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Reducing Emissions by Turning Nutrients and Carbon into Benefits
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Deliverable No: D.3.5 – Assessment of costs and benefits for selected eco-technologies. CBA analysis of selected eco-technologies in the BSR

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x	PU	Public.
	PP	Restricted to other project partners.
	RE	Restricted to a group specified by the consortium.
	CO	Confidential, only for members of the consortium.

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EXECUTIVE SUMMARY

The following report serves as "Deliverable 3.5" and contains the assessment of costs and benefits of ecotechnologies, which were selected in the three BONUS RETURN empirical case areas (Slupsk in Poland, Vantaanjoki in Finland, and Fyris in Sweden). This assessment aims to enable the understanding on how cost benefit analysis models based on a bottom-up approach are an instrument for decision-making of adoption of selected eco-technologies, where the social and private components of those costs and benefits, may trigger or hinder their adoption.

This report presents an overview of the cost and benefits for the selected eco-technologies. It combines cost-benefit analysis (CBA) and multi-criteria analysis (MCA) within wastewater treatment and reused nutrients, such as phosphorus products with the aim to support the effective implementation of ecotechnologies when prioritising projects to circulate and reuse available nutrient resources. By incorporating MCA results into a CBA this approach retains the strengths of each appraisal method and provides a procedure for decision makers to create an initial ranking of eco-technologies

Data were collected from a series of datasets gathered for key workshops and stakeholders and analysed on a Multi-Criteria Analysis (MCA) of the Bonus Return project executed by RISE -Research Institutes of Sweden. The co-enquiry process with stakeholders support an evidence-based review and a sustainability analysis of a number of selected eco-technologies. The primary and secondary data sources, literature and key stakeholders from the industrial, consultancy and farming sectors where all included.

Initial findings from this study indicate that only a few technologies provide a positive net present value at the current stage of the RETURN project.

However, the results and the outcome from the CBA analyses and its assumptions must be interpreted with caution as an update of the assumptions and assessment of cost and benefits according to scenarios may occur within the last part of the project period in RETURN.

1 INTRODUCTION

The degradation of the Baltic Sea is an ongoing problem, despite investments in measures to reduce external inputs of pollutants and nutrients from both diffuse and point sources. Available technological and management measures to curb eutrophication and pollution flows to the sea have not been adapted adequately to the contexts in which they are being applied. Furthermore, measures are often designed based on single objectives, thereby limiting opportunities for multiple benefits.

In addition, there is a general sense that measures to address the deterioration of the Baltic ecosystem are primarily technologically-driven and lacking broader stakeholder acceptance – the "experts" who define these measures have little engagement with industry, investors, civil society and authorities. This problem is magnified by governance and management, taking place in sectoral silos with poor coordination across sectors.

As a result, research shows that regional institutional diversity is presently a barrier to transboundary cooperation in the Baltic Sea Region (BSR) and that actions to achieve national environmental targets can compromise environmental goals in the BSR (Powell et al. 2013). The regional dimension of environmental degradation in the BSR has historically received weaker recognition in policy development and implementation locally. However, developments in recent years suggest a new trend with growing investments in environmental protection supporting social, economic, and territorial cohesion.

The BSR is an environmentally, politically and economically significant region and like other regions globally, its rapid growth needs to be reconciled with the challenges of sustainable development in a global setting that demands unprecedented reductions in GHG emissions. This poses a truly wicked problem exacerbated by the fact that many of the challenges in the BSR will also magnify in a changing climate. In order to navigate the uncertainties and controversies associated with a transformation towards a good marine environment, BONUS RETURN will enact an innovative trans disciplinary approach for identifying and piloting systemic eco-technologies.

The focus is on eco-technologies that generate co-benefits within other interlinked sectors, and which can be adapted according to geophysical and institutional contexts. More specifically, emphasis is placed on eco-technologies that reconcile the reduction of present and future eutrophication in marine environments with the regional challenges of policy coherence, food security, energy security, and the provision of ecosystem services.

1.1 Project Objectives

The **overall** aim of BONUS RETURN is to improve the adaptation and adoption of eco-technologies in the Baltic Sea Region for maximum efficiency and increased co-benefits.

The **specific objectives** of the project can be divided into six categories presented below. These categories are interlinked but for the purpose of providing a step-wise description, the following overview of each category proves useful. BONUS RETURN is:

1) Supporting innovation and market uptake of eco-technologies by:

- Contributing to the application and adaptation of eco-technologies in the BSR through an evidence-based review (systematic map) of the developments within this field.
- Contributing to the development of emerging eco-technologies that have the capacity to turn nutrients and carbon into benefits (e.g. bio-energy, fertilizers), by providing an encompassing framework and platform for rigorous testing and analysis.
- Developing decision support systems for sustainable eco-technologies in the BSR.
- Contributing to better assessment of eco-technology efficiency via integrated and participatory modelling in three catchment areas in Finland, Sweden and Poland.
- Contributing to methodological innovation on application and adaptation of eco-technologies.

2) Reducing knowledge gaps on policy performance, enabling/constraining factors, and costs and benefits of eco-technologies by:

- Assessing the broader socio-cultural drivers linked to eco-technologies from a historical perspective.
- Identifying the main gaps in the policy environment constraining the implementation of emerging eco-technologies in the catchments around the Baltic Sea.
- Informing policy through science on what works where and under which conditions through an evidence-based review (systematic map and systematic reviews) of eco-technologies and the regional economic and institutional structures in which these technologies evolve.

3) Providing a framework for improved systematic stakeholder involvement by:

- Developing methods for improved stakeholder engagement in water management through participatory approaches in the case study areas in Sweden, Finland and Poland.
- Enacting a co-enquiry process with stakeholders into opportunities for innovations in eco-technologies capable of transforming nutrients and pollutants into benefits for multiple sectors at different scales.
- Bringing stakeholder values into eco-technology choices to demonstrate needs for adaptation to local contexts and ways for eco-technologies to efficiently contribute to local and regional developments.
- Disseminating results and facilitating the exchange of learning experiences, first within the three catchment areas, and secondly across a larger network of municipalities in the BSR.
- Establishing new cooperative networks at case study sites and empowering existing regional networks by providing information, co-organizing events and engaging in dialogues.

4) Supporting commercialization of eco-technologies by:

- Identifying market and institutional opportunities for eco-technologies that (may) contribute to resource recovery and reuse of nutrients, micro-pollutants and micro-plastics (e.g. renewable energy).

- Identifying potential constraints and opportunities for integration and implementation of eco-technologies using economical models.
- Facilitating the transfer of eco-technologies contributing to win-win solutions to multiple and interlinked challenges in the BSR.
- Linking producers of eco-technologies (small and medium enterprises – SMEs), to users (municipalities) by providing interactive platforms of knowledge exchange where both producers and users have access to BONUS RETURN's envisaged outputs, existing networks, and established methodologies and services.

5) Establishing a user-driven knowledge platform and improved technology-user interface by:

- Developing an open-access database that maps out existing research and implementation of eco-technologies in the BSR. This database will be intuitive, mapped out in an interactive geographical information system (GIS) platform, and easily managed so that practitioners, scientists and policy-makers can incorporate it in their practices.
- Developing methodologies that enact the scaling of a systemic mix of eco-technological interventions within the highly diverse contexts that make up the BSR and allows for a deeply interactive medium of knowledge.

1.2 Project Structure

BONUS RETURN is structured around six Work Packages that will be implemented in three river basins: The Vantaanjoki river basin in Finland, the Słupia river basin in Poland, and Fyrisån river basin in Sweden.

Work Package 1: Coordination, management, communication and dissemination.
Work Package 2: Integrated Evidence-based review of eco-technologies.
Work Package 3: Sustainability Analyses.
Work Package 4: Environmental Modelling.
Work Package 5: Implementation Support for Eco-technologies.
Work Package 6: Innovative Methods in Stakeholder Engagement.

1.1 Deliverable context and objective

The current deliverable (Del. No. 3.5) is part of WP 3. The overall aim of this study is to assess the welfare economic net benefits of three selected eco-technologies in each of the catchment areas. The objectives of WP3 are:

"to evaluate sustainability aspects of eco-technologies selected in WP2 using a decision support-based framework for sustainability analysis for each catchment area. The application of sustainability analysis includes a step-wise systems analysis approach to be carried out together with local stakeholders by: 1) defining system boundaries; 2) selecting criteria covering health and hygiene, environmental issues, economy, socio-cultural dimensions and technical function; 3) selecting and formulating different system alternatives based on the review of eco-technologies from WP 2; 4) comparing the different options using the criteria from step 2. The comparison will be done by using substance flow-, cost-effectiveness and cost benefit analysis, energy analysis and also qualitative assessments. Results of environmental impacts will be imported from WP4. In step 4, a multi-criteria analysis will be used for an integrated assessment of all dimensions to reach a complete decision support system for municipalities or regions. A second objective of WP3 will be to identify upcoming innovations for reuse (TRL 5 or higher), using the same sustainability criteria as above. The final results of WP3 will be a selection of interesting eco-technologies for further development in WP5" (DoW 2019).

This deliverable describes the steps of the CBA analysis and provides an overview of the cost and benefits of selected eco-technologies. Usually a CBA analysis start with a pre-defined policy option made by decision makers or experts. Here the CBA begins with the underlying environmental problem, and then assesses the costs and benefits of the different solutions as identified by stakeholders found in the multicriteria analysis. In addition, this deliverable presents an overview of cost and benefits from these different solutions and selected ecotechnologies compared with a baseline scenario.

1.2 Outline of the report

This report is structured into the following sub-sections:

1. Assessment of the cost benefit analysis model in BSR.
2. Assessment and economic models of selected ecotechnologies
3. Limitations and concluding remarks

2 ASSESSMENT OF THE COST BENEFIT ANALYSIS MODEL IN THE BALTIC SEA REGION.

2.1 Background

2.1.1 Cost-Benefit Analysis (CBA)

Cost-Benefit Analysis (CBA) is a widely accepted method for evaluating policies and projects (Hanley & Barbier, 2009; Molinos-Senante et al., 2010). Essentially, CBA collects all costs and benefits of some intervention (like a project, policy or measure) into a bottom-line, the net present value (NPV). A positive NPV entails that the benefits outweigh the associated costs, and vice versa. From an economic point of view, interventions with positive NPVs should consequently be implemented. While originally only considering purely monetary values, the inclusion of social and/or environmental values into CBA was introduced in the 1980s (cf. Johansson, 1993; Molinos-Senante et al., 2010; Pearce & Nash, 1981). A CBA may therefore assess if some change is leading to a *potential Pareto improvement*, i.e. if the overall social welfare is increasing or decreasing. A CBA can be broken down to six consecutive analysis stages (Hanley & Barbier, 2009; OECD, 2018; Pearce, 2006):

1. Project or policy definition: Description of the change to be analysed; definition of the population and the spatial and temporal system.
2. Identification of physical impacts of the policy or project: Appraisal and quantification of the relevant physical impacts within the defined system boundaries.
3. Valuing the physical impacts: Allocating monetary values to the physical impacts, e.g. based on primary WTP/WTA-studies or benefit transfer.
4. Discounting of both cost and benefits: Conversion of all monetary flows into present value terms, based on a relevant (social) discount rate.
5. Applying the Net Present Value (NPV) test: Assessment whether the sum of discounted gains (benefits) exceeds the sum of discounted losses (costs).
6. Sensitivity analyses: Calculation of the NPV with changing key parameters.

Despite its limited use as the only criterion, CBA is increasingly applied as one component in environmental decision-making (Atkinson et al., 2018; OECD, 2018). For instance, the EU Water Framework Directive (WFD), the EU Marine Strategy Framework Directive (MSFD) suggest and/or request CBAs.

The use of CBA seems to be a pertinent method to approach to the study suggestions, on the need to mainstream circular economy across society and governance structures. It seeks the use of reliable data and significant understanding of the case specific scenarios, to simplify the legal framework for reused phosphorus products in the EU. Moreover, CBA are required to study the enforcement of sustainable solutions that ensure circularity in public procurement as well as support testbeds for circular solutions in municipalities. The eco-technologies approach new business models with increased collaboration between wastewater treatment plants (a source of Phosphorus), fertilizer companies (a potential client for reused Phosphorus), and farmers (potential end-users of recycled Phosphorus).

3 ASSESSMENT AND ECONOMIC MODELS OF SELECTED ECOTECHNOLOGIES

The bottom-up approach is achieved using data and processes including several stakeholder workshops in the catchment areas. Based on these series of workshops, the evaluation of sustainability analysis using multi-criteria analysis (MCA) was implemented by Johannesdottir, et al (2019) on deliverable 3.3.[1]

From the MCA, three selected ecotechnologies per catchment area are selected for the cost-benefit analysis (CBA) in order to evaluate and support decision–making processes for investment in the specific wastewater treatment plants (WWTPs). The MCA approach was part of the BONUS RETURN project (https://www.bonusreturn.eu/) and used as decision support tool for urban and rural water, wastewater and solid waste management in this context.

[1] https://www.bonusreturn.eu/wp-content/uploads/2019/05/BONUSRETURN_D3.3_REPORT_FROM_THE_MULTICRITERIA_ANALYSIS.pdf

This report develops and then applies an approach of combining CBA and MCA within a wastewater treatment and reused nutrients, such as phosphorus products with the aim to support the effective implementation of ecotechnologies when prioritising projects to circulate and reuse available nutrient resources. By incorporating MCA results into a CBA, this approach retains the strengths of each appraisal method and provides a procedure for decision makers to create an initial ranking of ecotechnologies, which is consistent between all candidate investments for the ecotechnologies and has a clear link to policy goals in the management of the Baltic Sea. We develop a CBA model based on data complementarity with the MCA for an incremental analysis that allows decision makers to develop a cost-effective investment programme in compliance with strategic goals. Stakeholder confidence in the outcome of any ecotechnology investment ranking exercise is important and can be enhanced by an understanding of the robustness of the ranking to variations in key inputs to the assessment exercise. The applicability of the approach will be interpreted in the results of the Net Present Value (NPV) which is the difference between the present value of cash inflows (benefits) and the present value of cash outflows (costs) over a period of time.

Using the MCA and the CBA methodologies approach in this deliverable aims to shed light upon utilised economic models in the context of the implementation or adoption of ecotechnologies. The assessment provides an overview of key data, where the focus is on recovery and reuse technologies integrated into wastewater treatment systems, but mostly from agricultural waste. The system alternatives (Table 1) focuses on the ecotechnologies selected in the course of the RETURN WP3 activities.[2]

Catchment Areas

Each area possess very specific characteristics in terms of how the wastewater reaches the WWPT treatment plants.

1. the Fyrisån River basin (1,982 km2) located in the south-eastern part of Sweden is a tributary of Lake Mälaren, which has its outlet through Stockholm into the Baltic Sea. The Fyrisån catchment area is distributed among forests (60%), agriculture (32%), wetlands (4%), lakes (2%) and urban areas (2%) [4]. For the Fyrisån case study, three ecotechnologies where evaluated in the CBA: i) incineration, ii) nutrient extraction and iii) source-separation.

2. The Słupia River basin (1,623 km2) is a diverse coastal catchment with an expansive area of dunes stretching along the coast. In the Słupia catchment area agricultural land and forest represent 54% and 42% of the basin, respectively. Urban areas constitute around 3%, of which the largest portion is taken by the city of Slupsk with 95,000 inhabitants, and two smaller towns (Bytów and Ustka) (Johannesdottir et al. 2019). In this case, three ecotechnologies are included for the CBA study: i) reject water, ii) anaerobic digestion and iii) source-separation.

[2] https://www.bonusreturn.eu/program/sustainability-analyses/

3. The Vantaanjoki River basin (1,680 km2) in Finland flows through the Helsinki metropolitan area before discharging into the Baltic Sea. The catchment area consists of 23% agriculture, 56% forestry and 17% urban area. Over 90% of the population is connected to a sewage network (Johannesdottir et al., 2019). Scenarios correspond to three ecotechnologies included in the CBA: i) composting, ii) anaerobic digestion and iii) thermal treatment (Table 1).

A full-detailed description of the selected ecotechnologies included in this study, are well described as system alternatives for each of the catchment areas in the BONUS RETURN project multi-criteria analysis (Johannesdottir et al. 2019), therefore no detail will be discussed on this paper in that regard.

Table 1. Selected eco-technologies for the CBA, based on data from MCA (Johannesdottir, et al., 2019).

Catchment area	Baseline	Ecotechnology 1	Ecotechnology 2	Ecotechnology 3
Fyrisån (SE)	Present treatment (conventional). Sludge is digested, stabilized and part of it return to fields	Incineration: Conventional treatment. Sludge incinerated and P extracted from the ash	Nutrient extraction: Screening+AnMBR. Ammonia stripping and struvite precipitation from permeate. Sludge hygienized and returned to field	Source-separation: Greywater treated with mixed wastewater as in baseline. Blackwater treated in a UASB-reactor, biochar filtration of reject water, sludge hygienized and returned to field
Slupia (PL)	Present treatment (conventional). Sludge is digested, composted and most is returned to field	Reject water: Conventional treatment with biochar filtration of reject water from anaerobic digestion. Sludge managed as in baseline.	Nutrient extraction: Screening+AnMBR. Ammonia stripping and struvite precipitation from permeate. Sludge composted and returned to field	Source separation: Greywater treated with mixed wastewater as in alt. 0. Blackwater treated in a UASB-reactor, biochar filtration of reject water, sludge composted and returned to field
Vantaanjoki (FI)	Baseline – only minor costs and benefits are associated with this scenario	Composting: Composted on-farm or locally	Anaerobic digestion: Anaerobic co-digestion on-farm or locally from agricultural residues and horse manure	Thermal treatment: Thermal co-treatment at central plant

Note: UASB: Upflow Anaerobic Sludge Blanket reactor.

The following data aims to reflect upon the most updated information to assess the CBA for the BONUS RETURN based on the workshop experiences, expert knowledge sharing and applied economic approaches. In light of the selected system alternatives, benefits and costs are included into the model and apply analyses to estimate their economic efficiency.

The case study work was divided in two workshops. The first workshop was dedicated to the three first phases: to formulate the goal and scope for the study, to select criteria for evaluation and to select alternatives. Between the meetings, the researchers were engaged in phase 4, analysis and evaluation and with phase 5 to begin scoring. A large group of stakeholders in each of the catchments (between 25 - 30 participants) was invited. These included representatives from water utilities, agriculture, forestry, universities and companies. The second workshop was dedicated to set the final scores and to weight the criteria in order to make an overall assessment of the alternatives. Between 12 – 20 stakeholders (from the same group that participated in the first workshop) in each of the catchments gathered to set the weighting. The criteria included in the MCA derives from a literature review of sustainability criteria. The selection of eco-technologies included in the system alternatives stem from the systematic maps of eco-technologies (WP2).

Tables 2-7 provide an overview of cost and benefits for the three catchments. The costs and benefits in the scenario 1,2 and 3 are relative to the baseline. Therefore, the cost and benefits for each scenario indicates the changes of cost and benefits compared to the baseline. The estimation of costs is based on opportunity cost (farm income foregone), investment (capital) and operational costs. The benefits are divided between market benefits and non-market benefits. The market benefits include benefits that are traded on the market such as biogas and fertilizer. The non-market benefits include goods and services that are not traded on the market such as clean air and water. Their economic value is not revealed in market prices such as GHG emission mitigation and eutrophication reduction.

For the Fyrisån catchment area, Table 2 shows data of the costs in Euros including investment costs and operational costs from the MCA data sources. The data regarding the benefits, both market and non-market can be seen on Table 3.

For the Slupia catchment area, Table 4 shows data of the costs in Euros including investment costs and operational costs from the MCA data sources. The data regarding the benefits, both market and non-market can be seen on Table 5.

For the Vantaanjoki catchment area, Table 6 shows data of the costs in euros including investment costs and operational costs from the MCA data sources. The data regarding the benefits, both market and non-market can be seen on Table 7.

Table 2 (next page) shows data for Fyrisån. For the baseline scenario it is assumed that sludge is digested, stabilized and a part of it is returned to the field. In this scenario, investment costs are related to investments in sewers systems and to some extent treatment of the sludge. Operation and maintenance costs adds up to almost 19 million EUR per year. For the incineration scenario. Sludge is incinerated and P is hereafter extracted from the ash. In this scenario, only minor investments are required in addition to the baseline scenario. This include mainly additional cost for the incineration plants and some further operation and maintenance costs.

Table 2. Data for all the costs (investment and operation) for the baseline scenario and the three selected ecotechnologies for the Fyrisån (SE) catchment area.

COSTS (EUR)														
Fyrisån (SE)	**Investment cost**											**Operational cost**		
	Treatment plants	Incineration plant	LeachPhos-system	Sewers	Pumps in sewers	Ammonia stripping	Struvite extraction	UASB	Storage of sludge	Septic tank+infiltration	Closed tanks+installation	Operation and maintenance	Resource use	Staff
0- Baseline	76.142.662	0	0	438.674.923	0	0	0	0	348.963	0	0	18.863.705	1.219.170	436.887
1.Incineration	-	4.027.902	1.922.507	-	-	-	-	-	-	109.433.96	-	129.016	- 112.645	- 8.197
2. Nutrient extraction	31.290.011	-	-	-	-	14.460.904	7.219.612	51.989.877	279.772	109.433.96	-	874.772	1.345.657	-
3. Source separation	60.699.964	3.497.198	1.668.853	32.387.267	1.518.976	6.381.755	3.186.093	22.943.700	173.259	109.433.96	52.066.509	3.265.206	- 642.581	- 2.422

For the nutrient extraction scenario (scenario 2), additional costs are related to investment at the treatment plants as well as additional investments for example of struvite extraction, ammonia stripping, UASB and septic tank installation. In the scenario 3, source separation, it includes investments in all systems with the highest in treatment plants, sewage systems and USAB.

Table 3. Data for all the benefits (market and non-market) for the baseline scenario and the three selected ecotechnologies for the Fyrisån (SE) catchment area.

Fyrisån (SE)	**BENEFITS**								
		Market benefits						**Non-market benefits**	
	Conventional sludge (ton/y)	Blackwater sludge (ton/y)	Calcium phosphate (ton/y)	Struvite (ton/y)	Ammonium sulphate (ton/y)	Biochar (ton/y)	Heat production (MWh)	Eutrophication reduction (tons P04-eq)	GHG emission mitigation (t C02-eq)
0- Baseline		0	0	0	0	0	0	-183	-5454
1.Incineration		0	125	0	0	0	0	-2	-57
2. Nutrient extraction	-43	0	0	133	906	0	0	85	1957
3. Source separation		440	90	36	328	21	628	52	700

Furthermore, Table 3 indicates, that most of the market benefits in terms of physical amounts for the incineration scenario is related to calcium phosphate as a market benefit and additional non-market benefits from reduced GHG emission compared to the baseline scenario. For nutrient extraction, additional market benefits in tonnes/year are gained from struvite and ammonium sulphate and additional non-market benefits from GHG emissions and less benefits from reduced eutrophication.

For the baseline scenario in Slupia, sludge is digested, composted and mostly returned to the fields. Investments are here related to wastewater treatment as well as additional investments in the sewage systems. Like in Fyrisån, the yearly maintenance costs are relatively high for this scenario. For the scenario 1, reject water includes treatment with a biochar filtration of rejected water from the anaerobic digestion. Sludge is here managed as in the baseline. For scenario 2, Nutrient extraction includes additional investments in mainly wastewater treatment, but also UASB, ammonia stripping and composting with additional costs for maintenance and operation. For scenario 3, source separation, it includes investments in all systems with the highest costs in wastewater treatment plants, sewage systems and closed tanks.

Table 4. Data for all the costs (investment and operation) for the baseline scenario and the three selected ecotechnologies for the Slupia (PL) catchment area.

	COSTS (EUR)										
	Investment cost								**Operational cost**		
Slupia (PL)	WWTPs	Composting	Sewage net	Sewage net, BW pump	Ammonia stripping	Struvite extraction	UASB	Closed tanks	Maintenance	Operation	Staff
0. Baseline	60.915.817	1.276.710	160.806.887	0	0	0	0	0	6.689.982	845.948	181.438
1. Reject water	-	-	-	-	850.235	-	-	-	25.507	364.525	-
2. Nutrient extraction	40.501.749	1.173.609	-	-	7.359.676	3.674.321	26.459.525	-	509.291	923.672	-
3. Source separation	60.791.633	1.153.860	178.885.461	660.939	2.263.125	919.041	6.618.196	41.314.152	2.088.210	472.037	-

Table 5 indicates that the market benefits related to reject water are related to ammonium sulphate and additional non-market benefits from mainly reduced GHG emission compared to the baseline scenario. For nutrient extraction (scenario 2), market benefits in tonnes are mainly gained from ammonium sulphate and struvite and additional non-market benefits from reduced GHG emissions and minor benefits from reduced eutrophication. Finally, in scenario 3 source separation a main outcome from this process is in physical amounts is blackwater sludge. Although this, process provides a significant amount in tonnes dry matter, the market value is limited as it is assumed to be provided for free or nearly for free at the farm gate.

Table 5. Data for all the benefits (market and non-market) for the baseline scenario and the three selected eco-technologies for the Slupia (PL) catchment area.

Slupia (PL)	**BENEFITS**					
	Market benefits				**Non-market benefits**	
	Composted sludge (tonnes DM) to agriculture	Blackwater sludge (tonnes DM)	Struvite (tonnes P)	Ammonium sulphate (tonnes N)	Eutrophication reduction (tons P04-eq)	GHG emission mitigation (t C02-eq)
0. Baseline	7912	0	0	0	-102	-7461
1. Reject water	0	0	0	58	3	91
2. Nutrient extraction	-98	0	66	450	38	-705
3. Source separation	-762	600	11	154	24	-35

In the baseline scenario for the Vantaanjoki catchment it is assumed that only minor costs (investment, operation and maintenance) as well benefits are associated with this scenario. For scenario 1, where composting is taking place on-farm or locally, investments are assumed to include compost facilities and black water hygienization as well as yearly costs of operation and maintenance. Scenario 2 involves a further on-farm anaerobic digestion or locally anaerobic digestion of agricultural residues and horse manure. This scenario requires mainly investments in a biogas facility as well as operation and maintenance costs. In scenario 3, it is assumed that thermal treatment is taking place at a central plant which include investments in for instance urea hygienization facilities as well as operation and maintenance costs.

Table 6. Data for all the costs (investment and operation) for the baseline scenario and the three selected ecotechnologies for the Vantaanjoki (FI) catchment area. *Note: The baseline scenario for the Vantaanjoki case is the same for the first alternative "ecotechnology" (Composting).*

	COSTS (EUR)					
	Investment cost					**Operational cost**
Vantaanjoki (FI)	Compost facility	Black water hygienization	Biogas facility	Pyreg plant	Urea hygienization	Operation and maintenance
0. Baseline	-	-	-	-	-	-
1. Composting	8.377.337	2.416.792	-	-	-	1.936.858
2. Anaerobic digestion	-	-	16.208.149	-	-	501.318
3. Thermal treatment	-	-	-	16.464.800	25.576.921	3.407.143

Table 7 indicates the market benefit and non-market benefits for the baseline scenario and the three selected eco-technologies for the Vantaanjoki (FI) catchment area. Here the main market benefit for composting is related to organic fertilizer N and P although it will also provide a negative non-market impact on GHG emission. The scenario 2, anaerobic digestion is assumed to provide mainly biogas as market benefit and a related impact on non-market benefits from reduce GHG emission. Thermal treatment in scenario 3 may provide a negative market impact on N fertilizer, but also a positive impact on organic P fertilizer as well as reduced GHG emission mitigation.

Table 7. Data for all the benefits (market and non-market) for the baseline scenario and the three selected ecotechnologies for the Vantaanjoki (FI) catchment area.

Vantaanjoki (FI)	**BENEFITS**								
	Market benefits							**Non-market benefits**	
	Organic fertilizer N (t/y)	Organic fertiliser P (t/y)	Biogas (MWh/y)	Biochar (t/y)	Heat production (MWh/y)	Biochar (ton/y)	Heat production (MWh)	Eutrophication reduction (tons P04-eq)	GHG emission mitigation (t C02-eq)
0. Baseline	0	0	0	0	0	0	0	0	0
1. Composting	549,7	121,5	0	0	0	0	0	0	-700
2. Anaerobic digestion	-8,7	0,7	44.237,00	-	-	-	-	0	6200
3. Thermal treatment	-201,2	-110,50	-	6010	1677	-	-	0	5800

The advantage of knowing the economic efficiency of any of the ecotechnologies is a fundamental criterion for public investment. Therefore, this deliverable describes the steps of the bottom-up CBA approach which instead of starting out with a pre-defined policy option, it begins with the underlying environmental problem, and then assesses costs and benefits of solutions called ecotechnologies as identified by local and directed affected stakeholders (Carolus et al. 2018). A set of key data were included in the model, in order to calculate the NPV for both costs and benefits, based on 2018 and 2019 market prices in EUR (Table 8).

Table 8. Key data for market benefits and non-market benefits for the three cases. The market prices sources as described below correspond from 2015, 2018 and 2019.

Description	Data	Unit	Source
Benefits			
Market			
Conventional sludge to agriculture	0	€/t (2018)	Assume no revenue. Farmers get it for free.
Blackwater sludge	0	€/t (2018)	Assume no revenue. Farmers get it for free.
Biogas	85	€/MWh (2018)	SYKE
Calcium phosphate	900	€/t (2018)	RISE (MCA)
Struvite	650	€/t (2018)	RISE (MCA)
Ammonium sulphate	441	€/t (2018)	RISE (MCA)
Biochar	1083	€/t (2019)	SYKE
Heat production	46,96	€/MWh (2018)	SYKE
Organic fertiliser N (t/y)	1050	€/t (2019)	SYKE
Organic fertiliser P (t/y)	1733	€/t (2019)	SYKE
Non-market			
Eutrophication reduction	1,78	€/kg(P043-eq) *	Massaro et al, 2015
GHG emission reduction	0,025	€/kg(C02eq)	Massaro et al, 2015
Acidification	0,638	€/kg(SO2eq)	Massaro et al, 2015

RISE: Research Institutes of Sweden; SYKE: The Finnish Environment Institute. MCA: Multicriteria Analysis
**Eutrophication Potential (EP) kg PO43− equivalent, where eutrophication is measured in measured in phosphate-equivalents (PO43−) eq. emissions.*

3.1 The net present value (NPV)

The net present value (NPV) is the present value of the cash flows and initial investments at a certain discount rate. According to the European Commission (2008), the social discount rate used in this CBA is 3,50%, where two sensitivity analysis discount rate (0% and 30%) have been included (Table 9). The lifetime of the project and the ecotechnologies as alternatives to the baseline scenario is calculated in the model to be 30 years.

• CBA can be a valuable tool when it is used carefully in policies that include environment and natural resources. Therefore, our approach to integrate the result form the MCA and adapting them to the CBA model to ensure that stakeholders are involved in the process of selecting relevant eco-technologies.

• The ideal economic model depends upon the purpose and its results upon the context. Each of the catchment areas are unique and the way nutrients such as phosphorous (P) and nitrogen (N), biogas, biochar etc, and other market benefits produced, depends completely on the primary sources provenance and the appropriate management of reusable resources.

Table 9 shows the Net Present Value (NPV) for the three catchment areas, Fyrisån, Slupia and Vantaanjoki, with their respective eco-technologies alternatives. For Fyrisån and Slupia the baseline scenario provide a negative NPV. For Vantaanjoki, the baseline scenario provide a neutral or zero NPV.

Table 9. Net Present Value (NPV) for the three catchment areas, Fyrisån (SE), Slupia (PL) and Vantaanjoki (FI), with their respective ecotechnologies alternatives. Social discount rate 3,50%.

						Sensitivity analysis (NPV with altered discount rate)	
Catchment /Alternative	**Present Value (Costs) EUR**	**Present Value (Benefits) EUR**	**Life time**	**Net Present Value**	**B/C-ratio**	**0,00%**	**30,00%**
Fyrisån (SE) 0. Baseline	905.775.953 €	-8.811.690 €	30	-914.587.643 €	0,0	-1.144.646.455	-606.056.719
Fyrisån (SE) 1. Incineration	115.539.971 €	2.042.026 €	30	-113.497.945 €	0,0	-112.411.400	-114.955.105
Fyrisån (SE) 2. Nutrient extraction	256.941.712 €	13.070.797 €	30	-243.870.916 €	0,1	-260.687.695	-221.318.003
Fyrisån (SE) 3. Source-separation	343.835.111 €	6.815.834 €	30	-337.019.276 €	0,0	-361.822.004	-303.756.441
Slupia (PL)	369.905.441 €		30	-376.902.035 €	0,0	-465.546.963	

0. Baseline		-6.996.594 €					-258.020.689
Slupia (PL) 1. Reject water	8.274.792 €	862.495 €	30	-7.412.296 €	0,1	-11.191.917	-2.343.463
Slupia (PL) 2.Nutrient extraction	106.446.430 €	7.657.543 €	30	-98.788.886 €	0,1	-110.089.629	-83.633.507
Slupia (PL) 3. Source separation	341.342.671 €	2.880.403 €	30	-338.462.268 €	0,0	-364.874.354	-303.041.127
Vantaanjoki (FI) 0. Baseline	- €	- €	30	- €		-	-
1. Composting	47.663.707 €	14.661.038 €	30	-33.002.668 €	0,3	-69.424.869	-19.259.781
Vantaanjoki (FI) 2. Anaerobic digestion	6.665.177 €	74.376.982 €	30	67.711.805 €	11,2	1.197.880.391	159.093.261
Vantaanjoki (FI) 3. Thermal treatment	106.899.302 €	119.033.165 €	30	12.133.864 €	1,1	-524.301	-36.047.050

4 LIMITATIONS AND CONCLUDING REMARKS

The circular economy approach and the inclusion of eco-technologies is urgent to understand how much of the “waste” can be reused as a biomass resource in a sustainably way. This report applies an approach of combining cost-benefit analysis (CBA) and multi-criteria analysis (MCA) to support the effective implementation of eco-technologies when prioritizing projects to circulate and reuse available nutrient resources. By incorporating MCA results into a CBA this approach retains the strengths of each appraisal method and provides a procedure for decision makers to create an initial ranking of eco-technologies

Initial findings from this study indicate that only a few technologies provide a positive net present value at the current stage of the RETURN project. However, the results and the outcome from the CBA analyses must be regarded as preliminary.

All alternative scenarios provide some additional benefits either market benefits or non-market benefits in terms of reduce eutrophication or reduced GHG emissions compared with the baseline scenarios. However, for most of the alternative scenarios the benefits are too small to cover the additional investments and additional operational and maintenance costs. The most promising alternative is anaerobic digestion in Vantaanjoki. This scenario provides a NPV of 67.mio € for the catchment. Thermal treatment also appears to be a promising alternative with a NPV of 12.mio € for the catchment in Vantaanjoki. For several of the other alternatives, in Fyrisån and Slupia a reason for negative NPV is mainly relative high investment costs especially in relation to source separation, which has high costs but relatively small benefits.

However, for all scenarios, its assumptions must be interpreted with caution as some costs for the alternative scenarios may already to some extent be covered in the baseline scenario. Therefore, an update of the assumptions and assessment of cost and benefits according to each scenario may occur within the last part of the project period in the Bonus RETURN project.

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