NPV*	Max. NPV*	–257,750	1,095,399	–426,703	418,245	–532,891	8,098
	P(NPV>0)**		0.854		0.414		0.000	
Best guess	**Best guess NPV**	**Best guess B/C**	**845,521**	**2.18**	**131,531**	**1.19**	**–222,782**	**0.69**
2060	Min. NPV*	Max. NPV*	–85,059	2,261,832	–356,348	807,595	–516,465	167,843
	P(NPV>0)**		0.996		0.688		0.071	
Maximum	**Best guess NPV**	**Best guess B/C**	**1,639,323**	**3.16**	**355,589**	**1.51**	**–157,291**	**0.78**
2070	Min. NPV*	Max. NPV*	165,399	3,998,392	–277,943	1,303,019	–486,598	290,685
	P(NPV>0)**		1.000		0.867		0.227	

* Range from minimum NPV and maximum NPV, obtained in the Monte Carlo sensitivity analysis

** Probability that NPV is positive, obtained in the Monte Carlo sensitivity analysis performed by 10,000 iterations

Appendix V: Case field by the river Aurajoki

Appendix V-A. Monte Carlo sensitivity analysis results in the BSAP scenario: average NPVs and minimum and maximum NPVs with different lengths of lifespan (in euros)

BSAP	Discount rate		Minimum	0.01	Best guess NPV	0.035	Maximum	0.06
			Best guess NPV	**Best guess B/C**	**Best guess NPV**	**Best guess B/C**	**Best guess NPV**	**Best guess B/C**
			*Min. NPV**	*Max. NPV**	*Min. NPV**	*Max. NPV**	*Min. NPV**	*Max. NPV**
			P(NPV>0)**		P(NPV>0)**		P(NPV>0)**	
Lifespan	**Best guess NPV**	**Best guess B/C**	**36,985**	**1.47**	**41,459**	**1.48**	**46,531**	**1.49**
2015	*Min. NPV**	*Max. NPV**	*5,420*	*196,206*	*7,475*	*227,115*	*10,482*	*242,037*
	P(NPV>0)**		1.000		1.000		1.000	

* Range from minimum NPV and maximum NPV, obtained in the Monte Carlo sensitivity analysis

** Probability that NPV is positive, obtained in the Monte Carlo sensitivity analysis performed by 10,000 iterations

Appendix V-B. Monte Carlo sensitivity analysis results in the BASELINE scenario: average NPVs and minimum and maximum NPVs with different lengths of lifespan (in euros)

BASELINE	Discount rate		Minimum	0.01	Best guess NPV	0.035	Maximum	0.06
			Best guess NPV	**Best guess B/C**	**Best guess NPV**	**Best guess B/C**	**Best guess NPV**	**Best guess B/C**
			*Min. NPV**	*Max. NPV**	*Min. NPV**	*Max. NPV**	*Min. NPV**	*Max. NPV**
			P(NPV>0)**		P(NPV>0)**		P(NPV>0)**	
Lifespan	**Best guess NPV**	**Best guess B/C**	**454,485**	**6.75**	**507,046**	**6.87**	**566,575**	**6.97**
2015	*Min. NPV**	*Max. NPV**	*199,897*	*1,743,153*	*213,685*	*1,987,170*	*228,918*	*2,268,989*
	P(NPV>0)**		1.000		1.000		1.000	

* Range from minimum NPV and maximum NPV, obtained in the Monte Carlo sensitivity analysis

** Probability that NPV is positive, obtained in the Monte Carlo sensitivity analysis performed by 10,000 iterations

Appendix VI: Case field by river Vähäjoki

Appendix VI-A. Monte Carlo sensitivity analysis results in the BSAP scenario: average NPVs and minimum and maximum NPVs with different lengths of lifespan (in euros)

BSAP		Discount rate	Minimum	0.01	Best guess NPV	0.035	Maximum	0.06
			Best guess NPV	**Best guess B/C**	**Best guess NPV**	**Best guess B/C**	**Best guess NPV**	**Best guess B/C**
			*Min. NPV**	*Max. NPV**	*Min. NPV**	*Max. NPV**	*Min. NPV**	*Max. NPV**
			P(NPV>0)**		P(NPV>0)**		P(NPV>0)**	
Lifespan	**Best guess NPV**	**Best guess B/C**	**–4,237**	**0.34**	**–4,211**	**0.34**	**–4,190**	**0.33**
2015	*Min. NPV**	*Max. NPV**	*–5,613*	*–2,196*	*–5,558*	*–2,066*	*–5,403*	*–2,237*
	P(NPV>0)**		0.000		0.000		0.000	

* Range from minimum NPV and maximum NPV, obtained in the Monte Carlo sensitivity analysis

** Probability that NPV is positive, obtained in the Monte Carlo sensitivity analysis performed by 10 000 iterations

Appendix VI-B. Monte Carlo sensitivity analysis results in the BASELINE scenario: average NPVs and minimum and maximum NPVs with different lengths of lifespan (in euros)

BASELINE		Discount rate	Minimum	0.01	Best guess NPV	0.035	Maximum	0.06
			Best guess NPV	**Best guess B/C**	**Best guess NPV**	**Best guess B/C**	**Best guess NPV**	**Best guess B/C**
			*Min. NPV**	*Max. NPV**	*Min. NPV**	*Max. NPV**	*Min. NPV**	*Max. NPV**
			P(NPV>0)**		P(NPV>0)**		P(NPV>0)**	
Lifespan	**Best guess NPV**	**Best guess B/C**	**20,164**	**4.15**	**19,627**	**4.10**	**19,137**	**4.05**
2015	*Min. NPV**	*Max. NPV**	*7,460*	*40,478*	*7,184*	*37,880*	*6,691*	*37,264*
	P(NPV>0)**		1.000		1.000		1.000	

* Range from minimum NPV and maximum NPV, obtained in the Monte Carlo sensitivity analysis

** Probability that NPV is positive, obtained in the Monte Carlo sensitivity analysis performed by 10,000 iterations

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