

BONUS RETURN

**REDUCING EMISSIONS TO THE
BALTIC SEA BY TURNING NUTRIENTS
AND CARBON INTO BENEFITS**

DECEMBER 2020



Image: Angela Schmidt / EyeEm

FINAL REPORT – RESULTS, CONCLUSIONS AND RECOMMENDATIONS

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1. EXECUTIVE SUMMARY

Phosphorus levels in the Baltic Sea continue to increase with internal loading from anaerobic sediments and runoff from the drainage basin. Decreased use of chemical fertilizer and better wastewater treatment has occurred over the past 30 years but even so, the state of eutrophication in the Baltic Sea has not significantly improved. The annual bloom of cyanobacteria (blue-green algae) especially in the Baltic Sea Proper is driven by this excess phosphate and these algae import to the Sea large amounts of nitrogen via atmospheric nitrogen fixation. This estimated 370,000 tons of nitrogen imported per year by the cyanobacterial blooms is larger than the anthropogenic riverine input (351,000 tons/yr). So, any reductions in nitrogen, phosphorus and even carbon additions to the Baltic Sea will help abate further degradation of the Baltic ecosystems.

The BONUS RETURN project set out to explore the reduction of emissions to the Baltic Sea from agriculture and wastewater by turning nutrients and carbon into benefits - closing the nutrient loops and promoting circularity. The overall aim of BONUS RETURN was to improve the adaptation and adoption of agriculture and municipal wastewater ecotechnologies for capture and reuse of nutrients and carbon in the Baltic Sea Region for maximum efficiency and increased co-benefits.

BONUS RETURN focused on two types of circular ecotechnologies: existing ecotechnologies and upcoming innovations. Regarding existing ecotechnologies, the project identified 25 recovery and reuse solutions in agriculture and 28 recovery and reuse technologies

within the wastewater sector, relevant to the Baltic Sea Region. Mature technologies such as struvite crystallization and ammonia stripping to produce ammonium sulphate could be further scaled up to provide added capture and reuse of both nitrogen and phosphorus. New ecotechnologies for nutrient and carbon capture that show promise include the in situ adsorption of dissolved phosphorus, production of phosphoric acid from sludge and biocoal production from sludge. Common farm practices such as controlled manure spreading, winter crop cover and runoff buffer zones (including wetlands and sedimentation ponds) still need to consider phosphorus levels in the soil.

Regarding innovative ecotechnologies, through an organised competition, BONUS RETURN identified, evaluated, and supported the further development of three innovative circular solutions with the potential to capture and reuse phosphorus, nitrogen and carbon for further applications. This was done through the set-up and monitoring of a testbed, pre-commercialization support to assess market potential, and benchmarking against other more established technologies.

The experiences of the innovators also contributed to building the project's knowledge based on market and policy barriers for closing nutrient loops within the EU. This experience, coupled with the systematic reviews, and evaluations of ecotechnology sustainability, economic viability, and efficacy in the three case study drainage basins in Sweden, Finland and Poland, provided findings

The project lasted for 3.5 years from May 2017 to October 2020 and involved partners from Sweden, Finland, Poland and Denmark. The project covered the following sub-topics:

- innovation and market uptake of ecotechnologies
- reduction of knowledge gaps on policy performance, enabling/constraining factors, and costs and benefits of ecotechnologies
- framework for improved systematic stakeholder involvement
- commercialization of ecotechnologies and
- user-driven knowledge platform and improved technology-user interface.

The project was organized around the following work packages:

- coordination, management, communication, and dissemination, led by SEI
- integrated evidence-based review of ecotechnologies, through a joint leadership between WULS and SEI sustainability analyses, led by RISE
- environmental modelling, led by SYKE
- implementation support for ecotechnologies, led by RISE
- innovative methods in stakeholder engagement, led by UU.

regarding research and policy gaps. Linear and “silo” thinking impedes progress towards circularity. New EU Regulations on Fertilizers have potential for promoting reuse products although the current low pricing of conventional fertilizer will need to consider externalities and cost more before the reuse products can become competitive. Although nitrogen reuse in agriculture within the EU is regulated by the Nitrates Directive, no such norm exists for phosphorus. There is a need for harmonised regulation of both N and P. At present P is regulated using national directives in only some of the EU countries. Only a few countries use farmgate nutrient balancing as a tool.

The project found that there are key drivers promoting increased circularity of nutrients. These include the need for sovereign, sustainable supplies of phosphorus, the drive towards reducing greenhouse gases through renewable energies and reuse of organic materials and bans on ocean dumping of manure and sludge. There are economic and administrative tools that can help promote capture and reuse (e.g. quotas -both tradable and non-tradable-, fixed and volume-based fees or taxes and subsidies). However, these are currently not being used, and as a result few circular ecotechnologies are likely to outweigh the benefits versus the costs, as clearly highlighted by the cost-benefit analyses (CBAs) carried out in the three project catchments areas. This is in fact the case for ecotechnologies that require large infrastructural investments, as with most wastewater treatment technologies. By contrast, the CBAs show that ecotechnologies for circulating nutrients from agricultural wastes can have a positive Net Present Value due to the low investment requirements.

The project observed that conventional fertilizers need to cost more and achieve higher user efficiencies for circular capture and reuse systems to develop and scale up. At present there are few incentives to be frugal with fertilizer. Technology development, innovation and procurement are important components in the quest for competitive ecotechnologies that will ensure increased circularity of nutrients and carbon in the region’s agriculture and wastewater systems. Ecotechnologies for nutrient and carbon capture and reuse can reduce runoff and drainage losses to receiving waters.

BONUS RETURN evaluated the role of stakeholder engagement and social learning as important components which can help ensure that nutrient and carbon circularity takes hold within agriculture and the wastewater sector. The debate surrounding reuse of sewage sludge on cropland was also explored showing that several drivers including deep-rooted attitudes and perceived risks surrounding recycling of human excreta are involved.

There is a need to increase policy steering towards P reuse, without closing promising systemic solutions. Mainstreaming the idea of circular economy across

society and local, national and supranational governance structures is a priority. This will require a shift in mindsets (away from take-make-dispose and towards reduce-reuse-recycle-recover strategy), new circular business models, and increased implementation capacity within national and local governments and municipalities.

The authors of this publication are listed on page 43, section 7.5 of the appendices.



Figure 1. The six contributions provided by the BONUS RETURN project.

2. INTRODUCTION



2.1. SCIENTIFIC BASIS AND RATIONALE OF THE PROJECT

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 lack broader stakeholder acceptance – and 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 but also concomitant emissions from exploitation of the nitrogen and phosphorus cycles. In order to navigate the uncertainties and controversies associated with a transformation toward a good marine environment, BONUS RETURN initiated an innovative trans-disciplinary approach to identify and pilot systemic ecotechnologies to capture and reuse nutrients and carbon within agriculture and waste-water systems.

The focus within BONUS RETURN has been ecotechnologies that generate co-benefits within other interlinked sectors, and which can be adapted according to geophysical and institutional contexts. More specifically, emphasis has been placed on ecotechnologies that reconcile the reduction of present and future eutrophication in the marine environment with the regional challenges of policy

coherence, food and energy security, and the provision of ecosystem services.

2.2. STATE OF THE BALTIC SEA WITH RESPECT TO EXCESS NUTRIENTS

The Baltic Sea Region, with a population of ca. 90 million has experienced decades of fertilizer overuse especially during 1950 to 1990 (McCrackin et al., 2018). Although the use of chemical fertilizers has decreased over the past 30 years and waste-water treatment has significantly reduced point source emissions, the levels of dissolved- and total phosphorus (P) in the open sea continue to increase (Savchuck, 2018). The Baltic Sea is eutrophic and now shows signs of seasonal dystrophy with large-scale neuro-toxic cyanobacterial blooms (Fig. 2) and extensive oxygen-free bottom sediments, a condition more common for smaller hypertrophic lakes. This has had negative impacts on such things as fisheries and tourism (Ahtiainen et al., 2014). The cyanobacterial blooms are driven by the available P and continue to occur across the Baltic Sea Proper every summer. These seasonal blooms fix large amounts of nitrogen from the atmosphere, importing some 370,000 T of N per yr which is larger than the current annual anthropogenic riverine input of 352,000 T of N (Wasmund et al., 2005). Excess P therefore is creating additional input of N through this N-fixation. The Baltic thus requires management of both N and P to “Save the Sea”.



Fig. 2. Large-scale cyanobacteria blooms across the Baltic Sea Proper driven by surplus phosphate. These blue-green algae are neuro-toxic and fix atmospheric nitrogen importing ca 370.000 tons of N/yr (ESA, 2005 https://earth.esa.int/web/earth-watching/historical-views/content/-/asset_publisher/pdy7KOLmvyaa/content/algal-blooms-baltic-sea-july-2005).

The explanation for the continued increase in phosphorus levels in the open water is two-fold: legacy P in the farmlands of the drainage basin from decades of additions of chemical fertilizer finds its way into the sea through runoff, and internal loading of P from the deep anaerobic sediments (McCrackin et al., 2018). Also spreading of manure on farmland based on nitrogen (N) crop requirements results in significant P overloading because manure contains relatively low N to P ratios. These loading sources are further aggravated by the fact that the Baltic Sea Proper is enclosed with a water residence time (time required for one volume change) of 25 to 40 years (Meier, 2005). Improvements in the water quality and degree of eutrophication are not occurring.

2.3. GENERAL KNOWLEDGE BASE REGARDING CAPTURE AND REUSE OF NUTRIENTS AND CARBON

Wastewater has been traditionally seen as a waste requiring treatment in order to reduce negative impacts before it is released into the receiving water system (Andersson et al., 2016). Content such as organic carbon (C), nitrogen (N) and phosphorus (P) have been water pollutants and treatment systems have been set up to render the released water less a pollutant. P was traditionally removed using flocculating agents like aluminium or iron sulphate and iron chloride (Yeoman et al., 1988). The sludge arising from this process is not easily available to crops in agriculture so alternative processes have been developed such as calcium hydroxide (lime) precipitation of phosphorus and biological uptake of phosphorus by activated sludge. Also, addition of

magnesium compounds (sulphate, oxide, hydroxide) has become popular in order to produce struvite which contains both N and P (Forrest et al., 2008). Excess nitrogen in wastewater has been reduced to volatile nitrogen gas by exploiting the biological process denitrification which occurs under anaerobic conditions (Lu et al., 2014). These processes result in potential reuse products such as sludge which contains P as well as struvite crystals which contain phosphorus, nitrogen, and magnesium.

Common practice in agriculture (Tybirk et al., 2013; Audette et al., 2016; Pintoa et al., 2017) shows there is value in reusing the "waste" products arising from farming such as manure, crop residues, other organic materials, digestates and leachates. Farmers are also interested in optimizing crop yields and key on nitrogen content of the manure, slurry or compost that is being spread onto fields. These compounds usually have N/P ratios lower than the crop needs, so in order to try to better match the nitrogen requirements of the crops, excessive amounts of P end up being applied to fields. This excess P is absorbed by most soils and can result in saturation of the upper layers after several years (McCrackin et al., 2018). Annual periods of runoff remove some of this excess P through soil erosion.

The knowledge base suggests that if we are going to "Save the Sea", one of the goals of the European Union's Strategy for the Baltic Sea Region (EUSBSR), the Baltic requires a cross-sectoral and comprehensive approach to managing nitrogen and phosphorus, going well beyond current EU policies and directives.



Spreading animal manure slurry on a field for grazing. Image: [DieterMeyrl / iStock Photo](#)

3. PROJECT OBJECTIVES, THEMES AND SUB-THEMES



3.1. PROJECT OBJECTIVES

The overall aim of BONUS RETURN was to improve the adaptation and adoption of agriculture and municipal wastewater ecotechnologies for capture and reuse of nutrients and carbon in the Baltic Sea Region for maximum efficiency and increased co-benefits.

The original specific objectives were to:

1. Support innovation and market uptake of ecotechnologies by:

- Contributing to the application and adaptation of ecotechnologies in the BSR through an evidence-based review (systematic map) of the developments within this field
- Contributing to the development of emerging ecotechnologies 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 ecotechnologies in the BSR
- Contributing to better assessment of ecotechnology efficiency via integrated and participatory modelling in three catchment areas in Finland, Sweden and Poland
- Contributing to methodological innovation on application and adaptation of ecotechnologies

2. Reduce knowledge gaps on policy performance, enabling/ constraining factors, and costs and benefits of ecotechnologies by:

- Assessing the broader socio-cultural drivers linked to ecotechnologies from a historical perspective
- Identifying the main gaps in the policy environment constraining the implementation of emerging ecotechnologies 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 ecotechnologies and the regional economic and institutional structures in which these technologies evolve

3. Provide 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 ecotechnologies capable of transforming nutrients and pollutants into benefits for multiple sectors at different scales
- Bringing stakeholder values into ecotechnology choices to demonstrate needs for adaptation to local contexts and ways for ecotechnologies 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. Support commercialization of ecotechnologies by:

- Identifying market and institutional opportunities for ecotechnologies that (may) contribute to resource recovery and reuse of nutrients and carbon
- Identifying potential constraints and opportunities for integration and implementation of ecotechnologies using economical models
- Facilitating the transfer of ecotechnologies contributing to win-win solutions to multiple and interlinked challenges in the BSR
- Linking producers of ecotechnologies (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. Establish a user-driven knowledge platform and improved technology-user interface by:

- Developing an open-access database that maps out existing research and implementation of ecotechnologies 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 policymakers can incorporate it in their practices.
- Developing methodologies that enact the scaling of a systemic mix of ecotechnological interventions within the highly diverse contexts that make up the BSR and allows for a deeply interactive medium of knowledge.

Image: [StockphotoVideo / Shutterstock](#)

3.2. PROJECT ORGANISATION AND SUMMARY OF MODUS OPERANDI

BONUS RETURN began operations on May 1, 2017 and ran for 3,5 years to October 31, 2020.

It was structured around six Work Packages:

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

BONUS RETURN received funding from BONUS (Art 185), funded jointly by the EU and Formas (Swedish Research Council for Sustainable Development); Sweden's innovation agency, Vinnova; Academy of Finland; and the National Centre for Research and Development in Poland.

The Project acronym:	BONUS RETURN
The project's full title:	Reducing Emissions by Turning Nutrients and Carbon into Benefits
The project comprised a consortium of six partners:	Stockholm Environment Institute (SEI) Warsaw University of Life Sciences (WULS) Finnish Environment Institute (SYKE) Uppsala University (UU) RISE Research Institutes of Sweden University of Copenhagen (UCPH)
The coordinating partner:	Stockholm Environment Institute (SEI)

For the list of deliverables and publications, please see the Appendix. Each deliverable had main authors but also partner contributors. The latter are named in each of the deliverables which can be found on the project website www.bonusreturn.eu.

4. SUMMARY OF PROJECT RESULTS

4.1. ECOTECHNOLOGIES FOR CIRCULATING NUTRIENTS AND CARBON IN THE BALTIC SEA

4.1.1. WHAT ARE ECOTECHNOLOGIES?

To better define the term "ecotechnology", which had never been scientifically defined before, the project conducted a systematic review with a thematic synthesis of all definitions of the term (Haddaway et al., 2018). A suite of bibliographic databases was searched, and definitions were extracted. A conceptual framework for definitions of 'ecotechnology' was constructed and tested by examining articles relating to carbon and nutrients. Of 77 carbon and nutrients articles providing definitions, almost half used the term 'ecotechnology' but mainly as a topical "buzzword". A working definition for the purpose of the project was then proposed -

"Ecotechnologies are human interventions in social-ecological systems in the form of practices and/or biological, physical, and chemical processes designed to minimise harm to the environment and provide services of value to society".

With this conceptual framework, the project could then proceed using the term ecotechnology referring to technologies and practices that capture and reuse nutrients and carbon within the agriculture and wastewater sectors of the Baltic Sea Region.

4.1.2. INVENTORY OF ECOTECHNOLOGIES FOR CIRCULATING NUTRIENTS AND CARBON

There are numerous technological solutions to recover nutrients, energy and other resources present in various organic waste streams. However, to our knowledge, prior to this project there were no systematic syntheses of technologies and practices to recover and reuse nutrients and carbon from different waste streams. Two systematic maps were therefore conducted with the aim of closing this synthesis gap: evidence was collated for technologies and practices for the recovery and reuse of nutrients and carbon within the wastewater treatment and agriculture sectors. The map of agricultural ecotechnologies focused on boreo-temperate climate regions, while the map of wastewater ecotechnologies had a global scope.

We searched for both academic and grey literature. English language searches were performed in 5 bibliographic databases and Google Scholar. Searches in 36 specialist websites were performed in English, Finnish, Polish and Swedish. The searches were restricted to the period 2013 to 2017. Eligibility

screening was conducted at two levels: title and abstract (screened concurrently for efficiencies) and full text. Meta-data were extracted from eligible studies including bibliographic details, study location, ecotechnology name and description, type of outcome (i.e. recovered or reused carbon and/or nutrients), type of ecotechnology used for recovery, and type of reuse (in terms of the end-product). Findings were presented narratively and in searchable databases and were also visualised via evidence atlases (interactive searchable tool that shows the locations of the studies included in the systematic map database along with extracted meta-data.). Lastly, knowledge gaps and clusters were identified and described for each evidence base.

The final database for ecotechnologies within wastewater treatment contained 450 articles, which in turn contained 476 individual studies of 27 types of ecotechnologies. Most articles are in English, originating from bibliographic databases and published in 2016. The database has a wide geographic scope, with included studies from all over the globe. **The most common wastewater streams to apply the ecotechnologies are conventional municipal wastewater and sludge (76%). The most common type of recovery is energy, followed by combined recovery of N and P. The most common type of reuse is combined reuse of nitrogen and phosphorus,** followed by combined reuse of organic carbon, nitrogen, and phosphorus. Combinations of different ecotechnologies were somewhat common (17%) and microalgal cultivation seems to be the most studied standalone ecotechnology (14%).

The agriculture database contained 173 articles, which in turn contained 177 studies including 25 different ecotechnologies for the recovery of nutrients and carbon. As for the evidence base of technologies in wastewater treatment, most articles are in English, originating from bibliographic databases and published in 2016. Most studies with reported locations have been conducted in Europe and North America explained by the focus on boreo-temperate regions. **The three most prevalent ecotechnologies in the evidence base (collectively 41%) are application of soil amendments, anaerobic digestion and (vermi) composting. Manure is the principal waste source used for recovery of nutrients or carbon, making up 55% of the studies,** followed by a combination of manure and crop residues (22%). There are 51 studies with 14 ecotechnologies that reported on recovery of carbon and nutrients together, predominantly via (vermi)composting and anaerobic digestion. 27 studies focus on reuse of recovered nutrients and carbon through soil amendments. The visual overview of the evidence base can be accessed from this link: <https://www.bonusreturn.eu/program/agriecotechevidence/>. Knowledge gaps and clusters were also identified based on the produced evidence bases.



Prashanth Kumar, Aquacare and Berndt Björleinius, RISE Research Institutes of Sweden, performing tests at the Aquacare testbed in Knivsta, Sweden. Image: SEI

4.1.3. EFFECTIVENESS OF SELECTED ECOTECHNOLOGIES

Drawing from gaps identified in the initial systematic maps, two additional systematic reviews for selected ecotechnologies were conducted. In the first review, we synthesized evidence regarding the efficiency of struvite precipitation and ammonia stripping for the recovery of P and N from anaerobic digestate. In the second review, we synthesized evidence regarding the fertilizer efficiency of the products of struvite precipitation and ammonia stripping, i.e. struvite and ammonium sulphate, respectively. The overarching primary question that both reviews sought to answer was: **are these ecotechnologies effective for capture and reuse?**

We searched for academic and grey literature published after 2013. Searches were performed in 5 bibliographic databases in English, and in the search engine Google Scholar in English and Swedish. Eligibility screening was conducted at two levels: 'title and abstract' and 'full text'. Included eligible studies were subject to a critical appraisal that assessed external and internal study validity. We extracted information on study characteristics, intervention, comparators, effect modifiers, and measured outcomes. Data synthesis included narrative synthesis (i.e. tabulation of findings and presentation of descriptive statistics) of each study of sufficient validity. We performed quantitative synthesis on subsets of studies.

The evidence base included 30 studies on struvite precipitation and 8 studies on ammonia stripping.

Both pH and Mg:PO₄ ratio were found to have a clear influence on the effectiveness of the struvite precipitation process (and thus nutrient removal rates). The response to pH was found to be non-linear, resembling a bell curve with a maximum around pH 9.5. Mg:PO₄ ratio was found to have a positive effect on removal up to a ratio as high as 4 to 1. However, dosing Mg in excess may be expensive, and it should be noted that high removal efficiencies were sometimes achieved at a ratio as low as 1 to 1 as well. Studies on ammonia stripping were relatively heterogeneous and different digested substrates were included, e.g. wastewater sludge and different types of manure. Due to the small size of the evidence base, and the heterogeneity between studies, no quantitative synthesis was performed for ammonia stripping. We provided suggestions of which data to report in future studies.

The evidence base for fertilizer efficiency contained 24 studies on struvite and 2 studies on ammonium sulphate. Because of the few studies on ammonium sulphate, quantitative synthesis was only carried out for struvite. **We found that the fertilizer efficiency (measured both as dry matter yield and P uptake of crops) of struvite is similar to that of mineral fertilizer. The effect of 4 different parameters (soil type, soil pH, crop type and experiment length) on the relative fertilizer efficiency of struvite compared to mineral fertilizer was also investigated. No statistically significant differences were found among these parameters.**



Aerial view of the Slupsk Waterworks wastewater treatment plant, known for its success in sludge reuse. Image: SEI

4.2. SUSTAINABILITY OF SELECTED ECOTECHNOLOGIES

4.2.1. STAKEHOLDER MULTI-CRITERIA ANALYSIS IN THREE CATCHMENT AREAS

A participatory multi-criteria analysis (MCA) was performed to assess the sustainability of selected ecotechnologies. Two stakeholder workshops were held in each catchment area (Sweden, Finland, and Poland). In the first workshop, stakeholders contributed and formed the problem definition, selection of evaluation criteria and selection of ecotechnologies to evaluate. At the second workshop, stakeholders contributed to evaluation of qualitative criteria and weighting (i.e. prioritizing) of the criteria. All system alternatives consisted of a hypothetical constellation of ecotechnologies for recovering carbon and nutrients. Results from the systematic mapping (described above) supported the selection of system alternatives.

In the drainage basins Fyris (Sweden) and Slupia (Poland), focus for the assessment was on domestic wastewater while in Vantaanjoki (Finland) it was horse manure, unutilized grass and source-separated blackwater (human excreta) from scattered settlements.

In Vantaanjoki, the ecotechnologies evaluated were composting, anaerobic digestion and thermal treatment

with urea hygienisation. **With the composting system used as a baseline scenario, results from the MCA in Vantaanjoki indicate that anaerobic digestion and thermal treatment were found to be more sustainable.**

In Fyris, the system alternatives were sludge incineration and P recovery from ashes, nutrient extraction by redesigning wastewater treatment and introducing source-separation. **Compared to a baseline system representing current treatment, results from the MCA in Fyris indicate that any of the three tested alternative systems were found to be more sustainable. The source-separation system received the highest score, followed by nutrient extraction.**

In Slupia, the system alternatives were ammonia stripping from sludge reject water and the other two were the same as in Fyris. **Compared to the baseline system representing current wastewater treatment, all the tested system alternatives in Slupia were found to be more sustainable. Nutrient extraction received the highest sustainability score, followed by ammonia recovery from reject water.** In one weighting exercise at the second workshop, the source-separation system was scored as less sustainable than the baseline.

In both Fyris and Slupia nutrient extraction and source-separation were comprised of essentially the same ecotechnologies. The differences were that

sludge was stored in Fyris for nutrient extraction and incinerated in source separation while the sludge was composted in both systems in Słupia. The degree of source-separation also differed between the case studies: 14% of wastewater was source-separated in Słupia while it was 37% in Fyris. These differences could explain why source-separation got the highest overall score for Fyris while it got the lowest in Słupia. Additionally, the stakeholders scored acceptance of this system as -2 in Słupia while in Fyris stakeholders scored it 1. This shows that **local context and stakeholder participation is an important part of sustainability assessments.**

The multi-criteria analysis informed by the local stakeholders showed an aggregated positive valuation of sustainability for the ecotechnologies in each catchment.

4.2.2. ASSESSMENT OF COSTS/BENEFITS OF SELECTED ECOTECHNOLOGIES

This part of the project provided an assessment of costs and benefits of ecotechnologies selected from the three catchment areas in Sweden, Finland, and Poland. By applying a CBA (cost benefit analysis)-based bottom-up approach partly informed by the MCA, this study showed how involvement of stakeholders could serve as an instrument for exploring the implementation of new solutions. The advantage of this approach was that the criteria included had gone through a comprehensive participatory process with stakeholder involvement, which provided more legitimacy to the decisions reached.

The CBA assessed the Net Present Value (NPV) that captures values of costs and benefits occurring within

a certain time, set here to 30 years. In the study, we compared a baseline with the selected alternatives derived from the MCA. We applied a partial budgeting approach that considered changes from the baseline to a new situation, meaning that we only included additional costs and benefits that were related to that particular new scenario. In line with the sustainability criteria defined for the MCA, the following non-market benefits were included in the CBA: global warming potential and eutrophication potential as well as other market benefits and cost of implementing these technologies.

Findings indicate that only one technology - anaerobic digestion of agricultural wastes in the Finnish case - provided a positive NPV. Generally, an outcome from comparing the three catchment areas was that eco-technologies for circulating nutrients from agricultural wastes could have a positive NPV while ecotechnologies in wastewater management show negative NPVs (Table 1). A positive NPV indicates that a given ecotechnology is economically viable and provides an overall welfare economic gain to society. A negative NPV indicates the opposite.

The significant differences in NPV are largely due to the need for expensive infrastructure for wastewater management, but also due to significant market benefits from agricultural wastes in relation to thermal treatment and anaerobic digestion in Finland. The NPVs from the ecotechnologies in Fyrisån and Słupia, decrease with increasing complexity and deviation from the baseline scenarios. There are large investments needed in the wastewater sector, which is one of the barriers to new technologies and treatment systems. However, some additional benefits, which are not included in this CBA could make the implementation of these technologies worthwhile. An

Table 1. NPV (net present value), PV (present value) of costs and benefits related to the alternatives to the baseline in the three catchment areas. In 2020, €, project lifetime: 30 years.

FYRISÅN (SE)	PV (COSTS)	PV (BENEFITS)	NPV
1. Incineration	9,117,773	2,225,031	-6,892,743
2. Nutrient extraction	86,719,735	38,753,254	-47,966,481
3. Source-separation	204,668,363	20,288,347	-184,380,016
SLUPIA (PL)			
1. Reject water	1,378,465	1,281,060	-97,405
2. Nutrient extraction	39,866,667	7,500,923	-32,365,744
3. Source separation	110,111,015	4,805,148	-105,305,867
VANTAANJOKI (FI)*			
1. Anaerobic digestion	7,352,532	97,986,522	90,633,991
2. Thermal treatment	181,932,557	172,491,181	-9,441,377

Note: *baseline here is composting of agricultural residues and horse manure at a central plant. Blackwater from scattered settlements thermally hygienised at the same plant.

example is source-separation, which can reduce the risk of environmental pollution due to overflow in the sewer systems during heavy rains. Also, accounting for longer time periods beyond the 30 years explored in this study might yield different results.

When conducting a CBA study, it is often difficult to assess costs and benefits due to lack of regional comparable data, especially in regard to the benefit site. There are for instance uncertainties in the transformation of GHG emissions into monetized benefits depending on whether an abatement cost or damage cost method is applied. Further, the benefit of reducing eutrophication is here put into monetary values through the marginal willingness to pay for improved water quality. By using a benefit transfer value, as applied here, it is subject to some inaccuracy. Future research could focus on establishing a common framework for valuing these non-market benefits that are targeted ecosystem services in the Baltic Sea- so that future CBAs could be less resource-intensive.

4.2.3. SWAT MODEL OF THE THREE CATCHMENTS

In the project, the SWAT (Soil & Water Assessment Tool - <https://swat.tamu.edu>, Arnold et al., 1998) model was used. The first step of the modelling work was collection and processing of the input data for each case study catchment. These data included digital elevation (DEM), land use and soil maps, as well as meteorological data and information on point sources, agricultural practices etc. Modelling periods covered broadly the years 2000-2015. Creation of model set-ups was done in a semi-distributed way, with the numbers of sub-catchments defined being high enough for a good spatial representation and distinction (e.g. between hotspots vs. less polluting areas). In the next phase of the modelling work rigorous calibration and validation for river discharge (m^3/s), sediment and nutrient loads (kg/day) were performed for each case. Here, automatic calibration and uncertainty analysis with SWAT-CUP software (SUFI-2 programme) were used. After calibration and validation, the model applications provided spatially distributed nutrient loads for the baseline conditions (0-scenarios, reference), on top of which scenarios were simulated (see section 4.2.4).

The **three baseline SWAT applications of the case study catchments were uploaded into the open data repository of the Finnish Environment Institute, SYKE** (<https://ckan.ymparisto.fi/dataset>). Thus, anyone with knowledge on SWAT can download the files and start making his/her own runs, simulations, and scenarios. Moreover, it is of great help to other modelers (researchers and practitioners) to utilize the numerous parameters determined for the case study catchments in their own SWAT projects. To find a

SWAT application in the public SYKE's Research Data Service, the user can either scroll or type e.g. "SWAT" into the search box, or use the direct link (<https://ckan.ymparisto.fi/dataset/free-access-to-functioning-swat-application-of-the-three-river-basins>).

4.2.4. ECOTECHNOLOGY EFFICIENCY FOR CAPTURING NUTRIENTS AND CARBON

To assess the efficiency of the selected ecotechnologies in reducing total inputs of carbon and nutrients from various waste streams and providing multiple benefits, we applied the SWAT model in the three case study catchments (Koskiaho et al., 2020) and simulated agri-environmental Best Management Practices (BMPs) on the basis of River Basin Management Plans (Piniewski et al., 2020), which are part of the EU Water Framework Directive (Chave, 2001).

We used the highest scored ecotechnologies from the MCAs (see sections 4.2.1 and 4.2.2): in Vantaanjoki, anaerobic digestion (biogas energy production based mainly on agricultural residues as feedstock and spreading of the digestate on cropland); in Fyrisån, source-separation of municipal wastewater; and in Slupia, nutrient extraction within the wastewater treatment process. The effects of applying nutrient- and carbon-rich digestate on agricultural soils in the Vantaanjoki catchment were simulated by adjusting the model parameters describing the organic carbon (OC) content and physical properties of soil. In the Fyrisån and Slupia case study catchments point sources in both catchment's SWAT applications were decreased according to the information provided in Johannesdottir et al. (2019).

The combined ecotechnologies and practices combining BAU, RBMP and Hotspot Targeting produced the largest improvements in nutrient loading (Table 2). For Vantaanjoki, the MCA-selected ecotechnology increasing organic carbon in soil from applied digested manure didn't show significant (<1%) reductions in nutrient loads to the Gulf of Finland. However somewhat greater reductions in nutrient loads were seen for Fyrisån (source separation in wastewater) feeding to Lake Mälaren in Sweden (-5% for nitrogen) and for Slupia River (nutrient extraction from wastewater) feeding to the Baltic Sea (-6 to -7% for nitrogen and phosphorus) (Table 2). **Although the selected ecotechnologies (Koskiaho et al. 2020) did not, particularly in the case of Vantaanjoki, show as high effectiveness in nutrient load reduction as the more traditional, hotspot-targeted BMPs (Piniewski et al. 2020), they have other multiple benefits including crop yield increase and electricity, heat and bio-based fertilizer production (Murcia López, 2019).**

SWAT WATERSHED SYSTEM

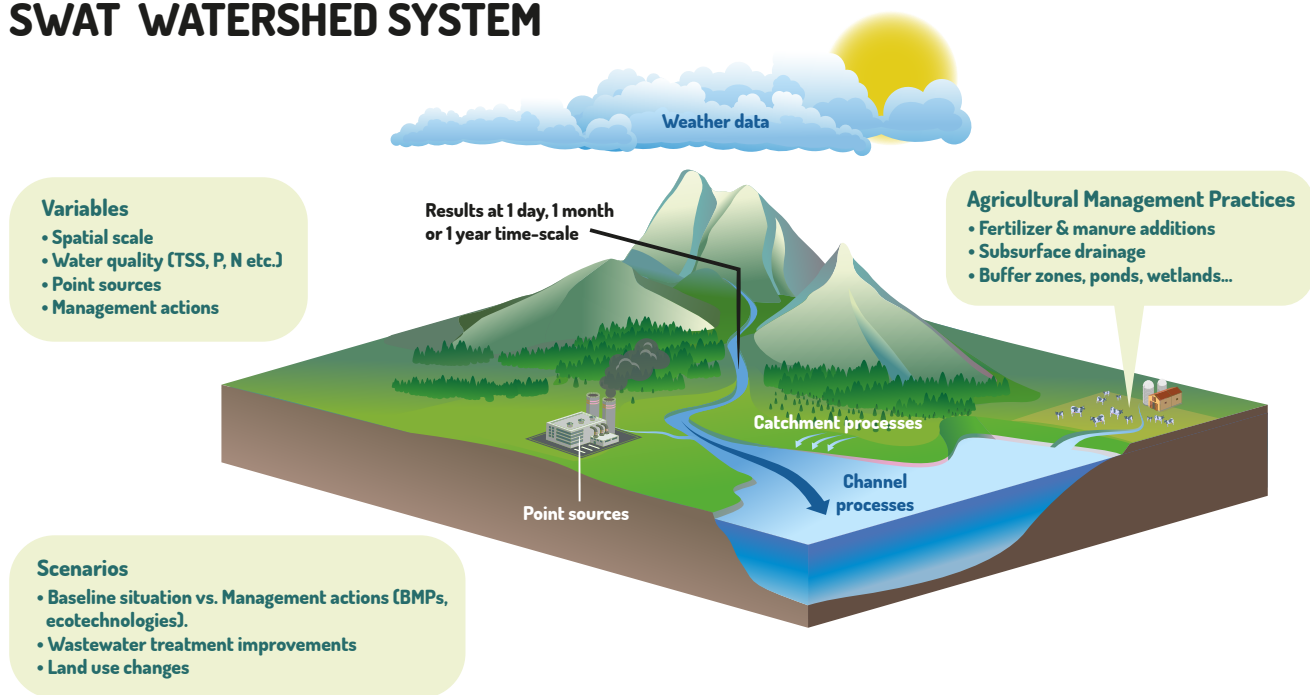


Figure 3. Details showing how SWAT pulls together various databases and management interventions to produce integrated loading data for a drainage basin.

Table 2. Results from the SWAT model running the selected ecotechnologies (Johannesdottir et al. 2019) and three cumulative scenarios (Business as Usual, Current River Basin Management Plans and Hotspot Targeting) compared with the baseline, estimating total nitrogen and phosphorus loads (kg/ha/yr) for the three drainage basins Vantaanjoki, Fyrisån and Slupia. Improvements greater than 5% are underlined.

	TOTAL NITROGEN			TOTAL PHOSPHORUS		
	VANTAANJOKI	FYRISÅN	SLUPIA	VANTAANJOKI	FYRISÅN	SLUPIA
% change						
BASELINE NUTRIENT LOAD KG/HA/YR	6.8	7.0	7.8	0.31	0.18	0.44
SELECTED ECOTECHNOLOGY*	<1%	-5%	<u>-6%</u>	<1%	-1.6%	<u>-7%</u>
BAU	-5%	-1.5%	+5%	+1.5%	+1%	-3%
BAU+RBMP	<u>-15%</u>	<u>-5%</u>	+4.5%	<u>-28%</u>	-3.5%	-3.5%
BAU+RBMP+HOTSPOT TARGETING	<u>-19%</u>	<u>-7.5</u>	-2.5%	<u>-34%</u>	<u>-10%</u>	<u>-10.5%</u>

* In Vantaanjoki, anaerobic digestion (biogas energy production based mainly on agricultural residues as feedstock and spreading of the digestate on cropland); in Fyrisån, source-separation of municipal wastewater; and in Slupia, nutrient extraction within the wastewater treatment process. Results from Koskiahio et al. (2020)

4.3. CIRCULAR INNOVATIONS IN THE BALTIC SEA REGION

BONUS RETURN carried out both practical and theoretical work to support circular innovations in the Baltic Sea Region, in the form of pre-commercial support to promising ecotechnologies as well as the production of a generic decision support toolbox for decision-makers interested in pushing and pulling the sector into a more circular economy.

Circularity is a key principle to decouple production from resource consumption and pollution. In a circular economy, not only products change, but also production processes and business models. To accelerate progress and fully benefit from circularity, economic and policy incentives need to be set very differently than they do today. Continued efforts to simplify the legal framework for reused phosphorus products are necessary, particularly at the EU-level.

This is to encourage increased adoption and implementation of circular closed loop ecotechnologies by municipalities when procuring products and services from the private sector.

4.3.1. DECISION SUPPORT GUIDELINES FOR THE TRANSITION TO A CIRCULAR ECONOMY

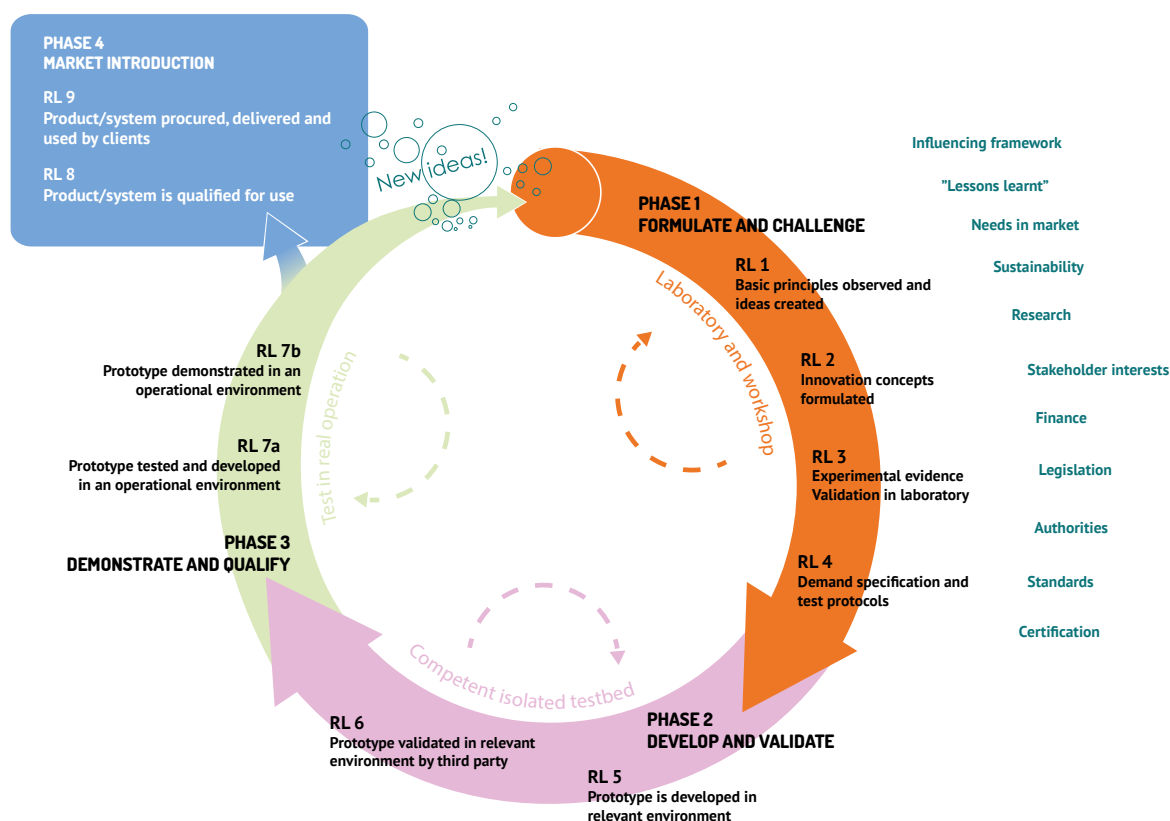
BONUS RETURN produced a set of decision support guidelines to assist the transition towards a circular economy, supporting implementation of emerging ecotechnologies for the recovery of nutrients and carbon out of by-products from wastewater and agriculture. These guidelines (Table 3) have been framed around providing support in responding to challenges that decision-makers and local implementers in municipalities and regions typically encounter when exploring the process of transitioning into a circular economy.

TABLE 3. DECISION SUPPORT GUIDELINES FOR THE EMERGING ECOTECHNOLOGIES

CHALLENGES	PROPOSED GUIDELINES	COMMENTS
Criteria for ecotechnologies	<ol style="list-style-type: none"> 1. Social innovation 2. Stakeholder engagement workshops 3. Multi-Criteria Analysis (MCA) 	<ol style="list-style-type: none"> i. What is the common understanding of the issue? ii. What are the requirements that need to be met for the issue to be solved? iii. What eco-technologies would be most suitable for the local context?
Evidence of ecotechnologies	<ol style="list-style-type: none"> 4. Literature reviews 	<ol style="list-style-type: none"> i. What are the sustainable ecotechnologies? ii. How efficient are they?
Possibilities for ecotechnologies	<ol style="list-style-type: none"> 5. The Innovation Development Cycle 	Which ecotechnologies are ready for implementation and which solutions need further support for research, development and innovation?
Sustainability of ecotechnologies	<ol style="list-style-type: none"> 6. Sustainability analysis 	Which ecotechnology is the most sustainable?
Promoting existing ecotechnologies	<ol style="list-style-type: none"> 7. Sustainable Public Procurement 8. Circular Public Procurement 	How to promote ecotechnologies already on the market?
Supporting innovative ecotechnologies	<ol style="list-style-type: none"> 9. Innovation procurement (RL 6-8) 10. Partnerships for public and private research and innovation grants (RL 5-8) 11. Innovation competition (RL 6-7) 	How to assist pulling ecotechnologies under development into the market?
Development of innovative ecotechnologies	<ol style="list-style-type: none"> 12. Market survey 13. Independent comparative study 14. Testbed trials 	How to increase the Readiness Levels of innovative ecotechnologies?
Creating incentives for ecotechnologies	<ol style="list-style-type: none"> 15. TIS light workshop 16. Policy planning for co-benefits 	How to accelerate innovative ecotechnologies?

Box 1

THE INNOVATION DEVELOPMENT CYCLE



**The term "Readiness Level" (RL) is a direct development within the project of the more commonly used term "Technology Readiness Level (TRL)" used in Horizon 2020. The omission of "T" (Technology) is to stress that the readiness level of an innovation is often less dependent on technology choices than design of e.g. business models, image and support services. The project, in addition, developed a cycle-formed Readiness Level model illustrating the process of innovation and spin-offs (Guideline #5 in Table 3).

4.3.2. INNOVATION COMPETITION AND PRE-COMMERCIAL SUPPORT

BONUS RETURN provided pre-commercial support to three promising ecotechnologies for the BSR. An innovation competition was launched (Guideline #11 in Table 3) "to assist pulling ecotechnologies under development into the market". **An open challenge was announced by BONUS RETURN intended to attract emerging ecotechnologies with a potential to recycle nutrients and carbon from agricultural and wastewater by-products. The winners of the innovation challenge received support in their pre-commercialisation efforts directed towards improving their Readiness Level (RL)** (Box 1) including adapting the innovation to local market needs.**

The innovation competition award also functioned as a platform for meeting potential investors and clients. Out of approximately 15 applicants, four finalists that emerged from a jury panel evaluation were invited to present their innovations at the Baltic Sea Future Conference in Stockholm, March 2018. In addition

to the conference presentations, the candidates presented their innovations in an interview with the jury. **Three technologies were selected as winners of the innovation competition: RAVITA, developed by Helsinki Region Environmental Services Authority (HSY), TerraNova® Ultra, developed by TerraNova Energy and BiOPhree®, developed by Aquacare.**

Aquacare received support through testbed trials in a relevant operational environment, a prerequisite to reach TRL 7. BiOPhree® is an ecotechnology for phosphorus removal and recovery from liquid streams that is built around phosphorus adsorption onto a proprietary adsorbent material. The process can be used to reach less than 10 µg TP/L in the treated stream. The technology can be applied to remove and recover phosphorus directly at a wastewater treatment plant or it can be set up remotely to remediate phosphorus overloaded streams and lakes, thus offering the possibility of both closing the loop on phosphorus and restoring eutrophic water bodies. The BiOPhree®-technology testbed trials resulted in the

collection of operational data and information that will enable Aquacare to further develop and optimize their process. Tangible results included that the process could achieve the stated effluent quality under many but not all operating conditions, and that the need for routine maintenance, at least under the testbed conditions, was significantly higher than originally stated by Aquacare in the supplied technical documentation.

BONUS RETURN provided HSY with support by conducting a qualitative market survey (n=9 WWTPs, approx. 3 000 000 pe connected in total) directed towards wastewater treatment utilities. The RAVITA-process is intended for use in the wastewater sector with the purpose of recovering phosphorus from phosphorus-rich chemical sludge that is produced in the post-precipitation steps at wastewater treatment plants. The RAVITA process recovers phosphorus in the form of phosphoric acid at rates of 55-63% of the influent phosphorus levels (Rossi et al., 2018). The market survey resulted in the acquisition of information useful for further development of the process. Results indicate there is a market interest in the process, benefits and increased flexibility linked to sewage sludge disposal options. However, survey participants also expressed that as a prerequisite, regulations regarding mandatory phosphorus recovery or a ban on the spreading of untreated sewage sludge on land would need to be implemented for the ecotechnology to be attractive for their operation. Furthermore, the survey revealed that the market expressed a need for certain features (e.g. automation, robustness, and a good working environment) and operational data, in order to increase the attractiveness of the process. Carrying out the market survey had the supplementary effect of promoting the existence, performance, and applicability of the RAVITA process within the wastewater treatment sector.

TerraNova requested support from BONUS RETURN in performing an independent comparative analysis. The conducted analysis involved two technologies, the TerraNova® Ultra process, which was compared against sewage sludge mono-incineration with chemical phosphorus extraction from sludge ash. The TerraNova® Ultra ecotechnology is intended for use in the wastewater treatment sector with the functionality of recovering phosphorus and carbon originating from sewage sludge. The technology is at TRL 8, although further development and optimization is still ongoing in the nutrient recovery parts of the process. TerraNova® Ultra processes sewage sludge into a renewable fuel, sewage sludge hydrochar, and recovers phosphorus from the sludge with a recovery rate of 60-80% in the form of solid fertilizer. The analysis revealed strengths and weaknesses for both technologies. For instance, the TerraNova® Ultra process yielded far fewer waste streams in comparison with sewage sludge mono-incineration, while sewage sludge

mono-incineration had a better energy balance compared to the TerraNova® Ultra process. A comparison of phosphorus recovery rates showed that mono-incineration could achieve a higher recovery rate (95% for mono-incineration and 80% TerraNova® Ultra) but at slightly higher costs.

4.4. BARRIERS AND OPPORTUNITIES FOR CLOSING THE LOOP

4.4.1. POLICY, GOVERNANCE, MARKET, AND TECHNICAL FACTORS

BONUS RETURN reviewed market and technical factors that affect possible scaling of circular nutrient and carbon technologies (Barquet et al., 2020). The implementation and scaling up of technologies recovering and reusing nutrients and carbon is determined to a large extent by the global market price of phosphate rock, natural gas (for ammonia and biogas production) and other fuels and energy systems (for energy-based carbon and heat reuse) all of which ultimately affect the revenue and profitability of any recovery technology. Strictly following the market costs and benefits, recovered nutrients must therefore be supplied with the same or lower market price to be economically feasible, and at the very least be as similar in application and benefits provided as nutrients used in synthetic fertilizers. Of course, there are significant societal drivers that go beyond just market drivers. The need to increase sovereign sources of phosphorus is a driver that promotes reuse of P. Another significant driver that affects the reuse of organic material in both agriculture and wastewater is the need to close the loop on carbon to reduce greenhouse gas emissions. Also, the banning of ocean dumping and landfills for the disposal of sludge and manure has created new drivers for extraction of nutrients and reuse.

The project summarized the policy and governance structures that could facilitate or impede the transformation of the agriculture and wastewater sectors towards a more circular economy (Barquet et al., 2020). Although the EU Circular Economy Package has been adopted by the European Parliament in 2018, most of the affected EU policies and regulations remain dominated by linear resource-waste thinking and not yet circular economy concepts. Priority areas for changing this are packaging, plastics, and climate-related measures. **Phosphorus has yet to be included in the EU Nitrates Directive in order to better harmonize the reuse of P with N in agriculture systems.**

HELCOM works under the umbrella of the EU as a regional coordination body that produces recommendations on nutrient emissions from



Algal bloom in the Baltic Sea, Hölö, Sweden. Image: [BMJ / Shutterstock](#)

each member country as well as recommendations to promote best practices to reduce nutrient flows. However, **historically, HELCOM has not had a focus on circularity, something which member states increasingly call for.** As a result, phosphorus recycling within the EU and the Baltic Sea Region is governed by fragmented decision-making in regional administrations. Active regulatory support, such as recycling obligations or subsidies, is lacking in most countries. Legislative harmonisation, inclusion of recycled phosphorus in existing fertiliser regulations and support of new operators would speed up market penetration of novel technologies, reduce phosphorus losses and safeguard European quality standards. Furthermore, actions need to be taken to promote recycling other nutrients and organic matter in wastewater, and “upstream” work to reduce the contaminants entering wastewater streams at the source as a way to minimize the public health and ecosystem risks associated with reuse and wastewater management more broadly.

Despite signs of increased focus on circular solutions across the EU, there are indications that this **progress is driving the system towards a narrow focus on a few new technologies for recovering and reusing phosphorus, which could lead to new lock-ins rather than context-based solutions.** Systemic impacts such as better accounting for costs and benefits over longer time periods, monetizing co-benefits,

and setting legislation that is locally relevant, could prevent crowding out of promising and locally appropriate solutions. Furthermore, solutions need to address the acceptability of the technologies and waste-derived products to users. Thus, more focus on developing user-friendly products, and not only technology-effective processes, will be fundamental to activate the market mechanisms necessary to close the loop.

4.4.2. VALUES AND BEHAVIOUR - REUSE OF SEWAGE SLUDGE IN SWEDISH AGRICULTURE

Generally, the spreading of sewage sludge on agricultural land especially for food crop production faces resistance and remains a subject of a highly polarized debate among different stakeholders in the agriculture sector in Sweden (Wallenberg and Eksvärd 2018 ; SOU, 2020). A ban on this practice is even being considered and was part of the terms of reference of the most recent inquiry commissioned by the Swedish government (SOU, 2020).

As part of the BONUS RETURN project, **we examined perceptions on the use of sewage sludge on agricultural land in Sweden including the health, economic, environmental, and social implications of the practice, and the potential implications that a ban on the practice may have on the agricultural**



A farmer distributing sewage sludge on farmland. Image: [SuSanA Secretariat / Flickr](#)

sector (Ekane et al., 2020). Stakeholders were interviewed discussing the extent to which farmers depend on sewage sludge as an agricultural input; farmers' perceptions and choices regarding sludge reuse; organizational and institutional arrangements including compliance regimes; the future of sewage sludge management in line with the recommended options of the recent inquiry.

The study showed a polarized landscape where actors from both ends highlight benefits as well as risks from the spread of sludge. This is the same for other agricultural inputs such as cattle manure and pig slurry, but which are relatively more acceptable and widely used. **Sewage sludge is marked and stigmatized because of its origin, characteristics and the purpose for which it is to be used. Both sides of the debate have something to say in terms of the viability, safety and controllability and severity of the risks. But what remains influential is that perceived risks take precedence in situations of unknowns and uncertainties regarding characteristics, fate of microplastics, PFAS, substances of concern, including potential 'cocktail effects' and the absence of appropriate methods of monitoring and measuring these effects.** This explains the restrictions expressed by the food industry.

A market-driven approach seems to be the major driver in reuse of sewage sludge on croplands, with

entrepreneurs playing key roles in advocating the practice. Many farmers engaged in sludge reuse rely on the [REVAQ](#) certification system which has greatly improved the quality of sludge in Sweden by promoting upstream removal of toxic substances such as heavy metals. Most importantly, transparency and mutual trust in the quality of what farmers receive as certified sludge and what they produce as cereals and other crops is worth emphasizing and is key for the system to function, knowing well that once trust is lost it is extremely difficult to recover.

This study revealed some stakeholder support for stricter regulations as a way forward in managing sludge. This could indicate that source control ('upstream ecotechnology work') as opposed to end-of-pipe control can be a way forward in line with the Swedish environmental objective to create and maintain a non-toxic environment. This, however, would require shared responsibility in terms of costs of the required innovation and transformation, mutual trust in the compliance regime that will be instituted, and oversight on the extent to which different activities contribute to the problem. Moreover, for instituting stricter regulations on the use of sewage sludge in agriculture in Sweden to make sense, similar measures must be taken at the international level to trace and monitor unwanted substances in food imported from other countries with much weaker regulations.

4.5. STAKEHOLDER ENGAGEMENT

The management of nutrient enrichment in the Baltic Sea Region has been and continues to be characterised by a top-down science-based approach. This is embodied as a techno-centric worldview which transfers partitioned scientific knowledge to those sectors that have traditionally been responsible for implementing actions (ecotechnologies) to reduce nutrient emissions within e.g. agriculture, forestry, and wastewater treatment. There is however, an increasing recognition that these ecotechnologies are nested in complex settings that exhibit non-linear and random properties (Berkes et al., 1998). They also need to be viewed systemically to reflect the mosaic of interdependencies between the biophysical and socio-economic domains (Ison, 2010). Interdependency moves problems and can compound or reproduce inequities across and between landscapes, timescales, sectors, and societal intersections (Powell et al., 2017). Moreover, the implementation of ecotechnologies has high decision stakes, and potential catastrophic risks with flow-on effects to other sustainability challenges such as, climate change, biodiversity loss, terrestrial and aquatic food security, and flood control.

To both make sense of the complex settings that BONUS RETURN has operated in, and to devise implementable constellations of ecotechnologies, we considered it necessary to apply a **knowledge co-production approach**. This approach recognises that a rich diversity of perspectives can be surfaced in the interplay of many kinds of knowledge from those considered as experts, lay people, and those of different social, intersectional, and cultural backgrounds (Sardar, 2010). In so doing, values and interests are evoked, and views on what constitutes a desirable ecotechnology are diversified and potentially contested. Thus the role of the project's "Innovative Methods in Stakeholder Engagement" was to foster this kind of dynamic with the aim of catalysing the selection of ecotechnologies that could both reduce nutrient emissions and provide co-benefits for diverse constellations of stakeholders.

Methodologically we focussed on two key vehicles to foster knowledge co-production processes between stakeholders and researchers from the project consortium. These are described below.

4.5.1. STAKEHOLDER REGIONAL EXCHANGES FOR LEARNING AND INNOVATION

Three regional learning exchanges were organised during the project. The purpose of these was to facilitate learning exchange between the project partners and local stakeholders as well as a broader network of actors from industry, academia, public, and private sectors in the BSR in order to contribute

to discussions on opportunities and challenges for deploying systemic innovations and eco-technologies in the BSR.

Some of the key insights from the discussions indicate **there is a need to obtain greater coherence between regional and local policy, more synchronization of existing directives at the regional level, and greater local understanding of how to utilize regional and international policy instruments (e.g. Agenda 2030, Farm to Form Strategy, Water Framework Directive) to accelerate circularity**. As part of this, the disconnect between national-level governments and cities was clear. A result was that available policy options at the local level, often framed in terms of procurement rules, do not reflect the macro-discussions of sustainability and circularity. Today procurement rules in cities often focus on obtaining the best price and not the most sustainable option. The disconnect between global sustainability discourses, national government agendas, and local priorities is also reflected on the lack of interest and engagement of the wider public. Lack of incentives and appropriate policy that fosters circularity further widens this gap between what citizens consider is important, what research identifies as crucial, and what policy opts for implementing.

Lack of public interest coupled with lack of adequate policies result in poor conditions for innovation uptake at local levels. Eco-technological innovation for a circular economy needs to be better framed in terms of service provision. At the same, changing the mindsets of decision-makers away from "quick fixes" that are often not sustainable in the longer term could produce a change towards procuring services instead of procuring "machines". Adopting national legislations in favour of circularity could send the right message to the private sector and create better conditions for innovation and local uptake. At the same time, financing for higher-risk projects (e.g. from the EU or national funds) needs to be made available, and these in turn, need to penetrate public procurement in cities.

One of the themes of the learning exchanges was **"Symbiosis in a Circular Economy: Exploring solutions for improved water and nutrient governance"**, which covered the topics: **public procurement for circular innovations; testbeds - infrastructure, finance and setup; payments and other schemes for nutrient and carbon recycling; and requirements for market uptake of recycled fertilizer products**. The sessions reviewed sharing of market risk among buyers and sellers of ecotechnologies and the need for changes in attitudes among stakeholders to support decision-makers. Testbeds were reviewed as important ways of tapping into new innovative technologies in order to share benefits and outcomes among stakeholders. How a company's intellectual property and

patents are to be protected while they get involved in open demonstrations and testbeds was highlighted as an important element to manage. Carbon farming was discussed as a 'win-win' approach to compensate for CO2 emissions, manage nutrients, soil structure and water sustainably, and provide benefits for farmers as a potential payment scheme to serve these purposes and enable a transition to climate-smart agriculture. Lastly, the requirements for market entry of recycled fertilizer products were discussed. The discussions confirmed the lack of a holistic strategy for nutrient recycling among the Baltic Sea countries. It was suggested that "cleaner" and more efficient recycled organic products be made more attractive to farmers compared to conventional fertilizers. Also, legislation with possible subsidies for organic products, taxes on mined phosphate or stipulated levels of phosphorus recycling were mentioned as ways to help encourage use of recycled products. Finally, standardization of product quality and certification were mentioned as important elements in enhancing market entry.

The third and last Regional Learning Event **"Mission Blue"** had two objectives: to test the architecture of a mission-oriented approach underpinned by a co-creation process; and to engage participants in a reflection about what kinds of interventions, and what 'innovation mixes' or 'innovation portfolios' might have the greatest potential to achieve transformative interventions as part of an overall "mission" in the context of the Baltic Sea.

Despite the wealth of knowledge produced throughout the region and the actions taken to abate pollution, eutrophication of the Baltic Sea by wastewater, agriculture, industry, and atmospheric deposition remains a challenge. A combination of technical and policy innovation as well as financial and economic incentives are needed to transform the sources of pollution in land, watersheds, coastal areas, and the open sea into resources.

The aim was to contribute to producing more tangible cross-sectoral prototype interventions that could be taken forward and further developed as impact projects within the broader umbrella of "Missions" for oceans. In line with HELCOM's goal for the region, the mission addressed in this workshop was of a Baltic Sea unaffected by pollution. Accordingly,

interventions consisted of a selection of different measures to address a carbon and nutrient stock or flow.

Forty-nine participants from Germany, Netherlands, Latvia, Poland, Denmark, Finland and Sweden representing funding agencies, research, branch organizations, the private sector, and regional organizations collaborated to develop five circular interventions that could address eutrophication in the Baltic Sea. For each intervention, participants identified the actors and processes, existing and required capabilities, and positive and negative impacts. The design of the interventions was guided by criteria related to circularity, efficiency, feasibility, co-benefits, innovation potential, coherence, and risk.

To design interventions, we used the synopses of new measures or actions collected by HELCOM at the end of 2019 from regional stakeholders, and which would inform the update of the Strategic Plan for the Baltic Sea Action Plan (BSAP). This list was organized, categorized, and further developed by workshop participants. The preparatory process culminated with a list of 21 land-based, catchment-based, or coastal/offshore-based measures, and organized in four categories: coordination, data, ecotechnologies and policy. The list of measures was used during the workshop to design five interventions consisting of up to four measures.

The result is illustrated in Figure 4, with the following five interventions:

- Increasing incentives for valuing nutrients, resource recovery and circular nutrient economy
- Improving the integration of farming practices with required nutrient reductions across the BSR
- Integrated approach between sea-based and land-based measures
- Reducing nutrient surpluses and increasing efficiencies in BSR agriculture
- Rebalancing hotspots - Cost-efficient routes from fork to farm to fork



Figure 4. Overview of the five interventions created during the Regional Learning

4.5.2. SERIOUS GAME SYSTEM

The development of a Serious Game System (SGS) (Fig. 5) epitomized the emphasis on innovative methodologies for stakeholder engagement. The overall aim of the SGS was to provide a creative, safe and inclusive learning space that invited deliberation over the feasibility of different constellations of ecotechnologies by drawing on empirical insights generated by the BONUS RETURN project and enacting a co-inquiry process with stakeholders from the three case study settings. Furthermore, it supported a participatory monitoring and assessment of the vulnerability of different constellations of ecotechnologies within local BSR contexts. The SGS served as a platform to enhance agility and adaptive capacity when selecting ecotechnologies through introducing an awareness of the obstacles posed by conflicts of interest and the uncertainties associated with system shocks.

Our iterative development process resulted in two SGS outputs, namely SELECT ECO-TECH in the format of a board game and MONITOR ECO-TECH in the format of a digital game. SELECT ECO-TECH embodies a learning platform that hosts knowledge co-production processes enacted by a series of iterative playing sessions. It created the space for exploration and experimentation of innovative constellations of ecotechnologies that have the capacity to create synergies. Stakeholders both informed and co-developed parts of the SELECT ECO-TECH through their engagement, from contributing to the game content with their knowledge and experience of

ecotechnologies, development interventions, system shocks that have relevance to their local contexts; to testing and validating the game mechanics. Findings from the development of SELECT ECO-TECH suggest that (i) within the open and iterative structures of the board game setting, meaningful and locally relevant narratives can be created to enable choices that move beyond technocratic solutions to take into account the inherent complexity of the biophysical, socio-cultural, economic and political landscape; (ii) the learning and co-production of knowledge already began at the onset of the development process and was not dependent on a fully functional game with prescriptive rules and mechanics.

Drawing on the feedback emerging from previous playtesting sessions in the board game version, the digital game system, MONITOR ECO-TECH, utilised the computational power to provide tracking capacity, finer granularity of data, and the ability to test and evaluate a multiplicity of choices and constellations of ecotechnologies. MONITOR ECO-TECH is an interactive digital SGS underpinned by socio-ecological data and simulated dynamics that supports an experiential and exploratory learning environment to enhance the adaptive capacity of stakeholders to respond to system shocks that can lead to unexpected nutrient and pollution emissions in the BSR. The increased optimisation of the system mechanics in the digital game allows for increased number of turns and increased opportunities to monitor the performance of different constellations of ecotechnologies, especially under complex and chaotic conditions characterized by system shocks.



Figure 5. Mediating stakeholder co-inquiry by testing out different constellations of ecotechnologies that both tackle nutrient emissions and provide local co-benefits in a serious game system.



5. BROADER SOCIETAL IMPLICATIONS

5.1 RESOURCE, ENVIRONMENT AND SOCIETAL IMPLICATIONS OF A NUTRIENT CIRCULAR ECONOMY FOR THE BALTIC SEA REGION

There are several underlying benefits and costs related to society's adaptation to nutrient circularity in the Baltic Sea Region. The benefits include new opportunities for employment in the process of shifting from mixed solid and liquid waste disposal systems to source-separated capture and extraction systems. Part of that are new local industry clusters combining agriculture, food, energy and water services involving closed loop solutions. Economic incentives for these to flourish will mean an increased trend towards localization of tax and subsidy systems in order to promote circular and regenerative systems using local capacities. However, this requires a change in the value given to local nature-based systems that provide recycling services and those that prevent nutrient runoff within drainage basins. With increased recycling of nutrients and carbon between agriculture, wastewater systems and energy production, there will be a reduced exploitation of virgin natural resources linked to production of chemical fertilizers and use of fossil fuels. Positive impacts will be reduction in greenhouse gas emissions, reduced nutrient runoff and improved water quality, reduction in algal blooms, and improvement in fishery production.

Investments will be required in the development of new industries for capture and extraction of C, N, P from agriculture and wastewater wastes that are turned into resources. These investments in circular systems will have knock-on impacts on the cost for food, energy and water supply plus sewage services. Society will need to understand that circular systems are not free and require sharpened resource use efficiency in order to reduce wasteful practices both within industry and among consumers. Other costs will be generated through the need to provide subsidies to agriculture, wastewater, urban sanitation and energy producers as incentives to use BATs to increase efficiency and nutrient circulation.

5.2 OPTIMISING CAPTURE AND REUSE OF WASTES AND TURNING THEM INTO ENERGY AND FERTILIZER RESOURCES

Capture and reuse technologies represent opportunities to close the loop within the agriculture and wastewater sectors. The starting materials include manure, crop residues, digestates (liquid and solid), wastewater and sludge. Important factors that need to be prioritised in implementation are bioavailability of the products for fertilizer, the transportability of the products to markets and the ability for storage without losses of volatile N and C or water-soluble N and P. The technologies readily at hand include:

- anaerobic digestion of wet matter which has the added advantage of producing biogas and allows N and P capture
- aerobic composting of dewatered matter which will allow for mineralization of N, P and C increasing the bioavailability of the resulting fertilizer
- pyrolysis of dried matter designed to retain C in the form of biochar which also retains P content
- incineration of dried matter to produce ash for extraction of P (N and C are lost to the atmosphere)

5.3 AGRICULTURE PRACTICES THAT ALLOW FOR RETENTION OF NUTRIENTS ON LAND PREVENTING RUN-OFF LOSSES

There are several farming practices that allow for trapping of runoff and soil to prevent losses to water courses. These include:

- planting of buffer zones that can trap runoff water containing N and P
- constructed wetlands that absorb N and P in wastewater and runoff
- sedimentation ponds on farmland to trap suspended soil particles containing N and P
- contour ploughing to reduces runoff formation
- cover crops that can trap and fix N and thus prevent losses to the atmosphere and water courses
- planting of crops without manure additions in order to reduce residual P levels

At the same time, there are several issues that presently impede but could be reversed or modified in order to promote circular, more integrated solutions for sustainable and beneficial C, N and P management. These are summarized below.

5.4 A FAIRER PRICE THAT CAPTURES EXTERNALITIES TO OPEN THE MARKET TO REUSE FERTILIZERS

Affecting the overall dysfunctionality of the nutrient cycles reviewed here including the whole aspect of creating more circularity, is the fact that conventional fertilizers are relatively cheap and are often not used efficiently. The steps from mining to the level of the food consumer incur losses running up to 80% for P [Schröder et al., 2010] and even

higher for the N system originating from atmospheric extraction [Sutton et al., 2013]. Because of the relatively low unit cost of mining, extraction and production, the reuse products cannot compete. For both the agriculture and wastewater sectors, production of commercially competitive and effective fertilizer reuse products remains therefore riddled with economic hindrances since chemical fertilizers are priced without considering many externalities while the nature of reuse products is that externalities directly steer the final price.

Implementation and scaling of the reviewed agriculture and wastewater technologies is steered to a great extent by commodity markets for the raw materials used in producing conventional fertilizers e.g. P-rock, methane (for ammonia production), potash, sulfuric acid, other chemicals and various fuels and energy sources. The reuse products have to compete then with relatively cheap fertilizers that are priced based on these scaled-up commodities.



5.5 ECONOMIC TOOLS TO PROMOTE NUTRIENT CAPTURE AND REUSE

The economics of capture and reuse of nutrients and carbon from agriculture and urban wastewater are central to determining the feasibility of scaling up promising technologies and practices. Whether or not a technology is economically feasible is typically determined by its cost, the market demand and price for the recovered and competing products, its transportability, and also levels of energy consumption [Pearce, 2015; Mayer et al., 2016; Pronk & Koné, 2009; Schipper, 2019]. There are economic and administrative tools that can help promote recapture and reuse (e.g. quotas (both tradable and non-tradable), fixed and volume-based fees or taxes and subsidies). Much depends on the context in which the technologies are applied, and at the end it becomes a political, public/private choice accounting for local circumstances and priorities. Combining different measures and tools can provide a more sustainable solution for all parties involved.

5.6 REGULATORY MECHANISMS TO BETTER MANAGE NUTRIENTS

Within the agriculture sector, focus on N content of manure and crop N requirements has shifted attention away from surplus levels of P in farm soil and watersheds. Stored manure has relatively low N/P weight ratios, 3:1 and less, while most crops require double that ratio, closer to 5:1 or 6:1 [Paterson et al., 2006]. To meet the crop N requirements, farmers

end up applying onto soils 5 to 10 times the crop P requirements, eventually leading to losses through seasonal runoff. The EU Nitrates

Directive does not control this problem [Barreau et al., 2018; Van Grinsven et al., 2016]. In the Baltic region some countries have national regulations for P application to cropland e.g. Sweden, Germany and Denmark's "harmony rules" [HELCOM, 2017].

The EU Water Framework Directive also identifies areas sensitive to surplus P, but this does not directly manage manure spreading on croplands. Also, manure, a source of C, N and P is not evenly distributed geographically and is not easily transported to areas where it is needed [Pellervo et al., 2013]. So, reuse requires accounting for capture technologies and further transformation of product (e.g. dewatering) in order to make transport logistics economic.

5.7 DRIVERS PROMOTING REUSE

Reuse of P is receiving attention www.phosphorus-platform.eu with increased awareness surrounding potential shortages of imported P fertilizer due to geo-political factors. Securing sovereign sources of P has created increased interest in reuse. Also, the risks surrounding exposure to cadmium (Cd) by using fertilizer from sedimentary P-rock (in which Cd occurs naturally at relatively high levels), are relevant to this discussion. P recycling in agriculture and wastewater provides an opportunity to produce fertilizer feedstocks with lower levels of Cd. Additionally, the high priority to reduce greenhouse gases by capturing and reusing carbon in soils is an opportunity for reuse of organic material from agriculture and

wastewater. Renewable energy in the form of biogas can be produced from sludge, manure and farm/food wastes. Digestates contain N and P and can be applied to cropland. Indeed, biogas can be seen as a fundamental driver to developing the circular economy and this has only begun since global production has reached only 2% of its potential [Jain, 2019]. Connected to all this is the legislation that has banned ocean dumping and landfills for the disposal of sludge and manure [Tornero and Hanke, 2016] thus forcing the development of alternative solutions such as capture and reuse.

5.8 REDUCTION IN LINEAR AND “SILO” THINKING TO PROMOTE CIRCULARITY

Although the situation above justifies action on how we manage nutrient-rich waste streams, the EU directives and HELCOM have been slow in promoting circular systems. These directives and recommendations suffer from decades of traditional linear systems management where resources once used are designed to produce waste for disposal [Barquet et al., 2020]. The wastewater and agriculture sectors have polarised views on the definition of waste [Cordell et al., 2009]. Namely, in agriculture,

waste is seen as a resource since farming commonly includes the age-old practices to reuse both manure and crop residues. Wastewater systems on the other hand are designed to treat and remove waste and produce safe effluents - making recapture and reuse a second priority. This polarisation in thinking often impedes implementation of circular, more integrated solutions between these sectors. There are also negative attitudes among farmers, the food industry, health officials and policy makers about spreading sewage sludge on fields because of unwanted contaminants e.g. pharmaceuticals, heavy metals and microplastics [Nizzetto et al., 2016]. On the contrary, these concerns should be a signal to work preventatively upstream to reduce or eliminate these substances so circularity can be introduced. The Swedish work around certifying municipal sewage treatment plants for safe reuse of their sludge is such an example www.ieabioenergy.com/wp-content/uploads/2018/01/REVAO_Case_study_A4_1.pdf.



6. CONCLUSIONS AND RECOMMENDATIONS

6.1. STATE OF THE BALTIC

The Baltic Sea Region is particularly vulnerable to nutrient and carbon emissions arising from agriculture and wastewater. Although the region has reduced the use of conventional fertilizer and improved wastewater treatment since the early 1990s, phosphorus levels remain high in the Baltic Sea. The ensuing phosphorus-driven annual cyanobacterial blooms fix more nitrogen from the atmosphere than what originates from the anthropogenic riverine input. Further reductions especially within agriculture in phosphorus and nitrogen are therefore necessary to abate the current levels of eutrophication.

Recommendations for policy: Both nitrogen and phosphorus need to be co-managed using legislation linked to balancing agriculture surpluses. Although nitrogen reuse in agriculture within the EU is regulated by the Nitrates Directive, no such norm exists for phosphorus. There is a need for harmonised regulation of both N and P. At present P is regulated using national directives in only some of the EU countries. Ecotechnologies for nutrient and carbon capture and reuse should be promoted to reduce runoff and drainage losses to receiving waters by closing the nutrient loops upstream.

Recommendations for future research: Studies should explore hotspots of leakage as well as hotspots where measures would be most effective. Furthermore, there is a need to design integrated and harmonized risk assessment of phosphorus losses from agricultural soils to surface waters.

6.2. ECOTECHNOLOGIES TO CAPTURE AND REUSE NUTRIENTS AND CARBON

There are technologies and practices (ecotechnologies) within the wastewater and agriculture sectors that can be applied at large-scale in order to close the loop on nutrients and carbon in the Baltic Sea Region and this way contribute to slowing the process of eutrophication. This project identified 25 recovery and reuse ecotechnologies in agriculture and 28 reuse and recovery ecotechnologies within the wastewater sector, relevant to the Baltic Sea Region. Using multi-criteria analyses, stakeholder input and the SWAT model (Soil, Water Assessment Tool), the project recommended a number of these ecotechnologies for application to the three basin case studies in Sweden, Finland, and Poland.

Recommendations for policy: Mature technologies such as struvite crystallization and ammonium sulphate production from ammonia stripping should be further scaled up in order to provide added capture and reuse of both nitrogen and phosphorus

from both manure slurry and wastewater. Also new ecotechnologies for nutrient and carbon capture that show promise need to be promoted, e.g. the in situ adsorption of dissolved phosphorus, production of phosphoric acid from sludge and biocoal production from sludge. Common farm practices such as controlled manure spreading, winter crop cover and runoff buffer zones (including wetlands and sedimentation ponds) need to be continued and enhanced taking also into account phosphorus levels in the soil. Alternative solutions such as source separation, which help recovery of multiple resources (nutrients, water, energy) could be more widely implemented. Nevertheless, this would require investment in different infrastructure and a long-term policy commitment. This could be feasible in newly-developed housing projects (such as H+ in Helsingborg - <https://hplus.helsingborg.se/>).

Recommendations for future research: Longer-term studies on plant uptake of hazardous substances and microplastics are to a large extent missing. Future studies on the subject could provide better guidance for technology development. Furthermore, research could inform annual field-level fertilizer planning and farm-gate nutrient balancing for nitrogen and phosphorus in farms (Barquet & Rosmarin 2020). Lastly, assessing costs for many of the ecotechnologies identified is difficult due to the lack of data and full field trials. More and better data would lead to more accurate comparisons and cost-benefit assessments.

6.3. DEALING WITH POLICY AND GOVERNANCE BARRIERS

Barriers and opportunities in policy and governance impact directly the promotion and marketability of circular ecotechnologies. Linear and “silo” thinking impedes progress towards circularity.

Recommendations for policy: The new EU Regulations on Fertilizers have potential to help recycled organic products enter the market. But for this to happen the pricing of conventional fertilizer will need to consider externalities. This could lead to a fairer P price which captures aspects such as health and environmental impacts from P mining. Parallel to this, continuing efforts to simplify the legal framework for reused P products, particularly at the EU level is necessary. At the same time, harmonising policies across different types of resources is important, to ensure that certain types of reuse that may be appropriate in a given context are not hindered, or that types of reuse that may be less appropriate in other contexts are indiscriminately supported (Barquet et al., 2020).

Recommendations for future research: There remain many unclarities when it comes to closing the loop. Sharing of responsibilities and ownership of

processes and material (e.g., what happens and who is responsible for sewage sludge when it exits a wastewater treatment plant and enters the recovery process chain?) should be clarified in order to reduce uncertainty in the final product, as farmers and consumers do not know all the characteristics and health and environmental risks related to the land application of these waste-derived fertilisers.

6.4. DEALING WITH MUNICIPAL ECONOMIC BOTTLENECKS

An outcome from comparing the three catchment areas in Sweden, Finland and Poland was that the economics of ecotechnologies for circulating nutrients from agricultural wastes can have net economic benefits while ecotechnologies in wastewater management show net costs.

Recommendations for policy: Sustainable solutions are today an option rather than an obligation in public procurement for wastewater treatment. Sustainable solutions that ensure circularity could be more actively implemented when municipalities are in the process of buying products and services from entrepreneurs. However, few cities have the knowledge and capacity necessary to procure for complex cross-cutting problems and procurement rules should therefore be more prescriptive than they are today. Also, economic and administrative tools should be used to help promote capture and reuse (e.g. quotas (both tradable and non-tradable, fixed and volume-based fees or taxes and subsidies). Technologies for P reuse are necessary and viable in larger cities, where the taxpayer base is large. However, smaller cities pollute disproportionately to their population because more effective wastewater technologies - and in the future technologies for P reuse - are too costly. Here, ensuring more sustainable practices in farms, or establishing adequate decentralized systems will continue to be important. Municipalities can create clearer guidelines and requirements that send strong signals to entrepreneurs on the type of technologies and services desired for the development of the city, while at the same time making it easier for circular innovations to succeed. For example, testbeds for innovations in municipalities could favour circular solutions with multiple benefits to society and minimized effects upon the environment. To deal with budgetary constraints, potential additional costs associated with more sustainable or more circular solutions could be matched to the work that municipalities have to carry out to comply with European frameworks and strategies (Farm-to-Fork, Water Framework Directive, EU's Circular Economy Strategy, Green Deal). A procurement system where solutions with the most gains are premiated -

rather than solutions with the lowest price- could further incentivize municipalities to transition to multi-sector solutions that provide longer-term sustainability.

Recommendations for future research: Future studies should use longer time-frames - than the traditional 30 years - when assessing costs and benefits of centralized wastewater treatment plants versus alternatives. Developing a common framework for valuing non-market benefits, including improving the data base, could simplify cost-benefit assessments and make them less resource-intensive. Furthermore, future cost-benefit assessments need to incorporate the monetization of multiple benefits (or co-benefits) beyond the infrastructure's main purpose to capture health, climate, environmental and social benefits. Such studies could compare costs, energy use, as well as the social and environmental benefits and drawbacks from different technologies. In addition, studies should investigate burden-sharing of costs stemming from capturing and recycling nutrients. At the same time, there needs to be a consideration of other streams for recovering nutrients, for example from the mining or forestry sectors, where significant technological progress has been made. More holistic cost-benefit assessments could in turn contribute to policy by informing municipalities' strategies towards European directives and frameworks.

6.5. RECYCLED FERTILIZER PRODUCTS TO CLOSE THE LOOP

The project identified a gap between technology development on the one hand and product development on the other. Innovative ecotechnologies for capturing and reusing nutrients are perceived as having great potential but without the entire process of product and quality development for delivery to the market, many of these would not become success stories.

Recommendations for policy: Increased focus needs to be placed on product development, and not only technology development. This implies fostering circular approaches throughout the Readiness Level process that accounts for technical effectiveness, but also a product's applicability and appeal that responds to users' values and market needs. Furthermore, product development needs to be founded on evidence concerning, for example, energy use, financial feasibility, potential to reduce emissions, and uptake capacity. Certification and quality standards also need to be part and parcel of this product development. Future innovation funds could have a more explicit inclusion of a user-approach. Market-product fit and developing the skills and resources to understand socio-economic contexts, should be as important as the technical readiness

level. Beyond product development, ecotechnologies to reduce, recover, and reuse nutrients in agriculture exist, however, their application is limited partly by the EU Common Agricultural Policy - that incentivizes large and homogenous farms - and partly by the Fertilizers Regulation - which continues to favour mineral fertilizers. These policies need to be rethought.

Recommendations for future research: The development of fertilizer from recycled particles in waste streams needs to account for plant uptake and nutrient availability. Longer-term studies on plant uptake of hazardous substances and microplastics are to a large extent missing. Future studies could provide better guidance for product development but also to future legislation that seeks to regulate practices (e.g., for using sewage sludge). Within agriculture, more research is needed to explore farm structures (including size and composition) and fertilizer levels that account for geological and climatological conditions. Better understanding of the role that small or medium farms could play for reuse of P sources is necessary. Relatedly, a comprehensive assessment of agricultural practices with focus on how P is currently used (and abused) in food systems is needed as it can contribute to establishing a system where lower use of nutrients is favoured (e.g. through tax, or incentives) (Barquet & Rosmarin 2020).

6.6. MANAGING STAKEHOLDER LEARNING AND ATTITUDES

Stakeholder engagement and social learning are two important components which will help ensure that nutrient and carbon circularity will take hold within agriculture and the wastewater sector. Indeed, the debate in Sweden regarding reuse of sewage sludge on croplands is at present a polarised one. But upstream use of ecotechnologies to remove toxic or risky substances and more rigorous certification of sludge are ways of finding safe solutions.

Recommendations for policy: Mainstreaming the idea of the circular economy across society and local, national and supranational governance structures is a priority. This requires 1) a shift in

mindsets (away from take-make-dispose and towards reduce-reuse-recycle-recover strategy), 2) new circular business models and 3) increasing implementation capacity of national and local governments and municipalities.

Promotion of new business models with increased collaboration between wastewater treatment plants (i.e. a source of reused P), fertilizer companies (i.e. a potential client for reused P), and farmers (i.e. potential end-users of recycled P) is a necessity for circular P economy. For this, collaborative platforms are necessary. There exists a number of such thematic platforms at European (e.g., Phosphorus platform) and national levels (e.g., Nutrient Platform or the Swedish Water Association in Sweden) that play very important roles in convening actors, brokering knowledge, and bridging across sectors. Continuity of such platforms beyond short-term project timelines is important not to lose momentum.

Recommendations for future research: Studies on how to improve knowledge uptake in a multi-level governance setup could explore the types of questions, formats, and services needed for decision-makers to use existing evidence more efficiently. Studies should explore what tools and methods could improve knowledge transfer and coordination between farmers, authorities, and decision makers (Barquet & Rosemarin 2020). Research could be carried out to explore capacity needs for implementation - including procuring, testing, and purchasing - circular innovations in cities. New collaborative platforms, for example borne out of research projects, should seek to support or collaborate with existing ones rather than create entirely new ones. This will strengthen regional efforts and avoid stakeholder fatigue.



7. APPENDICES

All project deliverables and refereed publications are available for download on the project website: <https://www.bonusreturn.eu/progress/#outputs>

7.1. LIST OF PROJECT DELIVERABLES

1. Ahlström M., Bigum L., Norefjäll F., Stenbeck S. & Barquet K. 2020. Decision support Toolbox. Deliverable 5.2 of the BONUS RETURN project.
2. Ahlström M., Johannesdottir S. & Kärrman E. 2019. Manual for assessing sustainability of ecotechnologies. Deliverable 3.4 of the BONUS RETURN project.
3. Bachelder S., Powell N. and Do T. 2020. Serious Game System - MONITOR - ECO TECH. Deliverable 6.8 of the BONUS RETURN project.
4. Barquet K., Järnberg L. & Macura B. 2018. Report on current policy instruments and governance structures in Baltic Sea Region. Deliverable 2.5 of the BONUS RETURN project.
5. Barquet, K. and Rosemarin, A. 2020. Mission Blue - Exploring Circular Interventions in the Baltic Sea Region.
6. Barquet K., Ochola B., Persson S., Piniewsky M., Okruszko T., Kärrman E., Koskiaho J., Tattari S., Powell N. & Do T. 2018. First Periodic Report 2017-2018. Deliverable 1.5 of the BONUS RETURN project.
7. Barquet K., Ochola B., Heini N., Piniewsky M., Okruszko T., Kärrman E., Stenbeck S., Tattari S., Powell N. & Macura B. 2019. Second Periodic Report 2018-2019. Deliverable 1.6 of the BONUS RETURN project.
8. Barquet K., Ochola B. & Lundh M. 2018. List of emerging ecotechnologies. Deliverable 3.7 of the BONUS RETURN project.
9. Barquet K. 2018. Regional exchange and learning event 1. Deliverable 6.2 of the BONUS RETURN project.
10. Olsson O., Gietczewski M., Koskiaho J. & Barquet K. 2018. Circularity from concept to practice. Deliverable 6.3 of the BONUS RETURN project.
11. Barquet K., Järnberg L., Rosemarin A., Macura B. 2020. Publication on Policy Environment. Deliverable 6.6 of the BONUS RETURN project.
12. Callesen E.G., López M.J., Carolus J., Johannesdottir S., Pedersen M. S., Kärrman E., Turo Hjerpe T. and Barquet K. 2020. Scientific publication on sustainability of ecotechnologies. Deliverable 3.6 of the BONUS RETURN project.
13. Carolus J. 2018. State of the art report on economic models in the Baltic Sea Region. Deliverable 2.4 of the BONUS RETURN project.
14. Dagerskog, L. and Olsson, O. 2020. Swedish sludge management at the crossroads. Policy brief. <https://www.sei.org/publications/swedish-sludge-cross-roads/>
15. Do T., Powell N., Bachelder S. 2020. Serious Game System – SELECT ECO TECH. Deliverable 6.7 of the BONUS RETURN project.
16. Haddaway N. & Macura B. 2017. Training workshop on systematic review and mapping methodology provided to all project partners. Deliverable 2.1 of the BONUS RETURN project.
17. Haddaway N. 2018. List of ecotechnologies – Agriculture and Municipal wastewater ecotechnologies for reusing carbon and nutrients in the Baltic. Deliverable 2.2 of the BONUS RETURN project.
18. Järnberg L., Ochola B., Do T., Stenbeck S., Johannesdottir S. 2019. Regional exchange and learning event 2. Deliverable 6.4 of the BONUS RETURN project.
19. Johannesdottir S. 2018. List of selected ecotechnologies to be transferred to WP4 and WP6. Deliverable 3.1 of the BONUS RETURN project.
20. Johannesdottir S. 2018. Baseline report on conditions of catchment areas. Deliverable 3.2 of the BONUS RETURN project.
21. Johannesdottir S., Kärrman E., Ljung E., Anderzén C., Edström M., Ahlgren S. & Englund M. 2019. Report from the multi-criteria analysis from workshop 2 with comparisons of the different alternatives in each case study and selection of ecotechnologies for further use in WP5. Deliverable 3.3 of the BONUS RETURN project.
22. Koskiaho J., Piniewski M., Kardel I., Marcinkowski P. & Tattari S. 2018. SWAT system setup report. Deliverable 4.1 of the BONUS RETURN project.
23. Koskiaho J., Okruszko T., Piniewski M., Marcinkowski P., Tattari S., Johannesdottir S., Kärrman E. & Kämäri M. 2019. Scientific article on the most effective ecotechnologies in river basins. Deliverable 4.2 of the BONUS RETURN project.

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26. López M.J. 2019. Assessment of costs and benefits for selected ecotechnologies. Cost Benefit Analysis of selected ecotechnologies in the Baltic Sea Region. Deliverable 3.5 of the BONUS RETURN project.
27. Macura B., Ahlström M., Kämäri M., Ksiezniak M., Lorick D., Osuch P., Piniewski M. & Tattari S. 2019. Systematic review report(s) with meta-analysis of ecotechnology effectiveness. Deliverable 2.7 of the BONUS RETURN project.
28. Macura B., Piniewski M., Johannesdottir S., & McConville J. 2018. Systematic map report, database and interactive geographical information system (GIS). Deliverable 2.3 of the BONUS RETURN project.
29. Ochola B. 2017. External communication, dissemination and website – Deliverable 1.3 of the BONUS RETURN project.
30. Ochola B. 2018. Promotional material. Deliverable 1.4 of the BONUS RETURN project.
31. Ochola B., 2019. Film. Deliverable 1.7 of the BONUS RETURN project.
32. Rasmussen M., Gielczewski M., Olsson O., Koskiaho J., Tattari S., Barquet K., Rosemarin A. Policy Briefs. Deliverable 6.5 of the BONUS RETURN project.
33. Rosemarin A. & Ek F. 2019. Closing the loop on nutrient losses from agriculture and cities – a review of ecotechnologies, best practices, policies and economics, striving towards a more sustainable Baltic Sea Region. Deliverable 2.6 of the BONUS RETURN project.
34. Rosemarin A., Macura B., Carolus J., Barquet K., Ek F., Järnberg L., Lorick D., Johannesdottir S., Pedersen M. S., Koskiaho J., Haddaway N. and Okruszko T. 2020. Circular nutrient solutions for agriculture and wastewater - a review of technologies and practices. Deliverable 2.8 of the BONUS RETURN project.
35. Stenbeck S. 2019. Framework for facilitating pre-commercialization. Deliverable 5.1 of the BONUS RETURN project.
36. Barquet K., Ochola B., Heini N., Piniewski M., Okruszko T., Kärrman E., Stenbeck S., Tattari S., Powell N. & Macura B. 2020. Third periodic report 2019-2020. Deliverable 1.8 of the BONUS RETURN project.
37. Barquet K., Rosemarin A., Ochola B., Heini N., Piniewski M., Okruszko T., Kärrman E., Stenbeck S., Tattari S., Powell N. & Macura B. 2020. Final report. Deliverable 1.9 of the BONUS RETURN project.
38. Piniewski M., Tattari S., Koskiaho J., Olsson O., Djodjic F., Gielczewski M., Marcinkowski P., Książniak M., Okruszko O. 2020. Scientific publication on results from SWAT application in three catchment areas. Deliverable 4.4 of the BONUS RETURN project.
39. Barquet K., Rosemarin A., Järnberg L., Joshi S., Leander E., Olsson O., Sindhøj E. 2020. Final regional exchange and learning event. Deliverable 6.9 of the BONUS RETURN project.
40. Powell N., Do T., Bachelder S., Tattari S., Koskiaho J., Hjerpe T., Väisänen S., Gielczewski M., Piniewski M., Książniak M. 2020. Publications: fostering co-enquiry, learning and innovation. Deliverable 6.10 of the BONUS RETURN project.

7.2. LIST OF PROJECT REFEREED PUBLICATIONS

1. Barquet K, Järnberg L, Rosemarin A, Macura B. 2020. Identifying barriers and opportunities for a circular phosphorus economy in the Baltic Sea Region. *Water Research* 171:115433, <https://doi.org/10.1016/j.watres.2019.115433>
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7.3. LIST OF POLICY BRIEFS

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Under Review

12. Callesen G.E., Pedersen S.M., Carolus J., Johannesdottir SL., Murcia Lopez J., Kärrman E., Hjerpe T., Barquet K. Recycling nutrients and carbon in the Baltic Sea Region – sustainable or economic infeasible? Submitted to *Regional Environmental Change*.

7.4. LIST OF COMMUNICATIONS OUTPUTS

Final conference presentations

On 8th September 2020, a three-hour final conference was held to present results, conclusions and recommendations from the project. The video presentations are available to watch on the BONUS RETURN website. <https://www.bonusreturn.eu/bonus-return-final-conference-presentations/>

Documentary Film

BONUS RETURN produced an 18-minute documentary film titled Sea of Opportunity. The film presents three innovative technologies that can recapture phosphorus and nitrogen for reuse in agriculture: Aquacare, TerraNova and Ravita. The three were winners of a competition run by BONUS RETURN to identify promising technologies in the EU.

The film highlights solutions for recovering and reusing nutrients in wastewater and agriculture, featuring sustainability experts discussing the way forward for these technologies to take root in the Baltic Sea Region.

[Watch the film \(https://www.youtube.com/watch?v=eM4otlAZlps\)](https://www.youtube.com/watch?v=eM4otlAZlps)

Event film

The regional exchange and learning workshop held on 16 May 2019 in Gdansk, Poland, showcased technological innovations centred around nutrient recovery and reuse in the Baltic Sea region and discussed the needed interventions to develop the sector. This film provides a summary of the views expressed by the participants in the panel discussion.

“What makes innovations symbiotic?” - [watch the film \(https://www.youtube.com/watch?v=NF2rXBSCqdM&feature=emb_logo\)](https://www.youtube.com/watch?v=NF2rXBSCqdM&feature=emb_logo)



Image 1-5: SEI
Image 6: Marc Buttmann / TerraNova Energy

EVENTS

Project kick-off meeting 19 – 20 June 2017, Stockholm, Sweden

First annual consortium meeting – 29 May 2018, Helsinki, Finland

Regional exchange and learning workshop – 30 May 2018, Helsinki, Finland

- Theme: How can we enable circular innovations to trigger sustainable transformations in the Baltic Sea Region?

Second annual consortium meeting – 16 May 2019, Gdansk, Poland

Regional exchange and learning event – 17 May 2019, Gdansk, Poland

- Theme: Symbiosis in a circular economy: exploring solutions for improved water and nutrient governance

Final consortium meeting – 10 June 2020, Stockholm, Sweden

Final regional exchange and learning event – 11 June 2020, Stockholm, Sweden

- Theme: Mission Blue Baltic: Healthy Oceans, Coasts and Inland Water

The Swedish sludge inquiry – what now for the region – 30 January 2020

Film screening: Sea of Opportunity – 30 January 2020

Baltic Sea Science Congress 22 – 23 August 2019

Network meeting on phosphorus and other wastewater resources – organized by Svenskt Vatten 17 December 2019

Presenting the innovation competition finalists at Baltic Sea Future Conference – 9 March 2018, Stockholm, Sweden

Almedalen – "From innovation to Commercialization" – 2 July 2017, Götland, Sweden.

Serious Game System workshops

Presentation: "Serious game & climate change adaptation" at the 5th Nordic Conference on Climate Change Adaptation. 23 – 25 Oct 2018, Norrköping, Sweden.

Hydrology of the Baltic Sea Basin: Observations, Modelling, Forecasting. 9 October 2019, St.Petersburg, Russia.

"Closing the loop on nutrient losses" – keynote at the Circular Economy conference. 1 October 2019, Helsinki, Finland.

Presentation at Baltic Sea Science Congress: "Drivers and barriers for phosphorus reuse in the Baltic Sea Region" – 23 August, 2019.

Sustainability analysis of scenarios for circular systems for nutrients and carbon – 22 August, 2019. [Poster session at the Baltic Sea Science Congress].

Ecotechnologies for the recovery and reuse of carbon and nutrients from wastewater and agriculture: findings from two systematic maps – 22 August, 2019. [Poster session at the Baltic Sea Science Congress].

Almedalen – "Can circular systems clean the Baltic Sea?" – 2 July 2019, Götland, Sweden.

Joint BONUS-HELCOM conference: Research and Innovation for Sustainability. 6 November 2018 – Copenhagen, Denmark.

SWAT Conference. 19 – 21 September 2018. Brussels, Belgium.

IVL Baltic Sea Forum. 4 October 2018. Stockholm, Sweden.

Ocean-Climate-Sustainability conference. 22 – 23 October 2018. Berlin, Germany.

Launch of Circular Water Challenges project. 21 November 2018. Stockholm, Sweden.

Sludge seminar. 12 June 2019. Gävle, Sweden.

Workshop on cost-effective measures for nutrient emission abatement to the Baltic Sea – featuring results from the BONUS TOOLS2SEA project. 4 November 2019. Berlin, Germany.



1. THE PROJECT WEBSITE

The project website, www.bonusreturn.eu, has been the primary source of external communication.

2. BONUS RETURN INNOVATION TECHNOLOGY COMPETITION CAMPAIGN.

BONUS RETURN held an innovation competition between December 2017 to March 2018 to find emerging ecotechnologies with the potential to reuse nutrients and/or carbon.

The communications outreach included:

- Competition media announcements (press releases).
- A manual with guidelines on how to apply.
- Social media campaign to promote the competition.
- Award certificates for the finalists.
- Pitches by each finalist at the Baltic Sea Future Conference in Stockholm in March 2018.

Image: [Popova Valeriya / Shutterstock](#)

3. THE PROJECT ALSO PRODUCED

Press releases

- BONUS RETURN kicks off – 21 June 2017
- EU competition for innovations in the Baltic Sea region – 1 December 2017
- Finalists in the Baltic Sea innovation challenge – 9 March 2018
- Winners in the EU Innovation challenge selected – 2 April 2018
- Two new techs to combat Baltic eutrophication get pre-commercialization boost – 27 November 2019
- New film showcases solutions for Baltic Sea eutrophication – 30 January 2020

Podcast interview

- “We don’t want phosphorus in our seas – we want it on land, to produce food” – interview with Karina Barquet in the Nordic Surfers Magazine podcast.

Op-eds (opinion editorials)

- “We hope the government will shift its focus from sludge and phosphorus” – debate article published in Swedish newspaper, Altinget.
- “Eat your way to a healthier Baltic Sea” – featured in Nordic Surfers Mag issue #28.

Features

- New competition seeks eco-tech innovations for a cleaner Baltic.
- What does the science say? A Q&A with Neal Haddaway on systematic reviews and systematic maps.
- How can we accelerate the transition to a circular use of phosphorus?



Image: oticki / Getty Images

- The Baltic – a sea of opportunity.
- “Watch: How the Baltic Sea’s pollutants could instead be turned into valuable resources.” – article featured in Bio Markets Insights quarterly magazine issue #17.
- The circular economy: workshop on the challenges of turning waste into profit cleaner Baltic.
- Event report: “Symbiosis in a circular economy: exploring solutions for improved water and nutrient governance”.

Video interviews

Short video interviews with project partners and affiliates, focusing on various aspects of the project are available on the website.

- “BONUS RETURN is creating a market for needed innovations in the Baltic” – Charlotta Möller.
- “What is BONUS RETURN?” – Marcus Carson
- “BONUS RETURN is about reconnecting people on the Baltic Sea coast” – Dariusz Szwed.
- “BONUS RETURN contributes knowledge and capacity within the Baltic Sea region” – Mats Johansson.
- “Where there are problems, BONUS RETURN sees possibilities” – Neil Powell.
- Recorded livestream: presenting the innovation challenge finalists.
- BONUS RETURN year in review – Karina Barquet.
- Interview with Marc Buttmann, TerraNova Energy – winner in the Innovation Challenge by BONUS RETURN.

- Interview with Mari Heinonen, Ravita – winner in the Innovation Challenge by BONUS RETURN.
- Interview with Joris Salden, Aquacare – winner in the Innovation Challenge by BONUS RETURN.
- “Circular systems are the solution to eutrophication in the Baltic” – Mats Johansson.
- “Implications of the Swedish sludge inquiry” – Olle Olsson.
- “Ideal future for sewage sludge management in Sweden” – Linus Dagerskog.
- “The Serious Game System helps stakeholders tell their story” – Steven Bachelder

Promotional material

- Progress brochures
- Roll-ups
- Graphic illustrations
- Policy Briefs

7.5. LIST OF PROJECT STAFF, TITLE AND ROLE IN THE PROJECT

Stockholm Environment Institute (SEI)

Arno Rosemarin	Senior advisor - nutrient recycling
Benedetta Crippa	Visual communication and design
Biljana Macura	Senior research fellow – evidence synthesis WP2 lead
Brenda Ochola	Communications officer - WP1 co-lead
Dag Lorick	Research engineer - wastewater
Filippa Ek	Research associate - marine biology
Karina Barquet	Senior research fellow - project coordinator WP1 lead
Kim Anderson	Senior expert - water and sanitation
Linn Järnberg	Research associate - participatory methods
Marcus Carson	Senior Research fellow - advisor
Mark Rasmussen	SEI associate - policy briefs
Natalia Heini	Financial controller
Neal Haddaway	Senior research fellow - evidence synthesis
Nelson Ekane	Research fellow - sustainable sanitation
Olle Olsson	Senior research fellow - Uppsala case study lead
Tom Gill	Editor
Somya Joshi	Head of unit - advisor
Ylva Rylander	Press officer

RISE Research Institutes of Sweden (RISE)

Berndt Björlenius	R&D engineer - wastewater expert
Charlotta Möller	Section chief urban water management - WP5 lead
Elisabeth Kvarnström	Researcher - circular processes in wastewater
Erik Kärrman	Director urban water management - WP3 lead
Jennifer McConville	Researcher - sanitation and wastewater management
Marcus Ahlström	Research assistant - sustainable wastewater specialist
Solveig Johannesdottir	Project manager - waste management engineer
Lukas Bigum	Project assistant - energy in wastewater
Sten Stenbeck	Senior project leader - WP5 lead

Uppsala University (UU)

Coordinating partner

Neil Powell	Professor - stakeholder engagement
Thao Do	Research assistant - stakeholder engagement
Steven Bachelder	Professor - game design

Finnish Environment Institute (SYKE)

Jari Koskiaho	Research engineer - Vantaanjoki case study lead
Sirkka Tattari	Hydrologist - WP4 co- lead
Turo Hjerppe	Researcher - river basin management
Sari Väisänen	Researcher - cost-benefit assessments

Warsaw University of Life Sciences (WULS)

Tomasz Okruszko	Director Institute of Environmental Engineering - WP4 co-lead
Marek Gietczewski	Assistant professor - Slupsk case study lead
Marta Ksiezniak	Technical associate - hydrology and geoinformatics
Magdalena Jarecka	Administration specialist
Mikołaj Piniewski	Associate professor - WP2 co-lead and SWAT modelling
Pawel Marcinkowski	Research assistant - SWAT modelling

University of Copenhagen (UCPH)

Gustav Marquard Callesen	Research assistant - cost benefit assessments
Jessica Murcia Lopez	Research coordinator - cost benefit assessments
Johannes Carolus	Research assistant - cost benefit assessments
Søren Marcus Pedersen	Associate professor - cost benefit assessments



Part of the team at a project meeting in Helsinki, Finland.

7.6 OVERVIEW OF COLLABORATIONS

TITLE	ORGANIZER	PLACE AND DATE	BONUS RETURN'S ROLE
Investigation for establishing an international market for nutrients – financed by HAV	WSP, SEI, Södertörn Högskola, IVL, KTH	2020 – 2021	Project partner
Investigation for increasing international cooperation for eutrophication – financed by HAV	WSP, SEI, Södertörn Högskola, IVL	2020 – 2021	Project partner
End of wastewater – Kamprad-financed project	Swedish University of Life Science, SEI, Linköping University, RISE	2020-2023	Project Partner
Swedish Nutrient Platform	RISE, IVL	2020 - 2023	SEI informed the challenges addressed in the platform https://www.ri.se/sv/svenskanaringsplattformen/vilka-ar-utmaningarna
Baltic Stewardship Initiative	World Wildlife Fund	2020 - 2021	Karina Barquet is member of the advisory board
B.Green Project for Green Infrastructure	Forum Virium	2020 - 2022	Karina Barquet is member of the advisory board
Unlocking the nutrient recycling potential in the Baltic Sea Region	Interreg-financed SuMaNu	Online, September 30th, 2020	Session facilitators (Karina Barquet and Arno Rosemarin) Keynote speaker (Arno Rosemarin)
Off-grid water and sanitation solutions	SIDA-financed Gridless Initiative Solutions (SEI) and BONUS RETURN	September 9th 2020, Stockholm	SEI Co-convener
SWASH & grow – upscaling circular solutions for water and sanitation	RISE and SEI on Vinnova-financed SWASH & grow project	September 10th 2020, Stockholm	SEI/RISE Co-convener
Innovation for multiple water risks	H2020 RECONNECT and BONUS RETURN	October 3rd 2019, Nice France	SEI Co-convener
SDGs and Ocean sustainability	Marine Regions Forum Berlin	October 1st 2019, Berlin	Session co-host (Karina Barquet)

TITLE	ORGANIZER	PLACE AND DATE	BONUS RETURN'S ROLE
Lokala åtgärdsprogram – verktyg för att följa MKN (Local program on solutions for improved water use in the Baltic Sea)	LIFE IP Rich Waters	Stockholm, 13 June 2018	Expert
Baltic Sea Solutions Lab	Race for the Baltic	Stockholm 16-17 October 2018	Keynote speaker
Innovation in development: the future of the EU international cooperation (non-Baltic)	European Think Tanks Group	Brussels, 18th October 2018	Invited speaker to the session the sustainability revolution: how can we continue on its path of "transforming our world"?
OCEAN – CLIMATE – SUSTAINABILITY	Science Conference by the three	Berlin, 22 – 23 October 2018	Invited speaker to the session "Sustainability"
RESEARCH FRONTIERS (non-Baltic)	ocean/climate related clusters of excellence of Northern Germany "MARUM", "CliSAP", and "The Future Ocean"		
PROJECT CIRCULAR WATER CHALLENGE	Swedish Royal Academy of Science (KTH)	Värmdö, 21 November	BONUS RETURN is a boundary partner of the project. The partnership will enable cross-fertilization of the projects
Expert group for the methodology of the indicator for Sustainable Development Goal 17.14.1: Number of countries that have mechanisms in place to enhance Policy Coherence for Sustainable Development (non-Baltic)	UN Environment	June – December 2018	The project coordinator (Karina Barquet) is a member of the Expert group.
Transnational seminar; nutrient recycling in agriculture and state of the Baltic Sea.	Ministry of the Environment and Ministry of Agriculture and Forestry of Finland	Jyväskylä, Finland, 12-13 February 2019	Presenting of the project at poster session, participating in workshop dealing with CAP. Circular economy, Cost-efficiency, Networking

TITLE	ORGANIZER	PLACE AND DATE	BONUS RETURN'S ROLE
3rd European Sustainable Phosphorus Conference 2018 (non-Baltic)	European Sustainable Phosphorus Platform	June 11-13 2018	Membership and selected abstract presentation
26th SuSanA meeting, Stockholm (non-Baltic)	Sustainable Sanitation Alliance	August 2018	SEI is together with GIZ part of the secretariat governing the alliance
Workshop on Circular and non-toxic reuse of Phosphorus from sewage sludge (non-Baltic)	TAEIX – EIR PEER 2 PEER and the Swedish EPA	Stockholm, 15 – 16 April 2019	Invited expert
Co-operation with University of Maryland, USA regarding modelling of organic carbon with SWAT (non-Baltic)	SYKE and WULS	April 2019	SYKE provided the original, on-line measured DOC / TOC data and studied the long-term grab sample data and scientific publications on the relationship between TOC and DOC in the Vantaanjoki River basin.
Swedish University of Agricultural Sciences (SLU)	WULS, SEI and SYKE	Ongoing	Professor Faruk Djoic is an ongoing collaborator and boundary partner to the project who contributes with local expertise of catchment flows in Uppsala.
Celebrating the Pioneer Cities of the Baltic Sea City Accelerator Pilot Programme 2016-2017	Race For The Baltic	28th June 2017, Stockholm	Race For The Baltic is a boundary partner to BONUS RETURN with an agreed cooperation to help each other's programs, share contacts and knowledge.
Baltic Sea Future Annual Conference 2018	Baltic Sea Future	8-9th March 2018, Stockholm	Session convener
2nd Collaboration for Environmental Evidence Meeting (non-Baltic)	Collaboration for Environmental Evidence	18-20th April, 2018, Paris	Presentation of the results of WP2 'ecotechnology' thematic synthesis, presentation of the methodology for randomization and blocking of search results prior to screening in WP2 systematic map

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