BONUS RETURN

Reducing Emissions by Turning Nutrients and Carbon into Benefits

https://www.bonusprojects.org/bonusprojects/the_projects/blue_baltic_projects/return

www.bonusreturn.eu

Deliverable No: D.5.2 – Decision support toolbox
Ref: WP (5) Task (5.2)
Lead participant: RISE – Research Institutes of Sweden
Date: 31/03/2020

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

Deliverable Title	**D.5.2 – Decision support toolbox**
Filename	BONUSRETURN_D.5.2_Decision support toolbox
Authors	Marcus Ahlström (RISE), Lukas Bigum (RISE), Fredric Norefjäll (RISE), Sten Stenbeck (RISE), Karina Barquet (SEI).
Contributors	Erik Kärrman (RISE), Solveig Johannesdottir (RISE), Berndt Björlenius (RISE)
Date	31/03/2020

Start of the project:	01/05/2017
End of the project:	30/06/2020
Project coordinator:	Stockholm Environment Institute (SEI)

Dissemination level

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

Table of Contents

EXECUTIVE SUMMARY

The overall aim of BONUS RETURN is to improve the adaptation and adoption of eco-technologies in the Baltic Sea Region for maximum efficiency and increased co-benefits in closing the nutrients and carbon loops between society and agriculture. The project is organised in five work packages (WP). The objective of work package 5 (WP5), which this report is a part of, is to facilitate pre-commercialization activities of emerging eco-technologies. Furthermore, this report summarizes experiences obtained in other parts of WP5 and additional developments, forming a decision-support toolbox for decision-makers. The target audience of this report consists of mainly local and regional authorities as well as public administrations involved with closing the nutrients and carbon loops between society and agriculture.

The transition to a circular economy will require significant changes in many aspects of how society is planned and operated in terms of production and consumption models. The concept of circular economy promotes new value structures lacking in traditional economic systems. This requires re-evaluating norms and traditional ways of how we account for benefits and cost. Supporting and financing innovative ideas, establishing the right policy structures that allow circular markets to flourish, in addition to endorsing new behavioural patterns can often be difficult in firmly established organisational structures. This is where the use of decision support methods for transparent assessments can be useful tools to justify risk-taking or pushing boundaries to promote innovative solutions that diverge from what can be considered business-as-usual.

To successfully transition to a circular economy it is necessary to, through dialogue, shift mindsets about waste and by-products among both decision-makers and the general public, to enable efficient recovery of valuable resources in abundant waste streams from society. Turning wastewater and agricultural by-products into new useful products will require cooperation in order to drive the necessary development of eco-technologies that are economically feasible to invest in and operate, that provide a product with suitable properties, and that is socio-culturally acceptable by the consumer who ends up purchasing the end-product. Social innovation approaches are increasingly advocated as they give stakeholders a voice, it allows them to present their concerns and be part of the creative process. Also, involving stakeholders improves the identification of local problems which likely improves the suggested solutions, and increases the chances of acceptance and uptake of the solutions. In order to create a real demand for solutions, policies and goals must be aligned with the needs; the market or an innovation system must be in sync with the needs and the procuring organisations must have procurement capacity.

The purpose of this report is to present a comprehensive toolbox for stakeholders such as authorities at regional, national and municipal levels, to support the transition to a circular economy by facilitating development and procurement of eco-technologies that are closing the loops of nutrients and carbon. The tools presented in this toolbox are designed to help with determining criteria for the selection of suitable eco-technologies through social innovation, providing evidence for their effectiveness and identifying their readiness for implementation, as well as determining their sustainability. Additional tools provide methods for promoting existing eco-technologies and ways to procure and support innovation as well as approaches to directly contribute to the development of innovative solutions. The concluding chapter of the toolbox presents ways of creating incentives, as decision-makers, for increased development of new innovative eco-technologies. Decision-makers need support to be able to make good decisions and these decisions need to be based on sound reasoning. In this aspect the BONUS RETURN project strives to add value and support.

1 INTRODUCTION

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

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

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

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

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

1.1 Project Objectives

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

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

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

- Contributing to the adaptation and adoption of eco-technologies in the BSR through an evidence-based review (systematic map) of the developments within this field.

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

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

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

4) Supporting commercialization of eco-technologies by:
- Identifying market and institutional opportunities for eco-technologies that (may) contribute to resource recovery and reuse of nutrients, micro-pollutants and micro-plastics (e.g. renewable energy).
- Identifying potential constraints and opportunities for integration and implementation of eco-technologies using economical models.
- Facilitating the transfer of eco-technologies contributing to win-win solutions to multiple and interlinked challenges in the BSR.
- Linking producers of eco-technologies (small and medium enterprises – SMEs), to users (municipalities) by providing interactive platforms of knowledge exchange where both producers and users have access to BONUS RETURN’s envisaged outputs, existing networks, and established methodologies and services.

5) Establishing a user-driven knowledge platform and improved technology-user interface by:
- Developing an open-access database that maps out existing research and implementation of eco-technologies in the BSR. This database will be intuitive, mapped out in an interactive

geographical information system (GIS) platform, and easily managed so that practitioners, scientists and policymakers can incorporate this knowledge in their practices.
- Developing methodologies that enact the scaling of a systemic mix of eco-technological interventions within the highly diverse contexts that make up the BSR and allows for a deeply interactive medium of knowledge.

1.2 Project Structure

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

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

1.3 Deliverable context and objective

The current deliverable (Del. No. 5.2) is part of WP5. The report summarizes the experiences obtained in Work Package 5 serving as a decision-support toolbox for decision-makers in mainly local and regional authorities and public administrations involved in closing the nutrient loops between society and agriculture. The work has been focused on adopting and validating eco-technologies using test beds and to develop a strategy for stakeholder collaboration.

The objective of WP5 is to facilitate pre-commercialization of selected eco-technologies in three pilot sites by identifying and setting up test beds and Living Labs, including supporting innovative and effective business models and tools for stakeholder collaboration and sharing of resources (sites and equipment), risks and benefits as well as tools for procurement of innovations (for example pre-commercial procurement and functional procurement). Results from WP2, WP3 and consultations with local stakeholders (WP6), was used to identify several promising existing or emerging eco-technologies that would benefit from testing in test beds/Living labs. Focus was to advance existing eco-technologies and/or emerging technologies with TRL of at least level 6, based on stakeholder collaboration and sharing resources, risks and benefits.

The objective of this deliverable is to develop a decision-support toolbox that gathers the experiences from throughout the BONUS RETURN project, in combination with social innovation, innovative procurement efforts and capacity building. The decision-support toolbox can be applied to support the transition to a circular economy by facilitating development and procurement of eco-technologies for closing the loops on nutrients, thereby transforming eutrophic emissions into benefits in the in the Baltic Sea Region.

1.4 Outline of the report

This report is structured around a collection of decision support tools applicable for a broad range of users, such as municipal, regional, national, transnational and international decision-makers. A total number of 16 different decision support tools are provided throughout the 11 different chapters of the toolbox. The chapters of the report consist of:

Chapter 2 – Decision support toolbox introduction,
Chapter 3 – Criteria for eco-technologies,
Chapter 4 – Evidence of eco-technologies,
Chapter 5 – Possibilities of eco-technologies,
Chapter 6 – Sustainability of eco-technologies,
Chapter 7 – Promoting existing eco-technologies,
Chapter 8 – Supporting innovation of eco-technologies,
Chapter 9 – Development of innovative eco-technologies,
Chapter 10 – Creating incentives for eco-technologies,
Chapter 11 – Concluding remarks.

These chapters describe different tools that can be applied by decision-makers to enable social innovation, execute innovative procurements and build capacity to support the transition to a circular economy. The tools facilitate the development and procurement of eco-technologies contributing to closing the loops on nutrients, thereby transforming eutrophic emissions into benefits in the in the Baltic Sea Region.

2 DECISION SUPPORT TOOLBOX INTRODUCTION

The transition to a circular economy will require significant changes to many aspects of how society is planned and operated in terms of production and consumption models. The concept of circular economy promotes new value structures that are lacking in traditional economic systems, which in turn will require to re-evaluate norms and the traditional ways of how we account for benefits and costs. Some important pillars in circular economy include technology readiness, behavioural change, adequate policy frameworks, and business models that consider not only technology development but also product development. However, supporting and financing innovative ideas, establishing the right policy structures that allow circular markets to flourish, in addition to endorsing new behavioural patterns can often be difficult in firmly established organisational structures. This is where the use of decision support methods for transparent assessments can be useful tools to justify risk-taking or pushing boundaries to promote innovative solutions that diverge from what can be considered as business-as-usual.

The purpose of this deliverable, is to introduce a selection of support methods and tools relevant for decision-makers to aid the transition towards a circular economy by supporting the implementation of emerging eco-technologies in the context of recovering nutrients and carbon from the wastewater and agricultural sectors. Eco-technologies are in the context of this toolbox defined as by Haddaway et al. (2018a) as "… 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".

2.1 Toolbox rationale

This toolbox is framed to provide support to the responding of challenges that decision-makers and local implementers in municipalities and regions usually encounter when exploring the process of transitioning to a circular economy. Table 1 indicates the types of challenges addressed in the toolbox, the type of tools suggested to meet the challenges, and the type of questions each of these tools can help answer. In broad terms these questions are:

1) What are the needs for circular solutions?
2) What circular solutions can be found on the market?
3) How to assist in pulling circular solutions to markets?
4) How to increase the Readiness Levels[1] of sustainable circular solutions?

Depending on where you are in the process you are likely to either have the answer to one or more of these questions and several follow up questions or you need assistance in finding answers. Decision-makers need support to be able to make good decisions and these decisions need to be based on sound reasoning. In this aspect the BONUS RETURN project strives to add value and support in the process of choosing suitable, sustainable eco-technologies to support and implement. Decision support tools intended to assist in answering the rationale questions will be briefly introduced in Table 1 and given further explanation in subsequent chapters of the toolbox.

[1] This concept is described in section 5.1.

Table 1: Overview of challenges and related support tools in the context of transitioning into a circular economy.

Challenges	Proposed tools	Comments
Criteria for eco-technologies	1. Social innovation 2. Stakeholder engagement workshops 3. Multi-Criteria Analysis (MCA)	i) What is the common understanding of what the issue is? ii) What are the requirements that need to be met for the issue to be solved? iii) what eco-technologies would be most suitable to the local context?
Evidence of eco-technologies	4. Literature reviews	i) What are sustainable eco-technologies? ii) how efficient are they?
Possibilities for eco-technologies	5. The Innovation Development Cycle	Which eco-technologies are ready for implementation and which solutions need further support for research, development and innovation?
Sustainability of eco-technologies	6. Sustainability analysis	Which eco-technology is the most sustainable?
Promoting existing eco-technologies	7. Sustainable Public Procurement 8. Circular Public Procurement	How to promote eco-technologies already on the market?
Supporting innovation of eco-technologies	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 in pulling eco-technologies under development to the market?
Development of innovative eco-technologies	12. Market survey 13. Independent comparative study 14. Testbed trials	How to increase the Readiness Levels of innovative eco-technologies?
Creating incentives for eco-technologies	15. TIS light workshop 16. Policy planning for co-benefits	How to accelerate innovative eco-technologies?

3 CRITERIA FOR ECO-TECHNOLOGIES

The demand for eco-technologies on the market for circular nutrients solutions is rather constrained. New innovations need to comply with policies and legislative requirements, and the investments need to be paid off in a relatively short time frame. The market is primarily driven by legislation and requirements on wastewater treatment plants (WWTP:s), mainly managed by public utilities or the industry, and the farming industry – all with tough economic circumstances and where the majority of the end-users (consumers and voters) are not aware of the impact that non-closed nutrients loops have on their livelihood and overall well-being. The push from end-users is currently limited and thus the space to make radical innovation is also limited due to the lack of push and pull from market and policy. The wastewater and agricultural sectors are typical cases where increased cooperation is needed within the innovation system to make a radical change.

3.1 Tool 1: Social Innovation

Social innovation is defined as "the creation of long-lasting outcomes that aim to address societal needs by fundamentally changing the relationships, positions and rules between the involved stakeholders, through an open process of participation, exchange and collaboration with relevant stakeholders, including end-users, thereby crossing organizational boundaries and jurisdictions" (Voorberg et al., 2015). In other words, social innovation are ways in which people are creating new and more effective answers to the challenges that societies face and embedding these solutions in a way that address societal needs (and not only steered towards economic profit). Social innovations stem from the insufficiency of existing structures and policies to deal with complex problems, the inadequacy of traditional government and market solutions to implement the necessary tools and incentives, and the lack of capacity, skills and resources in civil society to upscale ideas (Murray et al., 2010). As social innovation approaches place social value at the heart of the innovation process (Nicholls and Murdock, 2011), stakeholder inclusion through citizen participation (in the public sector) and end-users in the private sector are fundamental (Murray et al., 2010). Effective stakeholder engagement in innovation is an important element for improving the development and implementation of policies and programs. At the same time, stakeholder engagement for improved cooperation is fundamental for transitioning towards a circular economy.

Figure 1 illustrates the different steps of cooperation that are needed in order to enable a transition. To successfully make a transition to a circular economy it is necessary that, through dialogue, both decision-makers and the general public are ready to shift mindsets about waste and by-products to enable efficient recovery of valuable resources in abundant waste streams from society. Top down steered circular systems can be difficult to successfully realise and implement, and the development of circular solutions needs to be, at least partially, driven by a common agenda and a bottom up demand from both potential end-users of fertilizer products and the general public for more sustainably produced products. It is unwise to create a product that there is no demand for on the market, be it by farmers in direct need of fertilizers or by fertilizer companies in need of raw materials. Turning wastewater and agricultural by-products into suitable fertilizer products will require cooperation with nutrient providers (e.g. WWTP:s), nutrient buyers (e.g. farmers) and the end customer. This in order to drive the necessary technological development that results in eco-technologies:

- that are economically feasible to invest in and operate for the nutrient provider,
- that provide a fertilizer product with suitable properties for the nutrient buyer, and
- that is socio-culturally accepted by the consumer who ends up purchasing the fertilized end-product.

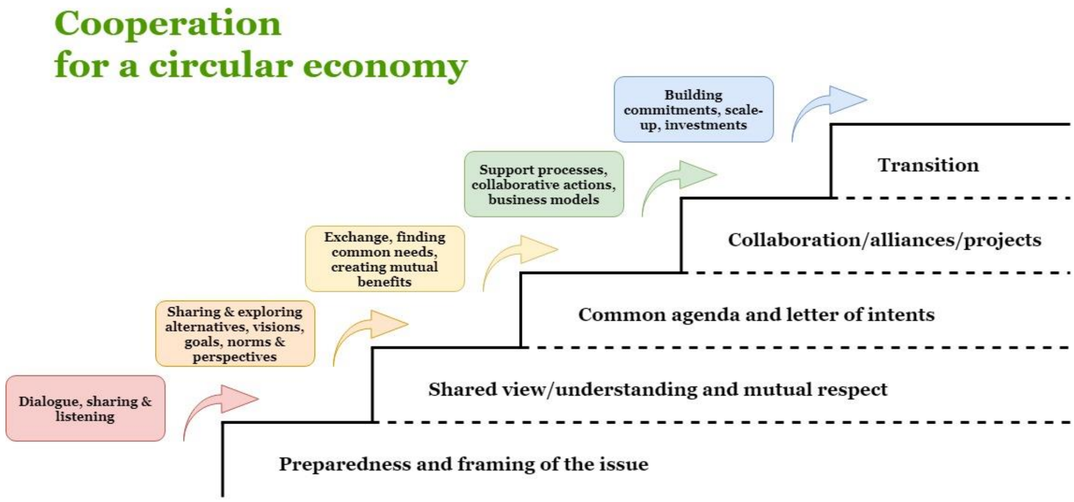

Figure 1: Cooperation for change, new adaptation of ”Samverkansspiralen” (Eriksson, 1998).

Social innovation approaches are increasingly advocated as they give stakeholders a voice, it allows them to present their concerns and be part of the creative process. At the same time, involving stakeholders improves the identification of local challenges, enables suggestions of actual feasible solutions, and increases the chances of acceptance and uptake of solutions (Barquet and Cumiskey, 2018). This is of particular importance when implementing measures that introduce systemic changes in already firmly established structures.

Bonus Return eco-technologies, as part of a social innovation approach, can potentially have a large impact on current business models in the wastewater and agricultural sectors. The use of eco-technologies reduces potential environmental hazards, through processing of material streams traditionally considered as waste. Furthermore, it creates entirely new products and business opportunities, leading to the creation of a new market that needs to be properly established before eco-technologies can fully contribute to a sustainable part of circular economy.

3.2 Tool 2: Stakeholder engagement workshops

As an initial step of a decision-making process a list of potential stakeholders should be compiled and the stakeholders that are deemed the most important for the issue in question should be given opportunities to give input and feedback on possible alternatives and decisions. In BONUS RETURN, stakeholder inputs for selecting circular eco-technologies were gathered through workshops in three different case studies in the BSR. Workshops are an efficient way to enable dialogue about visons and priorities among stakeholders. Workshops can also serve as forums for interaction that creates a broader understanding of the needs of other stakeholders, which in turn can enable the formulation of common goals to reach at the end of the decision-making process. Outcomes of this dialogue can then be used to construct technical systems which meet the needs and demands of stakeholders and are in line with social, economic and political priorities. An example of how a stakeholder workshop was structured and conducted in BONUS RETURN can be found in Appendix A.

For example, information gathered via stakeholder engagement processes can be used as a starting point to drive the search for certain kinds of solutions (i.e. eco-technologies) that are deemed preferable. As an example, local farmers might already be spreading sludge or manure on arable land to recirculate nutrients which makes eco-technologies for phosphorus recovery from liquid streams an interesting option as the solid/semisolid fraction is already utilized. Once a number of interesting eco-technologies have been identified (and other detailed information necessary for analysis is available), further assessments (e.g. sustainability analysis) can be conducted.

3.3 Tool 3: Multi-criteria analysis

Multi-criteria analysis (MCA) is the name of a broad group of decision-support methods that can be applied to facilitate systematic and transparent assessment of alternatives in a decision-making process. MCA can be used to aggregate different aspects, that do not necessarily lend themselves to straightforward comparison, into more easily comparable metrics. MCAs can favourably be applied when there is an interest or a need to integrate qualitative stakeholder perspectives with more conventional quantitative dimensions when making decisions. They are typically applied as a decision support tool once the decision-making context has been established (i.e. once the goal and scope of the project has been formulated) and possible alternatives or solutions have been identified. An MCA for decision-making is typically preceded by an extensive stakeholder identification process and stakeholder engagement (as described in Tool 1 and Tool 2) to gather important feedback.

In BONUS RETURN Johannesdottir et al. (2019) used MCA and stakeholder engagement workshops as tools to conduct sustainability analysis of multiple full-scale resource recovery systems (for both the wastewater and agricultural sectors) in three different case studies; for the Vantaanjoki catchment area in Finland, the Fyriså catchment area in Sweden and the Słupia catchment area in Poland. Ahlström et al. (2019) further expanded on the methods applied by Johannesdottir et al. (2019) and formalized a framework for conducting sustainability analysis as a decision support tool for the selection of eco-technologies. The MCA part of the sustainability analysis method is based on assessing criteria in five dimensions of sustainability, environmental sustainability, economic sustainability, socio-cultural sustainability, technical function and health and hygiene, while simultaneously taking local factors and stakeholder interests into account. Table 2 illustrate a set of criteria that are commonly applied in an MCA.

By applying the criteria selection procedure of an MCA (as described in Appendix A) as a tool of its own it is possible to identify the needs and wants of the involved stakeholders, which in turn will help drive the search, and ultimately the demand, for the kinds of eco-technologies that can meet the identified needs. The selection of a set of sustainability criteria will help narrow down the choices towards a limited selection of eco-technologies. This in turn creates a limited decision space in which possible alternatives can be found. An extensive list of criteria that have previously been applied for MCA within the agricultural and wastewater sectors in the scientific literature was compiled by Johannesdottir et al. (2019) and can be found reprinted in Appendix B.

Table 2: Examples of sustainability criteria separated into the five different dimensions of sustainability. Table reprinted from Ahlström et al. (2019).

Environmental	Economic	Socio-cultural	Technical function	Health & hygiene
Greenhouse gas emissions	Life cycle cost	Acceptance	Flexibility	Work environment
Reuse of resources	Capital/investment costs	Laws and policies	Reliability	Health risks
Emission of pollutants	Operation and maintenance costs	Attitudes and behaviours	Technical complexity	Spreading of diseases
Impact on biodiversity	Economic lifetime	Cultural and aesthetic values	Robustness	Exposure to toxic substances

4 EVIDENCE OF ECO-TECHNOLOGIES

In order to identify what eco-technologies that are feasible it is necessary to conduct a market review to uncover available solutions on the market, and a literature review to investigate what types of technologies that are currently under development. Literature reviews can be conducted in different manners with different purposes, and an overview of literature reviews as a research methodology can be found in Snyder (2019). Market reviews can be structured in the same way as a literature review. The purpose of this chapter is to introduce literature reviews as a method of identifying interesting eco-technologies to implement or/and support.

4.1 Tool 4: Literature reviews

When conducting a conventional narrow-search literature review it is likely that the results of the review are going to be biased to some extent as the results are based on the used search string(s) and the searched database(s) (e.g. Scopus, Web of Science and Google Scholar). Depending on the methodology and the search strategies that are applied it is likely that only a subset of existing literature will be found during the search. A conventional review with a narrow search strategy will not be exhaustive and is prone to overlook some interesting literature as is illustrated in Figure 2. In order to reduce bias and increase the scientific rigour of the search endeavour, a systematic review framework that utilizes a wider search strategy (amongst other standardized methodology) can be applied.

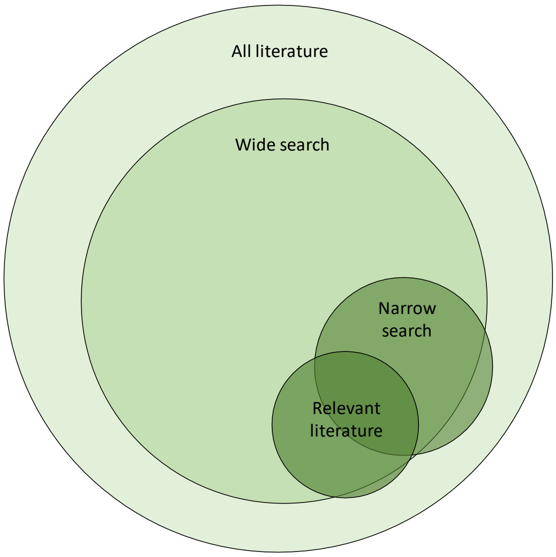

Figure 2: The expected outcomes using narrow and broad search strategies, i.e. the difference between a conventional literature review (narrow search) and a systematic review (wide search). Translated and adapted from Swedish Agency for Health Technology Assessment and Assessment of Social Services (2017).

Systematic reviews

The Centre of Environmental Evidence describes systematic reviews as "… an evidence synthesis method that aims to answer a specific question as precisely as possible in an unbiased way. The method collates, critically appraises, and synthesizes all available evidence relevant to the question. Reviewers use pre-defined methods to identify risks of bias in the evidence itself, and to minimise bias in the way evidence is identified and selected, and thus provide reliable findings that could inform decision making. " (Pullin et al., 2018).

To extract as much as possible of the relevant scientific literature for review, conducting a systematic review which, in a simplified sense, is an extensive and transparent type of literature review that is peer-reviewed throughout the process. Systematic reviews are exceptionally resource intensive endeavours and can require several person-years of full-time research to conduct. Systematic reviews are based on rigorous methodology and the screening of thousands to tens of thousands of research items, this in order to find all relevant literature which enables a meaningful evidence synthesis on the topic. Guidelines and standards for conducting systematic reviews can be found via The Collaboration for Environmental Evidence, see Box 1.

Systematic reviews are primarily an academic exercise to create meta-studies (i.e. studies of studies) to determine the current state-of-knowledge on a topic, but the results can be of widespread interest to society. Systematic reviews can be funded and used as tools by a sufficiently large group of need-owners (e.g. several municipalities, cities or regions) that see the same need for an answer to a particular question.

Several efforts to systematically synthesise the evidence base of available eco-technologies have been conducted within BONUS RETURN. Haddaway et al. (2018b) compiled a shortlist of eco-technologies for reusing carbon and nutrients that could be applied in agriculture and municipal wastewater sectors in the Baltic region. A systematic map of eco-technologies for the recovery and reuse of nutrients and carbon within the Baltic Sea region was conducted by Macura et al. (2018). These deliverables can be viewed as overviews of current and promising eco-technologies that are already on the market or can be expected in the future. Macura et al. (2019) conducted a systematic review on the effectiveness of two eco-technologies, struvite precipitation and ammonia stripping, that combined with anaerobic digestion could increase nutrient recycling and contribute to reduced environmental impacts and provide renewable energy and plant nutrients.

It is not advisable that decision-makers conduct systematic reviews on their own, but rather that these types of reviews should be used as decision support when they are available on the subject. If necessary, systematic reviews could be conducted by academia or research partners in joint research projects. The work done within BONUS RETURN can serve as a starting point for selecting eco-technologies for the recovery on nutrients and carbon from wastewater and agricultural by-products.

Box 1: Systematic reviews and the Collaboration for Environmental Evidence
The Collaboration for Environmental Evidence (CEE) is an open community of stakeholders working towards a sustainable global environment that provides guidelines for conducting systematic evidence synthesis. The CEE manages the journal Environmental Evidence that publish systematic reviews and maps. The CEE is a global not-for-profit and has formal charitable status. The CEE seeks to promote and deliver evidence syntheses on issues of great concern to environmental policy and practices as a public service. The CEE has national centres in Australia, Canada, South Africa, Sweden and the UK and international presence through Stockholm Environment Institute (SEI).

Additional reading and resources:
The Collaboration for Environmental Evidence: https://www.environmentalevidence.org/
Environmental Evidence Journal: https://environmentalevidencejournal.biomedcentral.com/

5 POSSIBILITIES FOR ECO-TECHNOLOGIES

After identifying a set of interesting eco-technologies, several follow up questions will usually arise, one of those questions being, which eco-technologies are ready for implementation and which solutions need further support? Eco-technologies existing on the market are expected to be ready for direct “off-the-shelf”-implementation while solutions described in the scientific literature, not yet existing on the market, can be expected to be under development by some organisation or entity. As a tool to understand the market readiness of innovations, the Innovation Development Cycle has been developed within BONUS RETURN and is described in the following section.

5.1 Tool 5: The Innovation Development Cycle

As a way of creating a shared understanding of innovations and their different stages of market readiness, BONUS RETURN has developed the Readiness Level (RL) framework for the facilitation of pre-commercialization activities for innovation development. The framework is illustrated in Figure 3 and is based on the perspective of how an innovation develops through four development phases, from a novel idea in Phase 1, through tests and development of prototypes in Phase 2, tests and demonstration with clients in Phase 3, to market introduction in Phase 4.

The Readiness Level of an innovation describes how ready it is for meeting the market demands and needs. Market demands and needs include all requirements necessary for an innovation to become a success on the market, such as an attractive design, packaging, logistics, market communication, maintenance service, business-models, technical functionality, sustainability and quality. The BONUS RETURN Readiness Level model is based on the more widely known Technology Readiness Level (TRL) model used and developed by NASA (NASA). The TRL-concept has also been applied by the European Commission (EC) for the Horizon 2020 programme (HORIZON 2020, 2019).

When discussing the TRL-scale with practitioners in BONUS RETURN and other projects there was often a critique on the emphasis of the term “technology” in the NASA and EC TRL-scales. This, partly due to the fact that many innovators do not define their innovations as a “technology”, but also due to the fact that technical issues are often of minor importance to the market success in comparison to other aspects such as design, business model and user communication issues. The proposed RLs range from 1 to 9 (as the NASA and EC TRL-models), to signify the stage of readiness in innovation development.

Moreover, the NASA and EC TRL-models are often illustrated as linear, in the form of a thermometer[2] or a ladder, while the BONUS RETURN-model is illustrated as a circular model. This since many practitioners within BONUS RETURN often mentioned that innovation development often creates more new ideas that become spinoffs from the main development, which can be illustrated as a circular system (even if most innovative ideas aspire to reach the market success as quickly and straightforwardly as possible). A more in-depth description of the elements of the Innovation Development Cycle can be found in Appendix C.

[2] See for instance Wikipedia about TRL

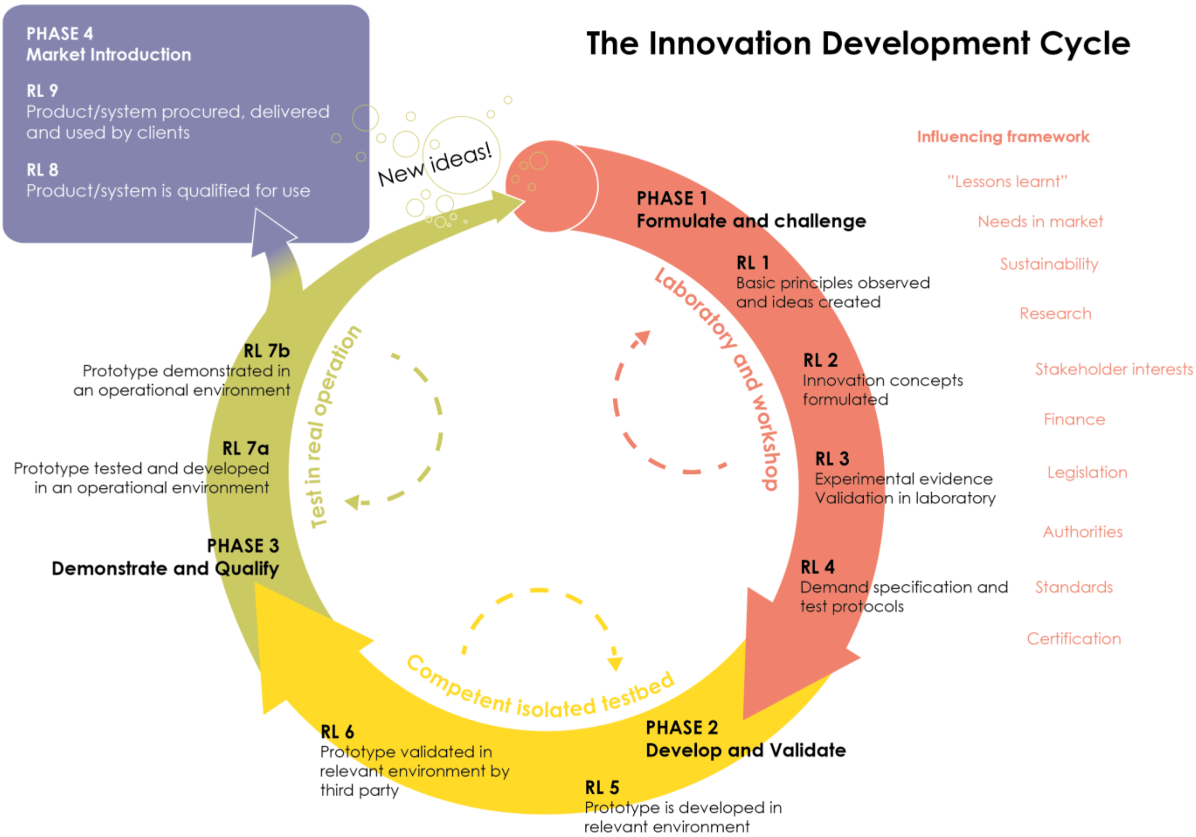

Figure 3: The innovation development cycle (Stenbeck and Quistgaard, 2018).

The general concept of the model is that there will be a gradual transition into an increasingly advanced test environment that depends on the needs - and market conditions - for developing the innovation. In the initial phase of innovation development resources such as a laboratory, close access to high level of expertise and technical support are typically needed. As an innovation begins to approach its final design, the innovation can be tested and demonstrated in a real market environment. The scale of RL ranges from RL 1 to RL 9, where RL 9 marks the innovation being sold, implemented and used successfully.

The RL framework is commonly used in the perspective of an innovator developing a product or service intended to be sold to the market – a seller's perspective. However, the framework can also be applied by a buyer looking for new innovative solutions to a complex problem. In the buyer's perspective the framework can be utilized as a tool for assessing the RL of emerging innovative solutions. If there are enough solutions on RL 9 (fully developed and already employed by customers) it is just a matter of conducting an ordinary procurement. However, if several of the interesting solutions are at RL 8 (fully developed but no units sold yet) or below, the buyer might consider conducting a *pre-commercial procurement* or an *innovation procurement*. These kinds of procurements are specially designed for procuring not yet fully commercialized products as a way of promoting new innovative solutions and procuring a desired function over an existing solution. Procurement options are described in section 8.1.

6 SUSTAINABILITY OF ECO-TECHNOLOGIES

Once a shortlist of interesting and contextually appropriate eco-technologies has been identified further analysis should be conducted to determine which of the alternatives that is the most suitable and sustainable in the implementation context based on stakeholder and decision-maker priorities. Sustainability has several dimensions and is non-trivial to assess without introducing bias, stemming from implicit priorities held by the individuals that are conducting the assessment. The risk of introducing bias requires the use of a transparent evaluation methodology to ensure a fair assessment. A transparent framework for conducting sustainability analyses of eco-technologies has been applied in BONUS RETURN by Johannesdottir et al. (2019) and was further detailed by Ahlström et al. (2019) where a full framework description can be found. A condensed description of this framework is presented in following sections of this chapter.

6.1 Tool 6: Sustainability analysis

The sustainability analysis method that was applied within BONUS RETURN was based on stakeholder engagement and the use of MCA for assessing five dimensions of sustainability. This sustainability assessment was used to enable a comparison of relative sustainability of different alternatives. The five dimensions of sustainability include environmental-, economic-, socio-cultural- and technical sustainability as well as health and hygiene. These dimensions are evaluated by analysing multiple criteria and indicators that are determined to be important by affected stakeholders and decision-makers. Examples of criteria that can be evaluated are presented in Table 2 in section 3.3. The sustainability analysis method applied within BONUS RETURN consists of the following eight steps:

1. Goal and scope definition,
2. Selection of criteria,
3. Selection of alternatives,
4. Analysis and evaluation,
5. Scoring,
6. Weighting,
7. Interpretation of results,
8. Sensitivity analysis.

The sustainability analysis method that is presented in this chapter is a combination of Tool 1, Tool 2, Tool 3 and Tool 4 that have previously been presented in the toolbox. The combination of these tools enables a more comprehensive analysis procedure than the application of each tool separately. The different steps and sub-steps of the method is illustrated in Figure 4. The sustainability analysis method is built around the entire decision-making process, starting with defining the goals and scope of the analysis and results in the identification of suitable alternatives. If the need for sustainability analysis is realized during an already ongoing decision process, it is still possible to apply the methodology that is presented below. Depending on what has been conducted previously throughout the process, some sub-steps will be possible to skip while others likely need to be revisited. Implemented and conducted correctly, sustainability analysis according to the presented method can be an effective tool for communication not only within a group of decision-makers but also when disseminating results to a large group of stakeholders.

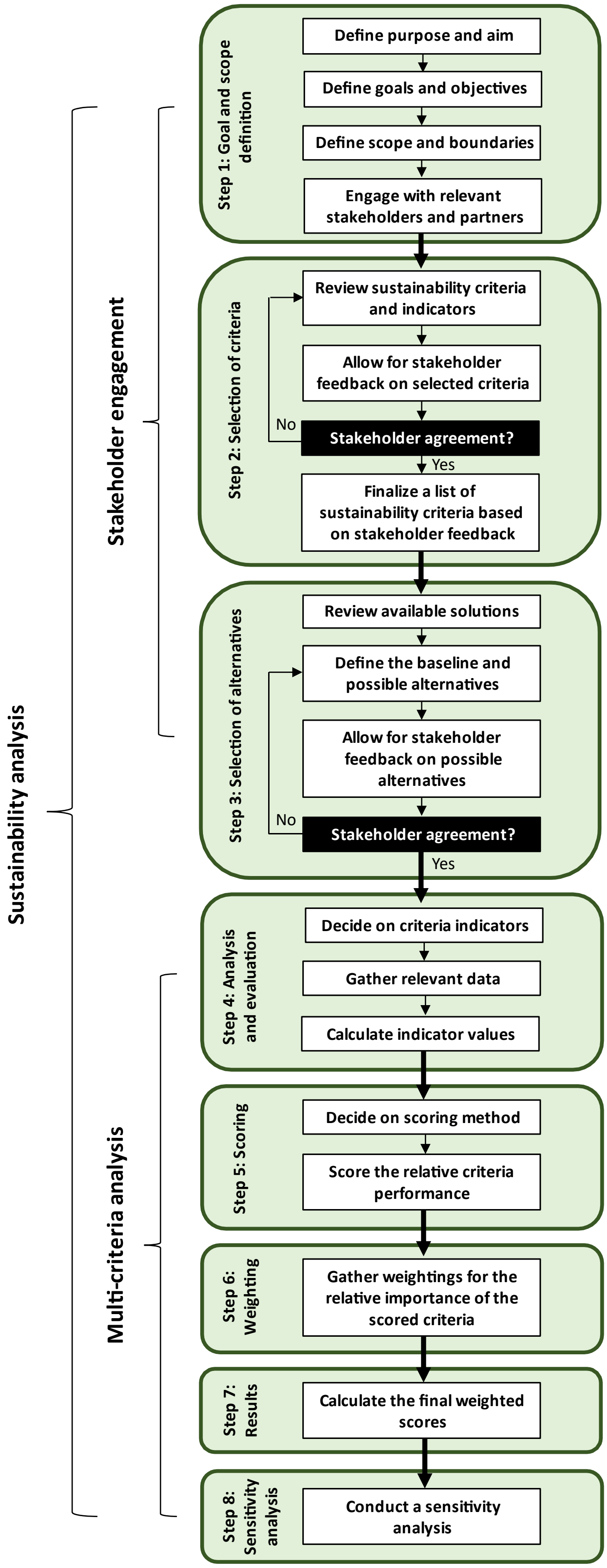

Figure 4: A flowchart describing the steps of the sustainability analysis method described by Ahlström et al. (2019).

Step 1: Goal and scope definition

Good decisions require clear goals and need to be based on accurate information. A good project definition forms a basis for clear communication with all participants and helps with setting the expectations for the involved actors. A good definition includes well-defined boundaries that set a clear scope for the analysis, it clarifies the purpose of the analysis, and states what is to be achieved for the project to be considered successful.

Define the purpose and aim

The purpose of the sustainability analysis should be concise and possible to state in a few sentences. The purpose should include why the analysis is being conducted and the challenges that needs to be addressed. The usefulness of results from the sustainability analysis will ultimately depend on how well formulated the aim is.

Define the goals and objectives

To ensure that the analysis can be conducted successfully there needs to be clearly defined goals to work towards for everyone involved. With clear and explicitly defined goals it is possible to keep the work effort focused on reaching the goals.

Define the scope and boundaries

The boundaries of the analysis need to be explicit as these will help guide the work that is being conducted. Without clearly defined boundaries it is likely that the project resources are spent inefficiently, and it is also possible that work is accidentally left out. The allocation of time and resources to different parts of the analysis should also be stated within the scope and boundaries.

Engage with relevant stakeholders and partners

A list of potential stakeholders should be compiled, and the ones deemed most relevant for the success of the analysis should be given opportunities to get involved. Subject matter experts could be tied to the analysis through a consortium and local stakeholders and decision-makers could be part of reference groups whose input can be used to assess the qualitative aspects of different criteria.

Step 2: Selection of criteria

It is necessary to consider what aspects of sustainability that are important to evaluate. Some aspects and dimensions of sustainability can be more or less relevant when considering a challenge by challenge basis, some criteria might be easier to assess than others, and there is not an objectively right or wrong choice of criteria nor a right or wrong way to assess these.

Review sustainability criteria and indicators

A good starting point for the analysis can be a review of the scientific literature to see what types of sustainability criteria that have previously been applied successfully to analyse similar challenges and how these different criteria have been assessed. A large set of sustainability criteria that have previously been applied for sustainability analysis within the wastewater and agricultural sectors has been compiled in a previous deliverable of BONUS RETURN by Johannesdottir et al. (2019) and is available in Appendix B of this toolbox. By conducting a literature review and starting the analysis procedure by looking into sustainability criteria in a broad context, narrowing down the potentially relevant sustainability criteria into a smaller subset will become easier.

Review of selected sustainability criteria by involved stakeholders

Once a subset of relevant criteria has been selected, it should be presented to the involved stakeholders for feedback prior to any further analysis. The stakeholders should be given an opportunity to provide input regarding which criteria they consider to be the most important in the challenge being addressed, preferably in an open forum where the relevance of different criteria can be discussed.

Finalize a list of sustainability criteria for analysis
Based on stakeholder feedback a shortlist of relevant criteria for use in the sustainability analysis should have been produced in the previous sub-step where all the criteria deemed irrelevant by the stakeholders should have been removed. The criteria in each category identified as the most important by the stakeholders should be given priority in the final criteria selection. Once the final criteria and alternatives are determined, further revisions should only be made if problems arise with data availability which may limit the possibility to adequately compare the different alternatives.

Step 3: Selection of alternatives
Once criteria are selected, it is necessary to explore the alternatives available to address the challenge within the boundaries that are set by both the selected sustainability criteria and the boundaries that were formulated in the definition step. It is important that all included alternatives fill the same function (e.g. they are all able to treat the same amount of water if the comparison is between different wastewater treatment solutions), as this is necessary to ensure a fair comparison between different alternatives.

Review available solutions
A good starting point for looking into available solutions is to conduct a review of the literature on the subject. A literature review can provide the necessary background information on available solutions and guidance towards finding possible solutions that are applicable in the decision-making context. Within BONUS RETURN a systematic map of eco-technologies for the recovery and reuse of nutrients and carbon within the Baltic Sea region was conducted by Macura et al. (2018). This deliverable was used for selection of technological system components and overall system design in the case studies in Johannesdottir et al. (2019). A compilation of the most promising solutions found during the review should be presented to stakeholders for feedback.

Define the baseline and the possible alternatives
The relative performance of the different compiled alternatives is presented through the comparison to a baseline alternative as part of its overall sustainability scoring method. The baseline alternative can be viewed as the standard to which the other alternatives are compared or the benchmark to reach. Current practices, or "business-as-usual", is commonly used as the baseline alternative as it is commonly of interest to know how much better or worse a certain alternative would be relative to what already exists or is implemented.

Finalize a list of alternatives for analysis based on stakeholder feedback
Stakeholders should be given opportunities to present feedback on the proposed alternatives before any further analysis is conducted. Stakeholder feedback should be used to rule out alternatives that are deemed unfeasible or undesirable in the implementation context. This feedback should result in a shortened list of feasible or desirable alternatives to progress further in the analysis.

Step 4: Analysis and evaluation
Once the baseline and the possible alternatives are determined, their relative performance needs to be evaluated by looking into different indicators. For a criterion such as *Life cycle cost,* a straightforward choice of indicator would be the calculated total costs over the entire life cycle of the alternative, but for a criterion such as *Air quality* the choice is less obvious. Suitable indicators could

be the emissions of atmospheric aerosol particles, nitrous oxides or sulphur dioxide resulting from operating a certain process, but the preferred indicator is ultimately context specific.

Decide on suitable indicators or measurements to assess
The choice of indicators to be used for assessing the criteria is crucial as this will affect the final interpretation of the analysis. For a fair assessment it is necessary to ensure that included criteria are independent so that the same criteria are not accounted for twice (or more). The choice of indicators should be in line with the views that have been presented by the involved stakeholders earlier throughout the process.

Gather relevant data for evaluation of criteria
Depending on the criteria selected for the analysis it will likely be necessary to collect both qualitative and quantitative data. Depending on the scope of the analysis and the resources available, quantitative background data may be gathered from scientific literature, by conducting necessary experiments or by consulting experts. Qualitative background data should be gathered from local stakeholders. Extrapolations or interpolations might be necessary for some types of data and information. Introduced uncertainties should be addressed by conducting a sensitivity analysis.

Step 5: Scoring
Scoring the relative performance of criteria
For each alternative that is being assessed, all the applied criteria are scored relative to the performance of the baseline alternative. For the baseline alternative all criteria are scored as 0, and the scores for other alternatives are calculated based on their performance relative to the baseline. The proposed method scores the criteria with integer scores between -2 and +2, where +2 is given for highest performance and -2 for the poorest performance as described in Table 3.

Table 3: Proposed method and cut-off thresholds for assigning scores when evaluating criteria.

Quantitative criteria	Qualitative criteria
Over 40% worse than baseline: -2	Most likely negative impact compared to baseline: -2
Up to 40% worse than baseline: -1	Possible negative impact compared to baseline: -1
Within 20% of baseline: 0	Negligible or no impact compared to baseline: 0
Up to 40% better than baseline: 1	Possible positive impact compared to baseline: 1
Over 40% better than baseline: 2	Most likely positive impact compared to baseline: 2

Step 6: Weighting
Gather weightings for the relative importance of the sustainability criteria
Stakeholder input to the weighting procedure can be gathered by hosting physical meetings (e.g. workshops), by sending out questionnaires (electronically or by mail), or by conducting phone interviews. Weightings should be gathered from as many relevant groups of stakeholders as possible. By enabling stakeholder interaction, it is possible to gather weightings based on informed discussions which should increase the consensus between the stakeholders and allow for a more balanced weighting procedure.

The proposed weighting scheme is to allow for individual stakeholders or groups of stakeholders to assign weights ranging from 0-100 to each of the evaluated criteria based on their perceived relative importance. Summed across all criteria the assigned weights should add up to 100 for each individual or group of stakeholders assigning the weights. In this scheme an assigned weight of 0 would mean that a criterion is deemed entirely unimportant, and conversely an assigned weight of 100 would mean that the weighted criterion is the only criterion that is deemed important. Table 4 illustrates how the weighting procedure could be structured.

Table 4: Example of how the weighting procedure can be structured in spreadsheet software. The assigned weights by j stakeholder groups and the computed average weights for criteria 1 to k for alternative i.

Criteria	Weights assigned by stakeholder group 1	…	Weights assigned by stakeholder group j	Average weight
Criteria 1	$W_{1,1}$	…	$W_{1,j}$	$W_1 = \frac{1}{j}\sum_{i=1}^{j} W_{1,i}$
Criteria 2	$W_{2,1}$	…	$W_{2,j}$	$W_2 = \frac{1}{j}\sum_{i=1}^{j} W_{2,i}$
…	…	…	…	…
Criteria k	$W_{k,1}$	…	$W_{k,j}$	$W_k = \frac{1}{j}\sum_{i=1}^{j} W_{k,i}$

Step 7: Interpretation of results

Calculate final weighted scores for each criteria and system

Applying the information that is gathered in step 5 and step 6 the sustainability score of each of the analysed alternatives is calculated using the weighted sum method as described in equation (1).

$$S_i = \sum_{j=1}^{k} W_j C_j = W_1 C_1 + W_2 C_2 + \ldots + W_k C_k \qquad (1)$$

In equation (1) S_i is the overall sustainability score of the i:th alternative that is being assessed and it is computed as the weighted sum of *k* different criteria. W_j is the weight assigned to the j:th criterion in step 6 and C_j is the score calculated for the j:th criterion in step 5. Put simply, the sustainability score is calculated by multiplying the score for each evaluated criterion with the corresponding weight and then adding up all the resulting products. The sustainability scores for the evaluated alternatives can then be compared and ranked according to their relative sustainability.

Step 8: Sensitivity analysis

Given uncertainties in assumptions that have been made during the analysis an evaluation of the effect of error margins on the computed sustainability score should be conducted. The purpose of the sensitivity analysis is to find out how sensitive the sustainability analysis, and ultimately the ranking of the alternative deemed the most sustainable, is to the parameters used in the analysis.

7 PROMOTING EXISTING ECO-TECHNOLOGIES

The implementation of eco-technologies that are already available on the market is generally done through the framework of public procurements. Public procurement constitutes a major share of public spending and is increasingly recognized as an untapped potential for driving the transition towards a circular economy. According to Tsanidis (2016) public procurements account for about 20% of the EU GDP, which corresponds to some € 2 400 billion per year. The criteria for winning contracts in these procurements carry a signalling function, signalling the market to develop certain products and services according to the set procurement criteria. If the procurement criteria are directed towards rewarding low cost alternatives, the development of new innovations will be mainly pushed towards low cost products. However, if the procurement criteria include environmental- and social performance as well as impact or even circular economy performance, the development of new products are pulled towards higher sustainability impact and circular economy performance. There lies a great challenge in balancing the possible procurement criteria in accordance to the Public Procurement Acts, which needs to be neutral towards all suppliers in the EU. Since it is not possible to prioritize local suppliers based on environmental reasons, it is nevertheless possible to formulate criteria concerning environmental impact and performance, if the criteria are evaluated according to international standards, common for suppliers in all EU member states.

The general idea for the role of public procuring organisations in promoting new technologies and solutions is to strive towards becoming an early adopter of the best available technology. This helps to promote the adopted technology to a larger volume of possible adopters and to increase the market share as is illustrated in Figure 5. The criteria employed for procuring the best available technology will also lead to old solutions being cut from the market and force suppliers to improve their solutions. This principle is the same regardless of what impact or SDG target the eco-technology aims to improve.

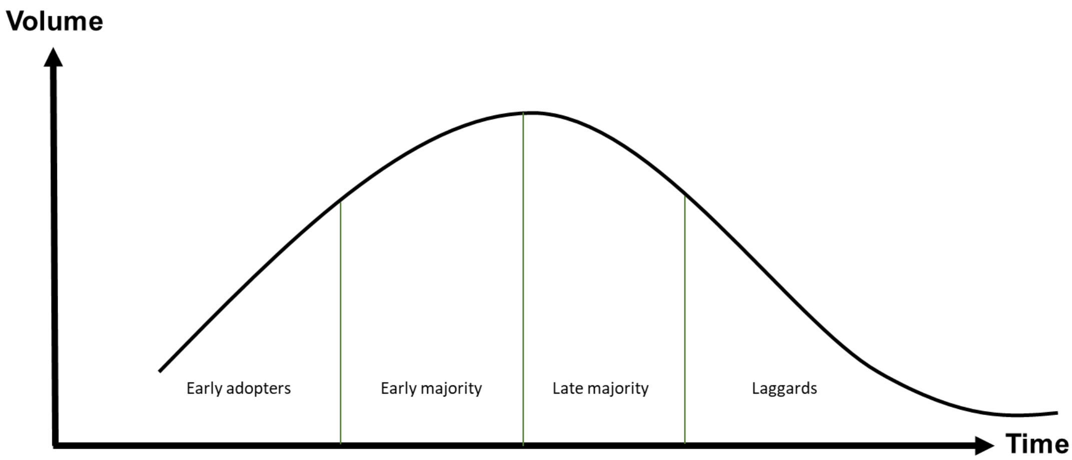

Figure 5: Innovation curve for the illustration of technology adoption over time, adapted from Rogers (2010).

The role of the procuring organisation as an early adopter can be facilitated by using methods developed for "innovation facilitation" or "innovation friendly" procurement. A key to act as a first customer or early adopter is to engage in an early market dialogue and include management and policy makers in the cost-benefit analysis as well as risk management. A way of illustrating the different roles of the procurer, the eco-innovators and the policy makers can be seen in Figure 6.

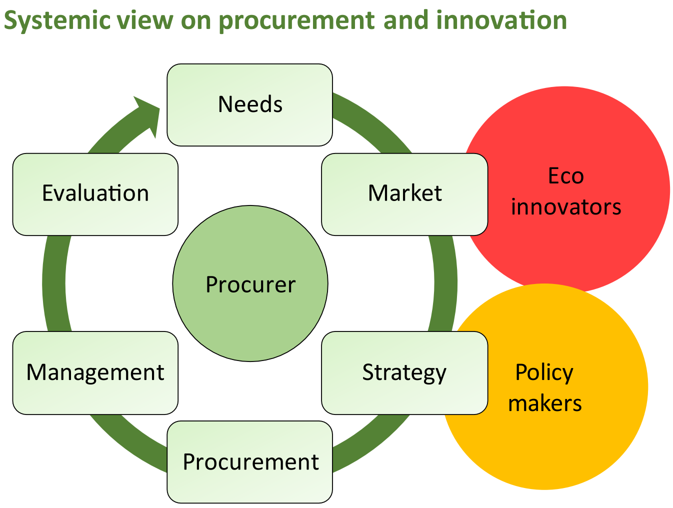

Figure 6: Systemic view on procurement and innovation, adapted from Norefjäll (2019d).

The general process of a public procurement is conducted in different steps, starting with a procurer with a certain need for one or more solutions and these solutions will be searched for on the market of suppliers including “eco-innovators”. Out of the existing different solutions as well as the existing legal framework and policies, the procurer develops a strategy regarding what solutions they need and how this need can be formulated in terms of procurement specifications. The procurement is carried out and a winner is selected based on the set criteria of the procurement. Traditionally, procurements are set to favour the lowest cost solutions. However, there is growing concern regarding quality issues and negative environmental impacts associated with economically cheap solutions. Alternatively, emphasis needs to be directed towards the importance of quality as well as sustainability criteria as the basis for selecting the winning bids. After selecting the winning bid there is a need for management of the implementation and an evaluation of the implemented solution to collect experience that can be applied for the next procurement.

7.1 Tool 7: Sustainable Public Procurement

Sustainable Public Procurement is a tool for decision-makers to increase the implementation of eco-technologies. A Sustainable Public Procurement (SPP) is a type of procurement where sustainable products and services are characterized by the implementation of sustainability criteria, to which the bids are assessed against in order to attain the *Best Total Value* as illustrated in Figure 7. The *Best Total Value* is a measure of the cumulative effects on social, economic and ecological values instead of the traditional focus on purely economic values.

Figure 7: Best Total Value, Swedish Ministry for Foreign Affairs (2019).

The products/services with the *Best Total Value* are often considered to be innovative, which still though means they are already existing on the market, i.e. products with RL 9. However, non-commercialized products and services, with a RL below 9 need to be procured via specially designed procurement procedures, either public procurement of innovation (PPI) or pre-commercial public procurement (PCP), both of which are described in section 8.2

Box 2: Sustainable public procurement
ICLEI is a global network of more than 1,750 local and regional governments committed to sustainable urban development and is active in more than 100 countries. ICLEI co-ordinates Procura+, a network of European public authorities and regions that connect, exchange and act on sustainable and innovation procurement and manage the Sustainable Procurement Platform. The platform has received funding through the Horizon 2020 programme and provides up-to-date news, case studies, events, tools, guidance and more on sustainable procurement efforts from across the world.

Additional reading and resources:
ICLEI Europe: https://iclei-europe.org/
Procura+: https://procuraplus.org/home/
Sustainable Procurement: https://sustainable-procurement.org/

7.2 Tool 8: Circular Public Procurement

Another term that is increasingly used by buyers and procurers is *"Procurement for circular solutions"*, sometimes also called *"Procurement for a circular economy"*, which is the procurement of products and services of RL 9 connected to the framework of Sustainable Procurement. The emphasis of the procurement criteria is on closing the material loops of a product's lifecycle and thereby decreasing the need for extracting raw-materials and natural resources, thereby reducing pollution and negative environmental effects.

Procurement for a circular economy often means to step up and increase the level of responsibility for sustainability in the procurement process, even if it has its emphasis on the environmental values and benefits and not on the socio-cultural values. The circular economy is an economy were natural resources and energy is continuously in a circular system in the whole supply, user and waste chain, as opposed to a linear economy process, which in the worst case could mean:

Raw material → Production → Supply → Consumer use → Waste → Landfill

The linear economy is inherently un-sustainable by extracting, consuming and polluting natural resources in line with economic development. Instead procurement for a circular economy promotes a sustainable society where the natural resources are protected, and even renewed, along with economic development. It means that the procurer considers its purchaser responsibility for selecting suppliers/vendors that have a more responsible management of a product's total lifecycle and its impact on the use and extraction of natural resources. Figure 8 below is an illustration of the concept of circular material loops from the Ellen MacArthur Foundation (2012).

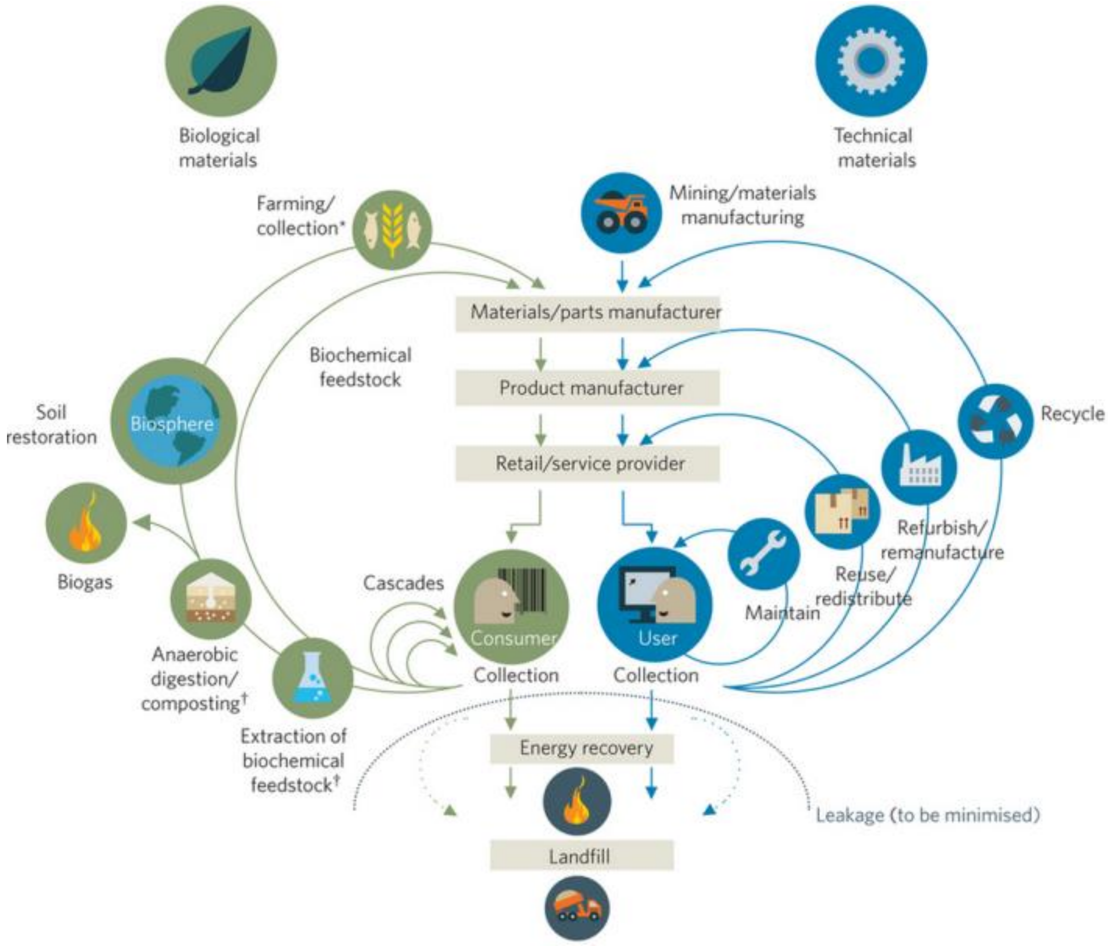

Figure 8: Closing the material loops in a circular economy (Ellen MacArthur Foundation, 2012).

There are many stakeholders involved in the entire lifecycle of a product; from the extraction of raw materials to the prolonged life by the consumer and the final waste management after the consumer has finished using the product. Closing all these loops requires extensive analysis, stakeholder cooperation and investments depending on the complexity of the supply chain of the product. The market might need a pull for this through Public Procurement, which could lead to a pull along the whole supply chain.

Countries like Germany, Sweden, Denmark and the Netherlands have new national policies in place to support circular procurement, and successful experiences are starting to emerge in the BSR. Some of the strategies raised for supporting circular procurement include the use of criteria for circular solutions in the procurement of circular products and services (such as leasing) but also through supporting the creation of industrial symbiosis and circular systems. Challenges remain for putting circular procurement in practice for the agriculture and wastewater sectors.

The inclusion of sustainability criteria and criteria promoting circular economy is still considered innovative in many countries in the EU and even more so outside of the EU. The promotion of these procedures is important as a driver for innovations and the needed transformation of society towards a truly sustainable and circular one. In a Nordic study on how the principles of the circular economy is promoted through public procurement, Alhola et al. (2017) recognized four different categories of approaches:

1. *Adding "circular criteria"*, i.e. criteria for recyclability, reuse of materials, use of recycled materials, etc. This means buying improved products and services, such as paper made from 100% recycled material.
2. *Creating criteria and conditions promoting products* that are considerably better in terms of recyclability, recycled materials, disassembly, long lifespan, etc. This includes products that would be developed as a result of the procurement process. Examples of such products are textiles with 100% recycled content or building components made of recycled plastic.
3. *Procurement of services and new business concepts* including product-service systems, leasing concept, shared use, buy-per-use and buying and selling back. A more traditional example includes furniture leasing while a more innovative example is lighting for the next 30 years instead of lamps.
4. *Procurement and other actions that promote industrial symbiosis and circular ecosystems.* This approach addresses large investments and the creation of ecosystems that call for commitment from different stakeholders. Circular ecosystems could use waste from one actor as a raw material for another. Examples include buses running by locally produced bioenergy or circular building materials.

It is most difficult (or least explored) to act for circular procurement in Category 3 *Procurement of services and new business concepts* and Category 4 *Procurement and other actions that promote industrial symbiosis and circular ecosystems.*

Box 3: Circular Public Procurement
Circular PP is a three-year project supported by the Interreg Baltic Sea Region programme running between 2017 and 2020. The main goal of the project is to develop an adequate framework for circular procurement in the countries belonging to the Baltic Sea Region (BSR), by following a four steps approach:

(1) Analysis of the status quo in Circular Procurement in the BSR and identification of improvement potentials at a at local, national and transnational level, (2) Building necessary capacity on circular procurement for relevant stakeholders of the value supply chain, including public procurers, SMEs and policy makers, (3) Delivering call for tenders aligned with the defined priority areas to enable learning by doing and ensure the projects develops practical capacity building material (e.g. training, guidance, future recommendations), (4) Disseminating the project results among European public procurers and SMEs, using strategic partners and relevant channels.

The partnership consists of The City of Aalborg (DK), Aalborg University (DK), North Denmark EU Office (DK), the Finnish Environment Institute SYKE (FI), Latvian Environmental Investment Fund (LV), Latvian Chamber of Commerce and Industry (LV), Rzeszow Regional Development Agency (PL), Saint Petersburg campus of National Research University Higher School of Economics (RU), The City of Malmö (SE) and the Dutch Ministry of Infrastructure and Water Management (NL)

Additional reading and resources:
Circular PP project website: http://circularpp.eu/

The circular customer

Moving closer to a circular economy is a massive shift for society and the public procuring organizations have an important role to act as a driver in this transition. Most work on circular public procurement so far, is focused on material flows and the procurement of goods. Figure 8, is used to explain both the technical and the biological cycles. The focus of the technical cycles is relatively simple, where goods and materials are tangible for the procurer. The procuring organization additionally have the role of the collection and handling of waste and energy recovery to close the loop in the technical cycle. The procuring organizations can procure better products, machinery etc. to their facilities. The biological cycle is more difficult to handle in procurement as it includes energy, waste, nutrients, carbon emissions etc. in many different procurements. The role of the procuring organizations is also different in the biological cycle as it includes more of the handling "downstream" and the cascades at the "bottom" of the circular loops. The procuring organizations responsible for the handling of waste and water treatment are the "last chance" to close the loop.

It might seem obvious, but controlling the inflow is not enough to close the loops in a circular economy. The use-phase and the outflow of materials and nutrients must also be handled. In order to fully understand the role of the procuring organization in an increasingly circular economy, the procurement scope must be expanded. To act circular as a customer does not just include buying a circular product or service. It includes to systematically develop internal routines and strategies as well as to work on extending the life and use of the bought products. For instance, through repair and proper storage routines, reducing waste (e.g. increased recycling) and investigating how the internal organization's structures can support circular work. The procuring organizations should try to capture energy and nutrients during the use phase as well as in the downcycle phase, avoiding leakage of resources out of the system. These principles are described in Figure 9.

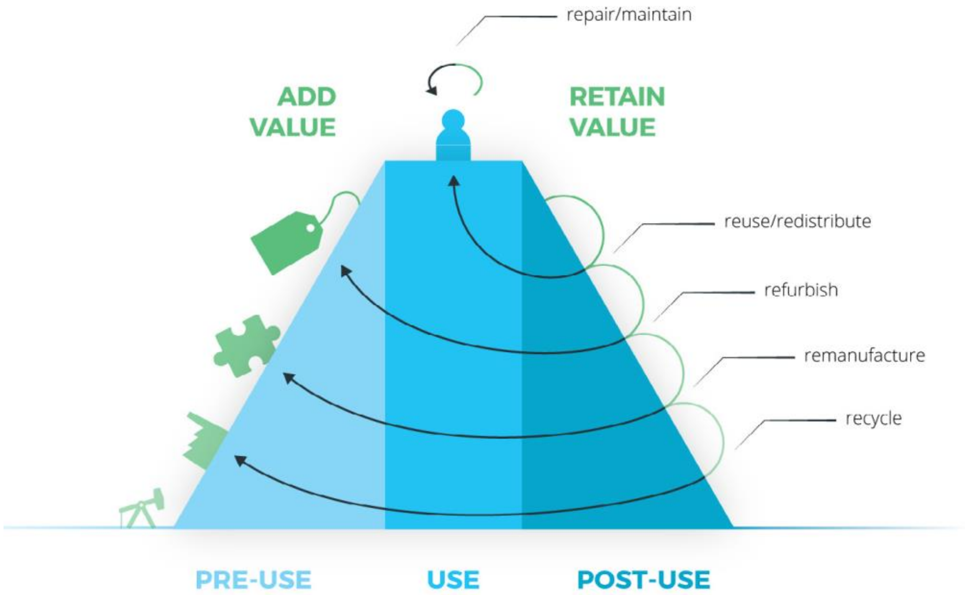

Figure 9: Circular business with the value hill (Circle Economy, 2016).

More circular organizations keep produced goods on a higher level of the value hill for as long as possible. To be circular also means to be a part in the recovery phase and to promote downhill recovery as well as closing the loop to uphill development of materials, nutrients etc. In order to close the loops or cascades in Figure 8 it is imperative to also include the downhill recovery.

The barriers and possible development steps for the circular customer could be arranged in development areas. A compilation of obstacles and opportunities from the procuring organisation's perspective indicates the need for parallel development of the circular customer in four areas:

1. To extend the perspective for products in the entire life cycle/value chain and the production system connected to the value chain and understanding its role in this whole.
2. Switching to new business models from circular products to more service-based solutions such as hiring/renting, function-oriented, or performance-based procurement.
3. To develop your own organization from buyers of products and services, to be involved and co-creative in the development of new circular services and other business models.
4. Increasing the degree of innovation, with a focus on modifying existing products and materials first, switching to new products and features in a later stage to completely new materials and products.

The circular customer needs to build expertise to overcome the barriers that exist for each stage of development in the four areas illustrated in Figure 10:

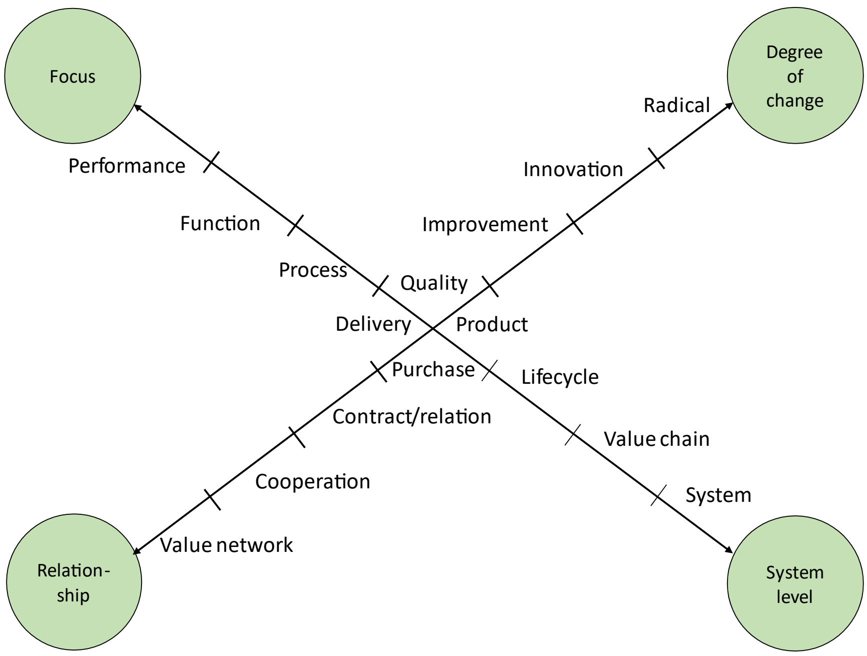

Figure 10: Barriers for circular procurement development, adapted from Norefjäll (2019a).

Expanded utility focus: Increased focus on circularity means a change in focus, from the delivery and the procurement object functions to a broader focus regarding the effects and benefits associated with the entire business, on the performance of the value network and the entire system.

The degree of change in the procurement item: In some areas, innovative solutions have been procured. The next step on the development axis is to buy new radical solutions, there are however challenges associated with this. Such as the need for capacity and processes for risk management as well as decision-making without all the facts.

The degree of systems thinking: The procuring organizations have come a long way with life cycle perspectives and carbon footprints in several procurement areas. However, there are difficulties in managing the entire supply chain, the next level is to consider the entire system value chain. This is particularly evident in the challenges of a circular economy.

The degree of collaboration in the business relationship: In order to manage the transition within the first two areas, our own organization must also evolve. Today, the organization is primarily a buyer of products and services. The next step in the development is to be involved and co-creative in the development of new services and other business models. In a circular economy, more product and material loops will be collective, and the organization must be involved in various forms of networking and collaboration. As a result, the boundaries of the organization will change, and the role of buyers and producers of goods will change.

These four areas and Figure 10 is intended to be a hypothesis and the axis and steps are not absolute. It is more about ensuring that all perspectives are included in an integrative work process to develop the capacity in the organization. Quality cannot be ignored when trying to reach radical innovation or to skip the contract as a basis for collaboration. There are barriers or thresholds to overcome in each step of every axis. It seems to be more difficult for each step further out from the centre of each axis. In order to develop on each axis, it is often necessary to develop on the others as well. In the hypothesis capacity increases outward and it also means that the procuring organization is more dependent on collaboration in its organizational innovation system to reach the exterior, levels and reach the full potential of its ability.

8 SUPPORTING INNOVATION OF ECO-TECHNOLOGIES

It is challenging to procure and finance solutions that are not yet on the market and it requires alternative methods from the traditional procurement, to act as *a first customer* and introduce a solution to the market. In order to meet eco-technologies at RL 6-8 it is important to first uncover the needs for eco-technologies (see chapter 3), understand the readiness of the eco-technologies (see chapter 5) and prioritize the benefits from the eco-technologies (see chapter 6). The role of an innovative procurer and partnered needs owner as a bridge in technology development, is illustrated in Figure 11.

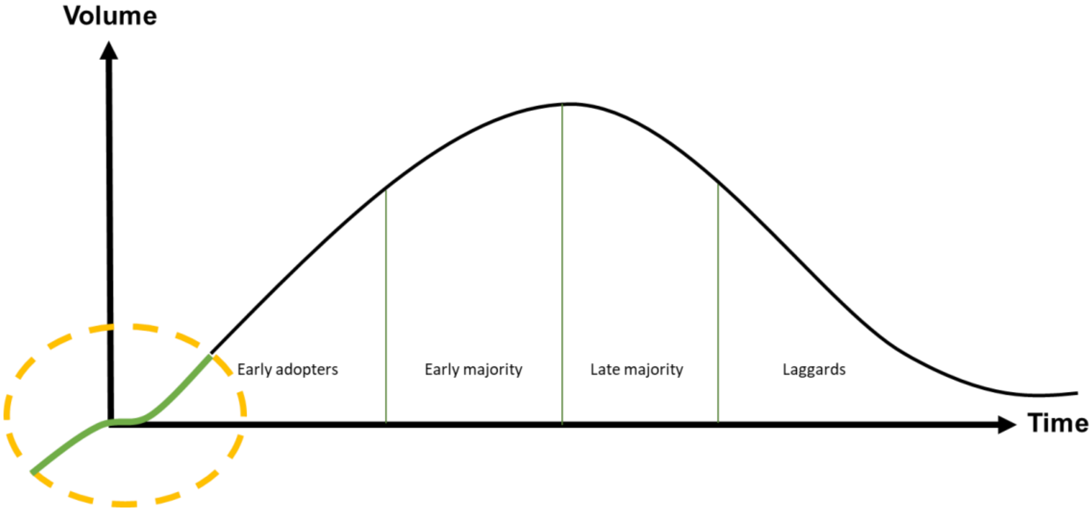

Figure 11: Innovation curve for illustrating technology adoption over time. The circled line illustrates the role of procurers in bridging innovation development and market introduction by acting as early adopters, adapted from Rogers (2010).

Innovation, research and development are resource and labour-intensive efforts and finding the necessary funding is oftentimes a significant hurdle that small scale innovators and entrepreneurs need to overcome in order to successfully develop their idea into a fully functional business with a product that has market potential. In broad terms start-ups and small and medium-sized enterprises have the options to seek private funding (e.g. venture capital), public funding (e.g. EU-supported grants) or try to enter public partnerships (with different levels of government) to secure capital and support. Financing a public partnership can be done through different types of procurement, for example innovation procurement or by applying for public grants, both of which will be described in later this chapter.

8.1 Tool 9: Innovation procurements

According to the EC-initiative *The European Assistance For Innovation Procurement* (eafip), Innovation procurement is a form of procurement where public procurers procure the development or deployment of pioneering innovative solutions to address specific mid-to-long term needs of the public sector (eafip, 2018). Innovation procurement can additionally be applied for the procurement of goods or services that are not yet fully developed or readily available for the commercial market. Innovation procurements focus on the procurement of potential commercial products and services, which means products that have not yet reached RL 9 but are at RL 8 or perhaps RL 7. It is therefore essential to differentiate *Innovation procurement* from *Sustainable Public Procurement*, *Procurement for circular solutions* and *Procurement promoting a circular economy* as these different procurement methods have different goals as discussed in previous sections. Even if Figure 12 indicates the procurement of goods and services with RLs as low as RL 6, goods and services with RL lower than RL7 are seldom procured as the risk of wasting public funds increases significantly with lower RL.

How innovation procurement works for innovators

Development of new products and services typically follow the development curve as is illustrated in Figure 12a, where two distinct phases, the pre-commercial phase and the commercial phase, can be seen. There is often a plateau in the middle of the development process where the development transitions from being in the pre-commercial phase with the support of public funding into the commercial phase where the funding comes from expected future sales. When trying to achieve the first sale of the fully qualified product (RL 8) there is almost always a reluctance from potential clients towards being the first customer. It is perceived much less risky to first get references from another satisfied customer before purchasing a product which typically results in a stalemate on the development curve.

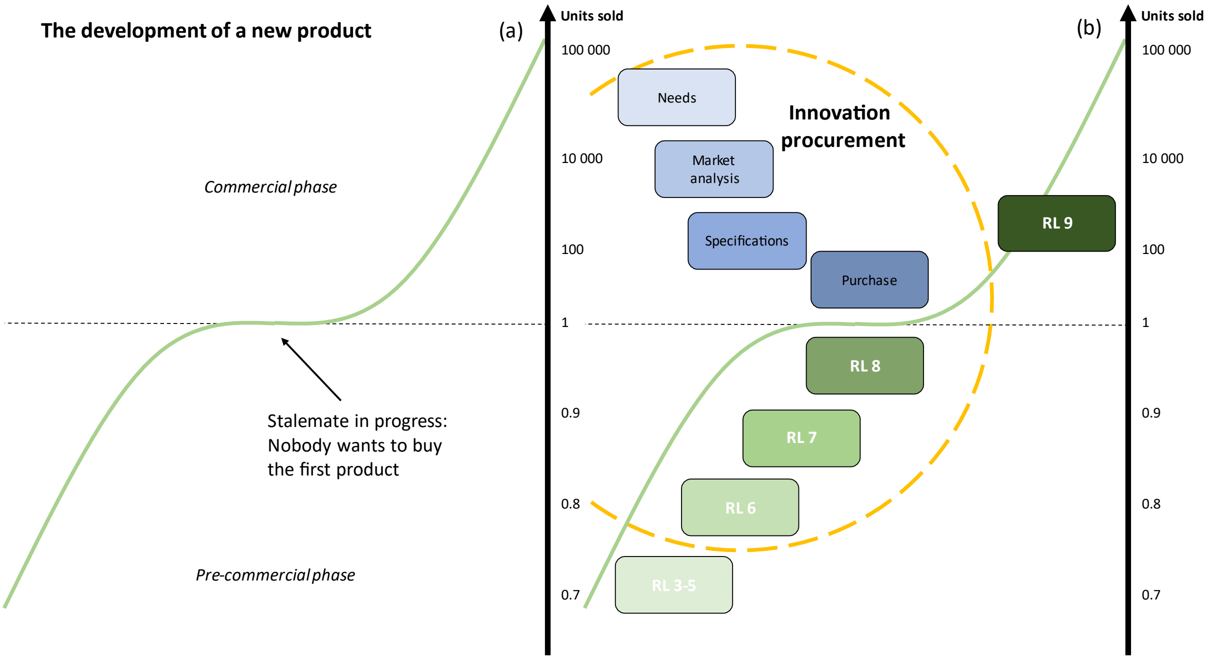

Figure 12: The development of a product through innovation procurement, adapted from Norefjäll (2019b).

The introduction of innovation procurement has been added to the development curve in Figure 12b, in which the innovators RL development is added along the product curve from the lower left corner and the procurer process coming from the left upper corner towards the intersection between the pre-commercial phase and the commercial phase. The innovation procurement could be the risky first customer of the first product or it could be part of the late pre-commercial phase to assist the development of innovative solutions through RL 7-8 by including specific needs from the public sector. The innovation procurement becomes an important driver for catalysing the development of needed innovations through special adapted procurement processes.

The different types of innovation procurement are based on the RL of the products and services on:

1) *"Pre-Commercial Procurement" (PCP)* (European Commission, 2019a) is used for early developed solutions which demands more research and development and when it is too early to know what to implement in the end. The procurement selects typically a couple of promising developers for the identified need.

2) *"Public Procurement of Innovation"* (PPI) (European Commission, 2019b) is used for solutions that are validated and market ready (RL8) but needs the public to become the first customer. The process ends up with a solution to be implemented and demonstrated.

The advantages of conducting a PPI for contracting authorities include:

- Cost savings in the long run when the process is thought through in advance,
- Improved quality of a product/service,
- Direct positive impact in society,
- Shorter time requirements for conducting the procurement procedure.

The process of innovation procurements

The process of an innovation procurement can be summarized as illustrated in Figure 13 based on the eafip-toolkit (eafip, 2019). See Box 4 for additional information about the toolkit. The procurement process starts with a need for an innovative solution (i.e. a solution is not currently available on the market) and ends with the innovative solution(s) being developed and procured. If a PCP has been conducted there are multiple procured solutions, while if a PPI has been conducted it ends up with the selection and implementation of one innovative solution.

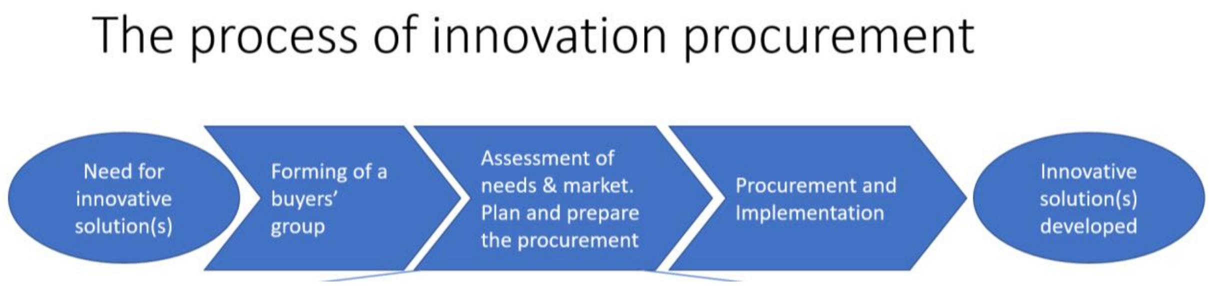

Figure 13: The process of innovation procurement, adapted from eafip (2019).

Box 4: The eafip-toolkit

The European Assistance for Innovation Procurement initiative (eafip) is an initiative launched by the European Commission to support public procurers across Europe in developing and implementing innovation procurement. The aim of the initiative is to promote good practices and reinforce the evidence base on completed innovation procurements across Europe and to encourage other public procurers to start new PCP and PPI procurement. The eafip-toolkit provides support to policy makers in designing PCP and PPI strategies, and to procurers and their legal departments in implementing such procurements.

Additional reading and resources:

eafip-toolkit: https://eafip.eu/toolkit/

As a first step of the process it is important to form a "buyer's group" which consists of several members having a common need for the same innovative solution(s). As an innovation procurement involves more risks and costs for both sellers and buyers it is important that the investment can be used by many buyers with common needs. This also ensures that the needs are generic and that many different buyers can ensure there are no solutions available on the commercial market. The seller can also be ensured that their investments and risks can pay off by being selected by a group of buyers.

The second step is the assessment of needs and the market. This means to more thoroughly assess if the needs are verified by experts relevant for the needs and the market, and by doing a stakeholder/open market consultation. The open market engagement:

- Brings the supply-side perspectives to a procurement process,
- Provides advance information to suppliers about forthcoming procurements,
- Tests the reaction of the market to a proposed set of requirements,
- Helps design an effective procurement approach.

The needs must be concretized into procurement specifications through a process of understanding and defining the functional needs and the performance characteristics of the procurable needs. All this goes into the work of planning and preparing the procurement. The main challenges for the procuring organization is to:

- Understand how the organizations real needs can be met,
- Using different procurement approaches and procedures,
- Inspire the market to innovate,
- Assess the risks in advance and proposing preventive measures,
- Deal with output-performance, instead of detailed descriptions of the process
- Agree on clear distribution of responsibilities concerning e.g. permits, intellectual property rights,
- Remain objective if solutions differ strongly.

The third step is the actual procurement process where vendors are invited to tender according to the Terms of References.

Figure 14 illustrates the innovation procurement process and presents an overview of the entire process and its sub-activities. The process description is based on the eafip-toolkit (eafip, 2019). The figure shows the different actions done step-by-step, starting and ending in the same way as the flowchart in Figure 13, with a need for innovative solution(s) and ending with the implementation of a solution if a PPI has been conducted or with the development of multiple potential solutions if a PCP has been conducted.

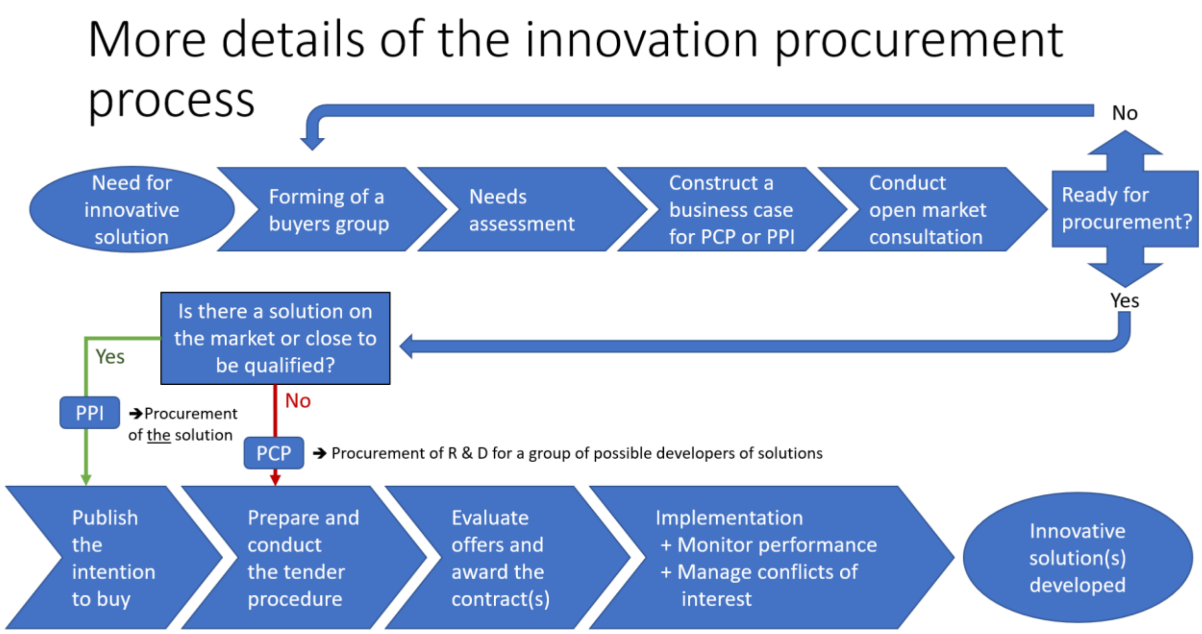

Figure 14: The Innovation Procurement process, adapted from Stenbeck (2019)

The upper part of the process is connected to the pre-feasibility actions where the needs are assessed and the business case for PCP or PPI is formulated to be shared in an open market consultation. This is to ensure that the needs are adequately generic and relevant and to ensure that there are no commercial products or services that already available on the market that can meet these needs. In a PCP or PPI process the aim is to get to an unmet need that is:

- Genuine – A real need – Not innovation for innovations sake,
- Accurate – Engage stakeholders, consult end users, get to the root of the issue,
- Credible – Organizational commitment, budget, embedded in the organization, timeframe,
- Focused on outcomes not solutions – Allow room for new ideas.

Following the open market consultation, there might be a need to adjust the size of the buyer's group or the business case and then possibly even a need to conduct an additional open market consultation to be ready for the actual tender process. The PPI process starts by the publishing of the intention to buy before the preparations of the tender documents. A PCP does not need that publishing of intention. Both processes, PCP and PPI, then have the same activities but with different sub-activities. More details of the different actions can be found in the eafip-toolkit (eafip, 2019).

Guiding principles for successful PPI implementation include:

- Starting early,
- Knowing the market,
- Assessing and actively managing risks,
- Seeking competition,
- Using flexible procurement procedures,
- Resisting the urge to over-specify,
- Making information freely available,
- Agreeing on intellectual property strategy,
- Including Key Performance Indicators (KPIs) in contracts.

Box 5: Innovation procurement

Procure2Innovate is an ongoing Horizon 2020 project aimed at improving institutional support for acquiring products and services from a range of sectors that implement innovation procurement. The project will establish or expand competence centres of for innovation procurement in 10 European Union countries: Five are already established in Austria, Germany, the Netherlands, Spain and Sweden; while five new competence centres will be established in Estonia, Greece, Ireland, Italy and Portugal. Finland and Lithuania are associate countries. Additional resources on innovation procurement as well as contact information to national competence centres can be found through the Procure2Innovate-website.

Additional reading and resources:

Procure2Innovate project website: https://procure2innovate.eu/home/
The European Assistance for Innovation Procurement: https://eafip.eu/
Innovation procurement: https://innovation-procurement.org/

8.2 Tool 10: Partnerships for public and private research and innovation grants

One possibility for securing financial assets for research and development of innovative ideas is to partner up as decision-makers/need owners and innovators to jointly apply for publicly available research grants. Research grants are given out by both publicly and privately funded organisations and institutions. Applying for grants is a common way for universities and institutes to secure funding for basic and applied research projects. Open calls for research proposals and funding opportunities can for example be found through national funding agencies, international funding agencies (e.g. through programmes funded by the EU: BONUS, INTERREG, Horizon 2020 and the upcoming Horizon Europe programme) and private organisations and non-profits (e.g. the Red Cross).

The process of applying for a research grant can be summarized into the following four general steps:

1. Formulate an idea for a research project,
2. Form a consortium with project partners and stakeholders around the research idea,
3. Identify a suitable funding opportunity,
4. Write an application that matches the requirements of the financier.

Depending on the opportunity and the pool of funds that is available, varying amounts of work will have to be put into the application to ensure a high-quality application that has a good chance of being granted. Some financiers have application procedures that demand highly detailed project descriptions and budgets already at the first application stage while other financiers have multi-stage application procedures that demands successively more detailed information, weeding out applications throughout the process before any grants are handed out. The competition for funding opportunities can be fierce and only a small fraction of the applications that are filed are likely to receive funding. However, some research calls are specifically aimed towards SMEs in order to support and accelerate innovation which might be of special interest for small and medium scale innovators and can aid in pulling novel ideas closer to market introduction.

8.3 Tool 11: Innovation competition

A scaled down version of an innovation procurement process was launched in BONUS RETURN in the form of an innovation competition, the process of which has previously been described by Barquet et al. (2018). The competition was applied as a tool for identifying eco-technologies with capabilities in line with the objectives of BONUS RETURN, e.g. technologies that have the possibility to turn nutrients (nitrogen and phosphorus) and carbon into benefits. An innovation competition can serve as a tool for identifying promising eco-technologies and enable a way to efficiently direct pre-commercial support, thereby benefitting both decision-makers and eco-innovators by bringing the technologies closer to market and reducing risks for decision-makers related to full-scale implementation of new technology.

Tool applicability and expected outcomes

An innovation competition intended for emerging eco-technologies can be conducted by issuing a technology challenge. The challenge should include a set of demands (or needs) that the applicant eco-technologies are required to fulfil in order to enter. The challenge can be directed towards pre-commercial eco-technologies by specifically including a demand on Readiness Level (RL) in the application demands. Applicant eco-technologies are reviewed, and additional information is collected regarding the applicant’s ability to meet the challenge demands. The applicant eco-technologies are then rated by a jury panel consisting of subject matter experts, decision-makers and stakeholders in terms of how well the technologies fulfil the set of challenge demands.

Based on the scores of the evaluated eco-technologies, one or several applicants can be selected to receive an award. Useful awards can either consist of financial support or assistance in conducting pre-commercialisation development activities, for instance; validation or testing of the technology in a relevant test-environment, identification of potential clients, business strategy development, facilitation of client and innovator networking, sustainability analysis and promotion.

General steps: Conducting an innovation competition

The execution of an innovation competition can be reduced to a series of actions in the following order:

- Identifying a set of demands that eco-technologies should be able to meet or solve,
- Defining the type of eco-technologies that are to be included in the innovation competition,
- Developing a strategy for promotion, communication and dissemination of the competition,
- Identifying and contacting individuals able to act as experts in a jury within the field of the targeted innovations,
- Reviewing and assessing the applicant innovations in terms of the set of demands,
- Selecting winners based on their performance in relation to the set of demands,
- Awarding the winners with support towards development of their eco-technologies.

Important notations

When conducting an innovation competition there are several aspects that need extra consideration. During the planning phase an efficient dissemination strategy needs to be developed in order to reach a large group of actors in the target audiences. To ensure that the competition has an impact it needs to target emerging eco-technologies with the right readiness level (RL) (as described in section 5.1). If the Readiness Level is too low, the outcome of the competition can be uninteresting for stakeholders as the finished products cannot be expected to be market-ready in the near future. With a Readiness Level, on the other hand, that is too high, the competition will not be supporting emerging eco-technologies and be uninteresting from an innovation development perspective. In order to find and support emerging eco-technologies with high probability of reaching the market it can be useful to target eco-technologies with a Readiness Level of 5-7 that has working prototypes. Another important factor related to the target audience are the challenge criteria, where the formulation of the most appropriate ones is a balancing act between targeting eco-technologies with an idea and a finished product. Lastly, the award(s) for winning the competition must be attractive for innovators so that they will spend the time and resources necessary to entering the competition. For instance, a prize consisting of publicity as well as development support, in the form of transferred knowledge, can add more value to the development process than a small cash prize.

Innovation competition: case BONUS RETURN

An innovation competition was utilized as a tool for directing pre-commercial support to promising eco-technologies within BONUS RETURN. An open challenge was announced by BONUS RETURN intended to attract emerging eco-technologies able to address the issues of nutrient and carbon recycling in the BSR. The competition sought to attract new, not fully developed eco-technologies with a potential to facilitate the reuse of nutrients and carbon from the agricultural and wastewater sectors. Winners of the innovation challenge would receive support in their pre-commercialisation efforts directed towards either increasing the Readiness Level of the eco-technology or adapting it to local market needs, as well as gaining access to a platform for meeting potential investors and clients. The general process of the innovation competition is described in the remaining sections of this chapter and is to a large extent based on what has previously been presented by Barquet et al. (2018).

The challenge

An open challenge was announced with up to three winners. Eco-technologies eligible for the challenge had to comply with a set of four challenge criteria. The eco-technology:

1. Addresses nutrient or carbon reuse from the agricultural or wastewater sectors, or both.
2. Can be applied in the Baltic Sea environment.

3. Is a biological, physical or chemical intervention designed to minimize harm to the environment and provide services of values to society.
4. Is a prototype at TRL 5 (=RL5) or higher, according to the EU framework programme Horizon 2020.

Innovation competition winners had the opportunity to receive support in their efforts towards commercialisation by selecting one support action suitable for their current needs. In addition, the winning eco-technologies had the opportunity to present their innovations to a community of investors, researchers and public sector actors at the Baltic Sea Future Conference in Stockholm, Sweden on the 8th and 9th of March 2018. Winners of the challenge had the opportunity to:

1. Perform tests,
2. Match their eco-innovation product to local needs,
3. Receive tailored procurement- and business plans,
4. Network with investors and private sector actors,
5. Introduce their eco-innovation to potential markets.

Innovation competition communication strategy

In order to maximize the reach of the innovation competition a communication and dissemination strategy was developed. The strategy was composed of two main parts, a strategic plan for developing communication materials for promotion of the innovation competition and a plan to disseminate the information through various sources and channels. Up until the final announcement of the winners in March 2018 the communication strategy followed the timeline below:

November 2017

The communications plan was set, and material required for promotion designed. These included:

- A webpage on the project's website.
- A booklet with facts, background information and instructions to be read by all applicants before submitting their applications.
- A brochure with a summary of the competition's guidelines, timeline, requirements, and information about BONUS RETURN.
- A communications toolkit: As part of the dissemination plan, the project worked with consortium partners as well as external partners to promote the competition. The toolkit was developed to ease the burden to these partners, as it contained all the necessary material required for promotion. The toolkit contained: A press release, the competition fact sheet and guidelines, a digital competition brochure, a news story, and social media package with prepared tweets

December 2017 – February 2018

The competition was officially launched on the 1st of December 2017 through an announcement on the BONUS RETURN website and a press release. The marketing campaign launched thereafter included:

- Twitter: a series of tweets and retweets from project partners using the hashtag #BonusReturn throughout the competition.
- LinkedIn: promotional posts on LinkedIn posted periodically throughout the competition.
- Facebook: marketing campaign ads on Facebook to reach a wider audience within the EU.
- Email marketing: strategic email marketing campaign to specifically targeted groups within the EU such as: innovation hubs, blue-tech companies, universities, Baltic Sea affiliated companies and networks, etc.

Evaluation of applicant eco-innovations

A jury was formed to review applicant eco-innovations and to rate their market potential. The jury consisted of internal and external experts in the agricultural and wastewater treatment sectors. Applicant eco-innovations were reviewed by the jury, resulting in a shortlist of four finalists. The eco-innovations where evaluated and rated on relevance, expected impact, sustainability and market potential. Each application was rated in relation to the assessment criteria with a scoring system ranging from 1-6 points; poor (1), limited (2), moderate (3), significant (4), very significant (5) and extremely significant (6). The five assessment criteria employed by the jury panel consisted of:

1. **Relevance of the application**

   Whilst the applications had been pre-screened, supplementary assessment of the level of relevance was conducted according to the following four sub-criteria, if the innovation:

   1) addresses nutrient or carbon reuse from the agricultural or wastewater sectors, or both,
   2) can be applied in the Baltic Sea environment,
   3) is a biological, physical or chemical intervention, or set of interventions, designed to minimize harm to the environment and provide services of value to society,
   4) is a prototype of TRL 5 or higher, according to the EU framework programme Horizon 2020.

2. **Impact**

   Assessment of the expected impact of the innovation upon nutrient and carbon reuse.

3. **Sustainability**

   Assessment of whether the application at bare minimum causes no harm, and at the very best contributes positively to one or several of the following four sub-criteria:

   1) Health and hygiene,
   2) Environmental issues,
   3) Economy,
   4) Socio-cultural dimensions.

4. **Market potential**

   Assessment of whether the innovation can be adapted to local markets. This refers not only to the potential of the innovation per se but also that the socio-political and economic conditions to enable its implementation (e.g. procurement, national priorities, region strategies, etc.) exists or are underway.

5. **Overall assessment**

   List of strengths and weaknesses of the application; additional comments and recommendations; can BONUS RETURN contribute to further developing the innovation?

Out of approximately 20 applicants, four finalists were selected and invited to present their innovations at the Baltic Sea Future Conference. In addition to the conference presentations the finalists also had the opportunity to privately present their innovations in an interview with the jury. Based on the presentations and interviews, three applicants were selected as winners of the competition: RAVITA, developed by Helsinki Region Environmental Services Authority (HSY), TerraNova® Ultra, developed by TerraNova Energy and BiOPhree®, developed by Aquacare.

Results

Hosting the competition final at the Baltic Sea Future Conference created an arena where decision-makers and innovators could meet in dialogue. This allowed decision-makers to get informed and acquainted with the innovations and the issues that the innovations sought to solve. Additionally, the pre-commercial support provided to the winners created benefits for decision-makers by bringing the innovations closer to the market and reducing risks associated with early implementation while also providing decision-makers with means to close the loop on nutrients and carbon in their sectors. Details of how the pre-commercial support efforts were conducted for the winning innovators are described in further detail in chapter 9.

9 DEVELOPMENT OF INNOVATIVE ECO-TECHNOLOGIES

New innovations will undoubtedly play an important role in society's transformation into an increasingly circular one. However, the road from innovative idea to a marketable product is often lengthy and plagued with obstacles, prolonging the development of new innovations. Tools and frameworks supporting the development of innovation are needed to increase the number of new innovations that successfully reach the market. This chapter provides three tools for supporting eco-technologies in their pre-commercial activities in order to bringing them closer to the market. These tools where adopted and used throughout BONUS RETURN and consisted of:

- a market survey,
- an independent comparative analysis,
- independent testbed trials.

The BONUS RETURN innovation competition provided the opportunity to evaluate different pre-commercial support tools. The competition functioned both as a support tool as well as a method to identify promising eco-technologies in need of assistance. Three eco-technologies were identified and awarded support via the innovation competition, these where; RAVITA, developed by Helsinki Region Environmental Services Authority (HSY), TerraNova® Ultra, developed by TerraNova Energy and BiOPhree®, developed by Aquacare. A collection of support tools and how they were applied for each of these cases is presented in the following sections.

Disclaimer: As these eco-technologies are in ongoing development, some of the results obtained throughout BONUS RETURN are confidential and thus cannot be disclosed in the results sections of the case descriptions. Publication of this information could potentially cause harm and impair the further development of the eco-technologies.

9.1 Tool 12: Market surveys

A market survey can be an appropriate tool for assistance in early pre-commercial efforts. A market survey can be designed to collect either quantitative or qualitative information where quantitative information could be obtained from multiple-choice questionnaires and qualitative information from questionnaires with more open-ended questions. A market survey was conducted for RAVITA – one of the winning innovators in the BONUS RETURN innovation competition, assisting in the early development process of eco-technology.

Tool applicability and expected outcome
Market surveys are a flexible measure that can be utilized in Phase 3 and Phase 4 of the Innovation Development Cycle (as described in section 5.1). For eco-technologies that are close to market introduction, a market survey can help prioritize company resources by identifying customers who are interested in the solution that the innovation provides, thereby leading to faster implementation while simultaneously reducing time and costs associated with broad communication and sales strategies. If the eco-technology instead is further away from market introduction, a market survey could guide and assist in the development of the product. By reaching out to potential customers, vital information can be collected regarding the market demands, and needs that are important for end-users can be determined. Information from potential customers can then be considered during development, leading to a more attractive product that is better suited for the need of the market. An additional positive effect of the market survey tool is the promotional aspect of reaching out to customers, as chances are that potential early adopters are not yet aware of the product in its early development

stages. A market survey can thus serve two objectives at once, the collection of valuable information from customer insights and interest as well as informing customers about the existence of a product they might benefit from once it is fully developed and ready for market introduction.

A market survey is conducted by identifying and seeking out potential customers or market segments where a product is thought to be of interest or importance. Identification of a target market segment can differ substantially and depending on the type of innovation, a market segment can either be well-defined or unknown (i.e. nutrient recycling from wastewater streams has a somewhat well-defined customer base). However, for completely novel eco-technologies, the target market segments will need to be identified prior to collecting information regarding demands and needs. In the context of BONUS RETURN, eco-technologies and innovators with the objective of increasing nutrient and carbon reuse from the wastewater and agricultural sectors might be highly interested in the market segments consisting of the wastewater treatment sector, the agricultural sector, the fertilizer producers and the waste management sector.

General steps: Conducting a market survey

The general process of conducting a market survey for emerging eco-technologies, applied in the context of achieving the objectives of BONUS RETURN can be done in the following steps:

- Decide what type of information the market survey should aim to uncover,
- Determine the nature of the market survey, qualitative or quantitative,
- Identify the target market segment(s) of the survey,
- In accordance with the survey client define the principal objective of the survey,
- In accordance with the survey client, develop a questionnaire composed of multiple-choice questions (quantitative) or open-ended questions (qualitative) or a combination of both,
- Prepare informative material regarding the eco-technology,
- Contact participants representative of the targeted market segment(s),
- Present or share the information material with participants of the market survey,
- Interview or have the participants fill out the market survey questionnaire,
- Transcribe interview answers and/or collect questionnaire answers from participants,
- Analyse the data for possible trends and common needs or demands,
- Compile the results of the market survey.

Important notations

It is important to note that extra emphasis needs to be put on the respondent's in the survey. Are the respondent's representative of the target market segment and are they the ones best suited to deliver accurate information and useful feedback? Do they possess the necessary knowledge and know-how about the issue that the product aims to solve? The respondents understanding of the product is also an important factor, especially when the survey is used as a tool to facilitate technology development. If the technology in question is an emerging technology that does not currently exist on the market it is important to provide the respondents with sufficient information to ensure insightful answers.

Market survey tool: case RAVITA

HSY expressed a need for assistance in bringing their RAVITA-process closer to the market, via efforts towards increasing the RL of the innovation as well as meeting possible implementers and investors. In order to meet the needs communicated by HSY, BONUS RETURN provided support by conducting a qualitative market survey. The target market segment of the survey consisted of wastewater utilities and no additional identification of new market segments was deemed necessary.

About RAVITA

The RAVITA process is an eco-technology that is in ongoing development by HSY in Helsinki, Finland. The process is intended for use in the wastewater treatment sector with the purpose of recovering phosphorus from the phosphorus rich chemical sludge that is produced in a post-precipitation steps at the wastewater treatment plant (WWTP). The eco-technology is in the later stages of development and active testing is currently being conducted in a pilot plant setup at the Viikinmäki WWTP in Helsinki, Finland. The eco-technology is currently at RL 5/6 and further efforts are required to increase the RL of the innovation to bring it closer to the market and commercial-grade operational standards.

The RAVITA process recovers phosphorus in the form of phosphoric acid at rates of 55-63% of the influent phosphorus levels (HSY, 2018). The process is conducted in two separate steps, first a phosphorus rich chemical sludge is produced through the addition of precipitation agents (which is common practise at most municipal WWTPs) and separated from the wastewater stream in a precipitation step *after* the wastewater has been biologically treated. The separated chemical sludge is then collected and processed to obtain the final product which is phosphoric acid (HSY, 2018). The phosphoric acid can be utilized as raw material for fertilizer production (amongst other uses) and thus offers the possibility of supporting efforts for closing the loop on phosphorus. Current development efforts are primarily directed towards chemical sludge- and phosphoric acid production. However, intentions are to further develop the RAVITA process to include additional processes to generate ammonium phosphate (a mineral fertilizer) and reuse the carbon in the sludge, ultimately resulting in a more holistic solution.

BONUS RETURN support process

The support process was divided into three phases, an initial phase, an action phase and an analysis phase. During the initial phase the principal objective of the survey, which was to obtain information regarding market interests, market needs and the conditions necessary for the implementation of the RAVITA process by other wastewater utilities, was determined. In cooperation with HSY a market survey questionnaire was designed for the current needs of the RAVITA process. The questionnaire was drafted and acted as a basis for all interviews conducted in the market survey and can be found as an illustrative example in Appendix D.

The action phase of the survey consisted of planning and conducting interviews with organisations in the wastewater treatment sector. In order to obtain relevant information, individuals acting within the decision-making level (related to phosphorus recovery issues) at each organisation where asked to take part. The agenda for each interview was comprised of two parts, an introduction to the RAVITA eco-technology followed by answering of the questionnaire. The conducted interviews were recorded and later transcribed for the purpose of data collection and subsequent analysis.

The analysis phase was carried out by compiling the transcribed data and analysing it. The analysis generated insights on the demands and needs of the market as well as necessary features for possible future implementation of the RAVITA process. Additional supplementary information regarding the wastewater treatment plants partaking in the market survey was collected through publicly available environmental reports for each WWTP. The information compiled throughout the survey was delivered as a comprehensive report to HSY.

Results

The market survey that was conducted for HSY resulted in the collection of information that can be applied towards further development efforts of the RAVITA process in order to bring the process closer to market introduction and more in line with the needs of the market. The market (nine WWTPs in

Sweden, equal to approx. 3 000 000 pe connected in total) expressed an interest in the solution and the provided benefits such as phosphorus recovery, chemical precipitant recovery and increased flexibility in sludge disposal options. However, the respondents also expressed that as prerequisite, regulations regarding mandatory phosphorus recovery or a ban on the spreading of sewage sludge would need to be implemented for the RAVITA process to be attractive. Additionally, the survey showed that the market expressed a need for certain features (e.g. automation, robustness and good working environment) and real operational data in order to increase the attractiveness of the process. Moreover, the survey had the supplementary effect of promoting the existence and applicability of the RAVITA process in the wastewater sector. The final outcome of the survey is yet to be known and will be determined by further commercialisation efforts by HSY.

9.2 Tool 13: Independent comparative analysis

A comparative analysis conducted by an independent third party can be applied as a tool to support pre-commercialization of emerging technologies. Comparative analysis can be used to compare emerging technologies with ones that are already established on the market and serve the purpose of determining whether the performance of the emerging technology is comparable to already commercially available alternatives. An independent comparative analysis was conducted for TerraNova Energy by BONUS RETURN, to support the development of their TerraNova Ultra® technology by increasing the knowledge about the technology's ability to meet market demands.

Tool applicability and expected outcome

Comparative analysis is applicable for supporting late-stage pre-commercial efforts. For the tool to be highly applicable the RL of the eco-technology should be in the later stages of Phase 4 in the Innovation Development Cycle, and at least at RL 7a (as described in section 5.1). A high RL is a prerequisite for a comparative analysis as large amounts of process data (e.g. treatment efficiency, energy balances and mass balances) is necessary for meaningful comparisons to other technologies. The type of process data that is needed will depend on which characteristics are included in the analysis as well as the intricacies of the eco-technology and its external inputs (e.g. wastes, products and emissions). With a high RL, the eco-technology should have been thoroughly tested in an operational environment and operational data should have been collected. In the context of eco-technologies for the reuse of nutrients and carbon, the technologies can be complex multi-step chemical processes. Important operational metrics for possible adopters of such processes can include energy and chemical demand, capital and operational costs, expected maintenance demand, operational up-time and different yields (e.g. phosphorus recovery yield).

A comparative analysis is conducted by identifying a set of technologies capable of achieving the same predetermined function(s) (e.g. recover phosphorus from sewage sludge). The technologies are then analysed in relation to the same set of system boundaries (e.g. streams entering and exiting the processing plant). The analysis is conducted by means of studying comprehensive operational data obtained from the included technologies allowing the technologies to be compared in terms of different operational metrics such as energy and chemical consumption, process availability, throughput, waste generation, greenhouse gas emissions, operational expenditures and capital costs.

The results of an independent comparative analysis can be beneficial for eco-technology innovators as well as decision-makers and stakeholders. Innovators are benefited by having their technology assessed by an independent actor, demonstrating the possibilities of the technology in comparison to other commercial alternatives. Decision-makers and stakeholders are benefited through impartially reported information and evaluations of the efficacy of the products in the comparison, which can facilitate a selection process and aid decision-makers in creating an increased understanding of the strengths and weaknesses of different eco-technologies that could be suitable for their use-cases.

General steps: Conducting an independent comparative analysis

Comparative analysis can be conducted in multiple ways but a general process for comparing emerging eco-technologies, applied in the context of achieving the objectives of BONUS RETURN WP5 can be described with the following steps:

- Formulate requirements sought to be achieved by the compared eco-technologies,
- Establish system boundaries for the analysis,
- Determine delimitations for the analysis (what should and should not be detailed),
- Identify aspects to be analysed,
- Establish a functional unit for the basis of comparison (energy, material, emissions, etc.),
- Limit the analysis by deciding a maximum number of technologies to include,
- Identify technologies with the possibility of fulfilling the predetermined set of requirements,
- Gather operational data from identified technologies (pilot plant or full-scale if available),
- Evaluate the possibility of conducting the analysis in agreement with the predetermined scope (system boundaries and areas of comparison), based on available operational data,
- Thoroughly research the processes of the identified eco-technologies,
- Analyse the available data for each eco-technology,
- Derive material- and energy balances (if applicable) for the included eco-technologies,
- Compile the findings for all eco-technologies,

Important notations

It is important to note that the availability (or lack thereof) of operational data for different technologies can have a large impact on the outcome of a comparative analysis. In order to successfully compare and assess multiple advanced technologies, a sufficient amount of data regarding the comparative aspects must be available to conduct the analysis, either through publicly available documentation or to be willingly supplied by the manufacturers. This is especially significant when investigating phosphorus extraction from materials since they, more often than not, involve multi-step chemical processing.

Independent comparative analysis: Case TerraNova

TerraNova expressed a need for assistance in bringing their eco-technology closer to the market via efforts towards increasing the RL of the technology as well as a need for meeting possible clients and investors. To realize the needs of TerraNova, BONUS RETURN offered support by performing an independent comparative analysis. The analysis included two technologies, the TerraNova® Ultra process and sewage sludge mono-incineration with chemical phosphorus extraction from the ash.

About TerraNova

TerraNova® Ultra is an eco-technology developed by the SME TerraNova Energy in Düsseldorf, Germany. The eco-technology is intended for use in the wastewater treatment sector with the purpose of recovering carbon and phosphorus from sewage sludge. The technology is a finished product and is currently at RL 8, although further development and optimization is still ongoing in the recovery of phosphorus. The eco-technology consists of two integrated systems, one for sewage sludge processing and another for phosphorus recovery. A full-scale plant with the technology, without phosphorus recovery, has been in operation in Jining, China since December 2016 where the processed sewage sludge is utilized for energy recovery purposes. Additionally, a pilot-scale plant with the process, conducting both sewage sludge processing and phosphorus recovery, is currently in operation in Germany. The TerraNova® Ultra process is now in a phase where partners are needed to introduce the technology on the market where it can offer wastewater utilities the possibility of supporting efforts towards closing the loop on phosphorus.

The TerraNova Ultra® process has the functionality of processing sewage sludge originating from wastewater treatment into a renewable fuel (sewage sludge hydrochar) while simultaneously recovering 60-80% of phosphorus contained in the sewage sludge in the form of a solid phosphorus fertilizer consisting of hydroxyapatite and struvite (TerraNova Energy, 2018a; TerraNova Energy, 2018b). The process is conducted in two steps, the sewage sludge is first thermally treated through hydrothermal carbonization resulting in a coal like solid (sewage sludge hydrochar) which is then further subjected to chemical processing to enable the extraction of phosphorus.

BONUS RETURN support process

The independent comparative analysis involving TerraNova® Ultra, and sewage sludge mono-incineration was divided into two phases consisting of an initial phase and an execution phase. Sewage sludge mono-incineration with phosphorus recovery was included in the comparative analysis. This alternative was chosen due to a combination of two factors: (1) sewage sludge mono-incineration is widely conducted in Germany, and (2) that the data deemed necessary for a satisfactory analysis was readily available.

The initial phase of the comparative analysis consisted of data collection and research related to both processes. Comprehensive process datasets were needed in order to accurately compare both technologies in terms of performance. Furthermore, based on the available data, system boundaries and comparison metrics were decided for the comparative analysis. The principal objective of the analysis was to illustrate the differences (and similarities) of the technologies in terms of process metrics such as chemical demand, waste streams, energy demand and phosphorus extraction yield.

The execution phase was conducted in two discrete steps, firstly the eco-technologies were described in detail, secondly the performance of each eco-technologies was presented via material- and energy balances. In order to allow decision-makers (the targeted end-users of the analysis) to comprehend the mechanisms of the technologies, both processes were described in detail with supplementary theoretical information. With the combination of information regarding the processes and their performance, a detailed case was constructed describing the advantages of each technology.

Results

The comparative analysis resulted in an independent assessment of the TerraNova® Ultra technology compared against an already commercialised process. The analysis revealed strengths and weaknesses with both technologies, for instance that the TerraNova® Ultra process yield far less waste streams in comparison with sewage sludge mono-incineration and that sewage sludge mono-incineration had a better energy balance compared to the TerraNova® Ultra process. The metric that the analysis was structured around, phosphorus recovery, showed that mono-incineration could achieve a higher recovery rate (95% for mono-incineration and 80% TerraNova® Ultra) but at a higher expense. Other aspects were also illustrated, for instance the number of processing steps included in the processes, where it could be seen that TerraNova® Ultra exhibited a less complicated treatment scheme.

Going forward the comparative analysis can be utilized by TerraNova in their ongoing development efforts and as a tool to inform decision-makers about the TerraNova Ultra® process and the advantages it provides compared to a solution that is already available on the market. Since the comparative analysis was carried out by an independent third party, the analysis has increased impartiality in its reporting thus increasing the confidence of the report in the view of potential readers.

9.3 Tool 14: Independent testbed trials

Independent testbed trials performed by a third party can be a useful development tool suitable for supporting emerging eco-technologies. Testbed trials are used to test and evaluate working prototypes or pilot configurations of technologies in real operational environments, serving the purpose of assessing performance and identifying needs for additional development. Independent testbed trials were conducted for Aquacare during BONUS RETURN, supporting the development of the technology through comprehensive testing.

Tool applicability and expected outcome

A testbed can in the most general sense be regarded as a physical or virtual environment in which companies, academia and other organisations can collaborate in the development, testing and introduction of new products, services, processes or organisational solutions. Testbeds should be open to users outside the specific organisation that own or operate the testbed and they should be available for use for extended periods of time by a variety of different actors. Testbeds can involve almost any environment but is generally divided into three types, laboratory, simulated environment and real environment. Laboratory and simulated environments are mostly used by academia, institutes and industry, while the real environment largely involves private sector companies. Testbeds are vital components of the innovation ecosystem and involve everything from equipment and machinery to policy labs, virtual and investigative environments (Vinnova, 2018; RISE, 2019).

When pre-commercial eco-technology is evaluated through independent testbed trials, the testing can yield important insights regarding the viability of the technology in its current state where the collected information from the operations can be used to facilitate development by identifying strengths and weaknesses of the technology. By evaluating eco-technologies in real environment testbeds, it is possible to gather insights that could otherwise be difficult or expensive to obtain through other methods. Testbeds operated by a third party can be of special interest to SMEs who might lack the necessary financial resources to set up and run their own test sites or testing infrastructure. For eco-technology developers, two of the main benefits of using independent testbed trials are decreased research and development costs and decreased time from idea to market introduction.

Testbeds can be set up by municipalities or regional governments to promote and support local and regional innovation, or to create arenas in which solution providers, with products that are not yet on the market, can test their solutions on real problems enabling development in conjunction with need owners in the area. Testbeds can be utilized directly by innovators to test their products or through third parties (e.g. certification companies or agencies) for independent testing, eliminating potential biases inherent with commercial interests in a product. Independent testing serves a variety of purposes, some of which can include:

- Demonstrating proof-of-concept for new innovative solutions,
- Providing data for scientific, engineering, and quality assurance purposes,
- Help with identifying and solving problems with current product design/prototype,
- Providing technical means for the comparison of similar products or solutions,
- Verification that different requirements (technical and/or legal) or regulations are met,
- Validation of product function and suitability for end-use on the market.

For independent trials conducted by a third party, necessary experiments and tests should be identified and determined collaboratively with the eco-technology developer, ensuring that the technology is evaluated in accordance with the current needs of the product. Testbed trials can be expected to add value and push development, effectively increasing the RL of the eco-technology no matter what stage of development the eco-technology is in prior to the trials. This information is useful for further development and can be obtained through active testing.

General steps: Setting up and conducting independent testbed trials

Testbeds can come in many shapes and sizes depending on the needs of the technologies that are intended to be tested in the testbed. For the purpose of setting up and operating testbed trials for eco-technologies that recover nutrients and carbon from wastewater and agricultural waste streams important steps include, but are not limited to:

- Acquire information regarding the eco-technology from the developer,
- Determine the testing needs of the eco-technology in accordance with the developer,
- Establish the objective and the timespan of the testbed trials,
- Determine a business/cost sharing model for the testbed trials,
- Based on the testing needs and objective, formulate a test strategy,
- Locate an appropriate site for the testbed with suitable conditions and access to the necessary input/feed streams,
- Determine appropriate testbed placement with access to necessary infrastructure,
- Develop standardised work routines and protocols for measurements and analysis,
- Perform a risk assessment regarding any liabilities in operating the testbed,
- Ensure that available staff possess the necessary knowledge and experience to successfully install the technology and operate the testbed,
- Acquire the necessary laboratory equipment for measurements and analysis or find external laboratories that can conduct the analyses,
- Ensure access to safety equipment and personal protective equipment,
- Ensure access to tools and a supply of critical spare parts in case of breakdowns,
- Set up access to necessary input/feed streams,
- According to the work routines and protocols, collect measurements and analysis data,
- Following the testing period, compile collected data and observations gathered throughout the testbed trials,
- Communicate the compiled information and results to involved stakeholders,

Important notations

When conducting testbed trials in a real operational environment there are some details that need to be taken into extra consideration. In order to gain as much information as possible, it is important to develop a sound strategy for the trials. Testbed trials are usually conducted with eco-technologies at prototype or pilot plant stage and the operation of these can often include unforeseen complications. Therefore, it is crucial that the operating staff have enough time, experience and resources to solve any complications (e.g. faulty or broken equipment, shutdowns and maintenance). A low technological maturity level of emerging technologies (prototype or pilot plant) can also lead to problems associated with the climate (heat, cold, rain, snow etc). This is especially true when technologies are developed and tested in different climate zones where different basic features are needed. It is therefore important to make sure that included equipment can function under the conditions that are present at the testbed site, and if not, that necessary modification can be made to better suit the local climate.

Independent testbed trials: Case Aquacare

Aquacare expressed a need for assistance in their pre-commercial efforts in order to bring their eco-technology closer to the market. Explicitly, support was needed in the form of independent testing of their eco-technology and meeting relevant stakeholders who might be interested in procuring the finished product. BONUS RETURN provided support to Aquacare via independent testbed trials in a relevant operational environment, a prerequisite to reach RL 7.

About Aquacare

BiOPhree® is an eco-technology for phosphorus removal and recovery from liquid streams that is being developed by the water treatment and innovation SME Aquacare Europe B.V. based in Den Bosch, Netherlands. The BiOPhree®-technology was initially developed to eliminate microbiological growth in closed industrial water systems in order to avoid biofilm build-up that decrease process efficiencies. The technology is now being further developed and tested to enable treatment of additional water streams. The technology is currently at RL 6 and further development is being conducted in order to increase its the RL in order to bring the solution closer to market introduction.

The BiOPhree®-technology is built around phosphorus adsorption onto a proprietary adsorbent material and the process can be used to reach less than 10 µg TP/l in the treated stream. Once the adsorbents have been saturated, they can be regenerated by applying an alkaline solution which yields a phosphorus containing regeneration solution. The regeneration solution can then be further processed and re-used as a liquid phosphorus fertilizer. 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 as a possibility of restoring eutrophicated waterbodies (Aquacare, 2019).

BONUS RETURN support process

The support process was conducted in three phases: a preparatory phase, a testing phase and an analysis phase. During the preparatory phase, several wastewater utilities where contacted in order to find an appropriate location for the testbed. A suitable site was eventually identified at Knivsta WWTP, which was operated by the multi-municipal water utility Roslagsvatten in Knivsta, Sweden. The site enabled access to two different waters streams; partially treated wastewater from the WWTP, and surface water from the adjacent Knivsta river which allowed for the evaluation of the process with two fundamentally different inputs. The Knivsta WWTP process layout and its influent characteristics are representative of conditions that can be found throughout Sweden. An important aspect which makes the testbed conditions representative of many likely operational environments that the BiOPhree®-technology could be relevant for once the technology is mature enough to enter the market. Work conducted during the preparatory phase also included planning related to logistics, laboratory analysis and testbed operation as well as acquiring the necessary equipment to conduct the trials.

The testing phase consisted of installation and operation of a pilot plant. A 40-foot shipping container housing a BiOPhree® pilot plant was transported to Knivsta by Aquacare and installed at the testbed site by RISE staff. The pilot plant was connected to the WWTP and set-up to continuously treat a side-flow of the main-stream of biologically treated municipal wastewater that had not yet been subjected to chemical precipitation to remove phosphorus. After treating approximately 1000 m^3 of municipal wastewater the input stream was changed to surface water from the adjacent Knivsta river (into which arable farmland is drained) and set to treat another 1000 m^3 in order to test how well the technology worked with another more diluted input stream and at significantly lower temperatures. RISE staff conducted daily maintenance, process assessment, sampling and laboratory testing (e.g. phosphorus content, pH, turbidity, electrical conductivity and temperature at different stages of the process) during the winter period November 2019 to February 2020, during which the process and equipment were subjected to various stresses (e.g. washout from a hydraulically overloaded WWTP, flooding of storage tanks and several power outages).

The concluding analysis phase consisted of analysis and evaluation of data gathered throughout the testing phase. This included determining phosphorus mass balances, treatment efficiencies, process uptime and phosphorus recovery yield. The results and observations obtained during the testing and analysis phases were compiled in a technical report communicated to Aquacare, serving as valuable material applicable for further development activities.

Results

The testbed trials of the BiOPhree® technology resulted in the collection of operational data and information that will enable Aquacare to further develop and optimize their process, thus assisting the development of the technology and bringing the technology closer to market introduction. The testbed trials resulted in: (1) the collection of more data for scientific, engineering and quality assurance applications, (2) the identification of issues with the current design and proposals for solutions as well as needs for additional functionalities, and (3) validation of performance, functionality and suitability for the end-user market. Tangible results include that the process could achieve less than 10 µg TP/l in the treated effluent under many but not all operating conditions, and that the need for routine maintenance, at least at these testbed conditions, was significantly higher than originally stated by Aquacare in the supplied technical documentation.

10 CREATING INCENTIVES FOR ECO-TECHNOLOGIES

Every eco-technology is also part of a broader socio-technical system shaped by complex interactions between the existing actors, policies, norms and attitudes. These interactions and “softer” factors either promote or hinder technological development and ultimately define whether an innovation will be successful.

This toolbox describes tools that can be applied to increase the implementation of eco-technologies that reconcile the reduction of present and future eutrophication in marine environments with the regional challenges of policy coherence between food security, energy security, and the provision of ecosystem services. Looking at the needs for efficient eco-technologies that can create co-benefits in the BSR, it is evident that only procuring eco-technologies currently on the market is not enough. An important role for the procuring organization is to contribute to the demand for the next generation of solutions and innovative solutions close to market. This role includes a wider engagement in the development of the whole innovation system.

The next generation of eco-innovations, relevant for the Bonus Return context, are created under certain conditions. Eco-innovations are developed if there is an overlap between a strong demand among procuring organisations, a clear direction in policy and goals and an innovation system working to solve that demand within the scope of that policy and goals. This reasoning is further developed in the simple model in Figure 15 below. The model helps to visualize the conditions for eco-innovations and how different activities can help to widen the scope for market uptake of eco- technologies.

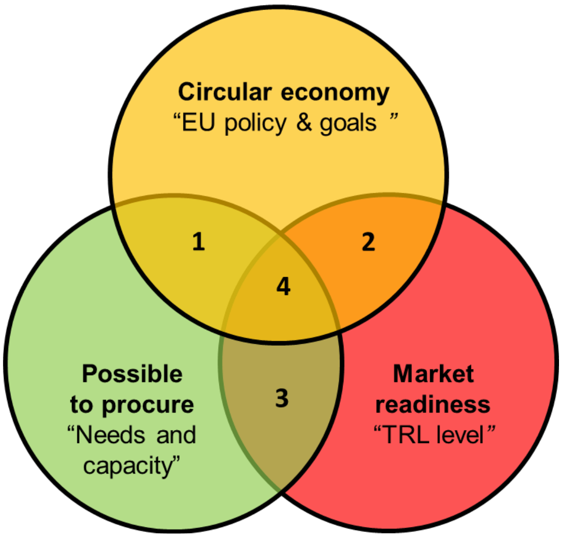

Figure 15: The scope of eco-technology market uptake. Model originally developed in the Horizon 2020 project PPI4Waste (Chacón et al., 2016).

The orange circle illustrates policy objectives and goals that reconcile the reduction of present and future eutrophication in marine environments with the regional challenges of policy coherence, food security, energy security, and the provision of ecosystem services. The circle includes the societal goals and the ambitions to reach them. The key players in this circle are the national and regional policy makers that are enforcing EU and regional policies in the BSR who are creating incentives and resources for the public to act as first customers, and the eco-innovators that create new solutions.

The green circle illustrates the parts of the needs of the procuring organizations that would be met by a procurement of solutions. Of course, the procuring organization must rightfully have the capacity to procure innovative solutions to that need. This includes defining a procurement scope that fits with the need and an innovative solution, a willingness to pay and a risk acceptance in order to define a real demand. There are several aspects of this capacity to find and procure innovative solutions including “customer readiness” and the possible leverage of buyer’s groups. The key player in this circle is the procuring organization with the capacity to act as the first customer to new solutions.

The red circle represents the market’s ability to meet the need with innovative solutions and the innovations system’s ability to deliver future solutions or innovations that are close to market introduction today. This circle represents the system’s ability to deliver solutions, especially in response to the buying process and the demand from a public organization. The key player in this circle is the eco-innovator delivering the solution to the first customer. However, the whole system supporting the innovator is of significance.

The model gives four overlapping areas describing different scenarios for the analysis of what types of actions are needed to support long term eco-innovations. The overlapping areas have been numbered Area 1 to Area 4:

Area 1: In this scenario the green and the orange circles overlap. There is a real need for solutions and that the procuring organisation has the capacity to express the need as a procurable demand for solutions. The demand for solutions have to be aligned with the policy and goals analysed. In BONUS RETURN the societal needs were analysed and policies and targets for the BSR were mapped into a comprehensive understanding of directions of the desired development. In the model the area where the societal need overlaps with the procuring organization’s needs, is labelled with the number (1). In this scenario there is not an overlap with the red circle. There is not a market readiness and the innovation system is not ready to deliver solutions in the short term. In Area 1 there cannot be a procurement of an innovative solution in the short term. A strategy in this scenario must be considered with regards to the market and innovation system’s readiness in order to find and support possible solutions close to the market.

Area 2: This area shows us the overlap between policy objectives, EU goals and challenges that the market and innovation system are committed to solve. However, this area is not obviously overlapping with the interest and engagement of the public procurement community. This can mean that the solutions are not possible to procure; the solutions could be too expensive; the solutions are ahead of the procurers or simply not aligned with procurers needs. In some areas the private company source and develop new solutions without assistance from the public sector. Industrial waste is relatively easy to control and to retain as much of the resources as possible to keep costs down as well as assuring high quality recycled materials. Investing in high quality recycling can be expensive and may not be competitive for household waste. Looking at solutions in this area and aligning the needs of the municipal or regional organization could lead to a successfully procured solution.

Area 3: In this area the market can deliver solutions to the needs of the procuring organization, but the needs and direction of development are not necessarily aligned with the EU circular economy challenges or national/regional policies. Procuring solutions in this scenario is following “business-as-usual” and is not promoting eco-innovations in line with, for example, the Bonus Returns goals. There is a risk that “business-as-usual”-solutions, even if they are good solutions, hide more innovative solutions with a higher potential for transformation into the circular economy. In order to reach the EU circular economy challenges, the solutions should be prioritized in accordance with the waste pyramid and the circular economy thinking.

Area 4: In this area all circles overlap and there is a possibility for market uptake of eco-innovations in line with the Bonus Return goals and ambitions. A successful procurement in this scenario makes sure the procuring organization is getting a solution that matches the needs, the innovator and market is getting the first customer for the solution and society gets a new solution aligned with the policy objectives.

Expanding the procurement scope (area 4)

The public organisation can support long term development of eco-innovations by proclaiming a coherent strategic need and expressing the purchasing power and conditions for a real demand for solutions to the need. The public organisation can also support the development of eco-innovations through policy making and as a part in the innovation system.

What if there are no procurable solutions in line with the policy objectives available? What if there is no overlap between the circles in the model and there is no Area 4? It is when Area 4 is hard to find that the overall strategic work and long-term thinking becomes important. This section is about the need for a long-term comprehensive strategy to facilitate more innovative solutions in the BSR. This is not really a tool but rather a suggestion for how to build a strategy based on the many tools in this toolbox.

The model described in Figure 15 illustrates how to create a strategy for promoting the development of the next generation of eco-technologies. In the model it comes down to trying to widen the circles in the model or draw them closer. If there are technologies in line with the policy objectives in Area 2, the procurement capacity could be developed to move the green circle closer to create a greater Area 4 overlap. If there is a strong demand for a solution from the procuring organization in line with the policy objectives in Area 1, then energy should be directed towards the red circle and pulling the eco-technologies closer to the procuring needs. Actions to widen the circles or draw them closer will create a larger scope for the adaptation and adoption of eco-technologies in the BSR for maximum efficiency and increased co-benefits.

All the tools suggested in this toolbox can be used in developing a comprehensive long-term strategy. From the perspectives of the procurement, the first step is about defining the needs in line with the circular policy objectives and this can be handled by using Tool 3 and Tool 6. The next step is finding out what solutions are available to procure right away; this is determined by applying Tool 4 and Tool 5 (and further in depth in Tool 12 and 13). The first two steps define the situations where procurement directly could facilitate innovation of new eco-technologies.

If the situation fits with Area 1, the ambition should be to try to move or expand the red circle to move the market and innovators closer in order to meet the demand of the procuring organisation. In order to expand the red circle and develop the direction of search and move technology closer to market, Tool 9, Tool 11 and Tool 14 are useful tools to apply.

If there are eco-technologies close to the market in line with the policy objectives, but the procurement organisations do not have the capacity to express their needs as a demand for solutions the situation could be described as being in Area 2 of the model. In this situation there is a need to expand the green circle and increase the procurement capacity. There could be a lack of knowledge of the possible solutions or lack of capacity to handle risks, new business models, behavioural changes or the implementation. In order to widen the green circle, there is a need for capacity building in circular procurement as described in Tool 8. In order to enlarge the orange circle and move towards a circular economy there is also a need to influence policy makers and policy making. This will help widen Area 4 and impact the development of the procurement capacity and the market readiness.

Longer term support of the innovation system

Each procurement by a first customer introduces RL 8-9 technologies to the market which lowers the threshold for other early adopters and gives the eco-innovator the chance to buy and scale up that technology on the market. This means that each new procurement of the technology drives additional development and helps innovators understand future needs and the necessary direction of development. Every technology is also part of a broader socio-technical system shaped by complex interactions between the existing actors, policies, norms and attitudes. These interactions and "softer" factors either promote or hinder technological development and ultimately define whether or not an innovation will be successful. To facilitate this development, actors can use a Technological Innovation Systems (TIS) approach, as illustrated in Figure 16, to build long term strategy and collaboration.

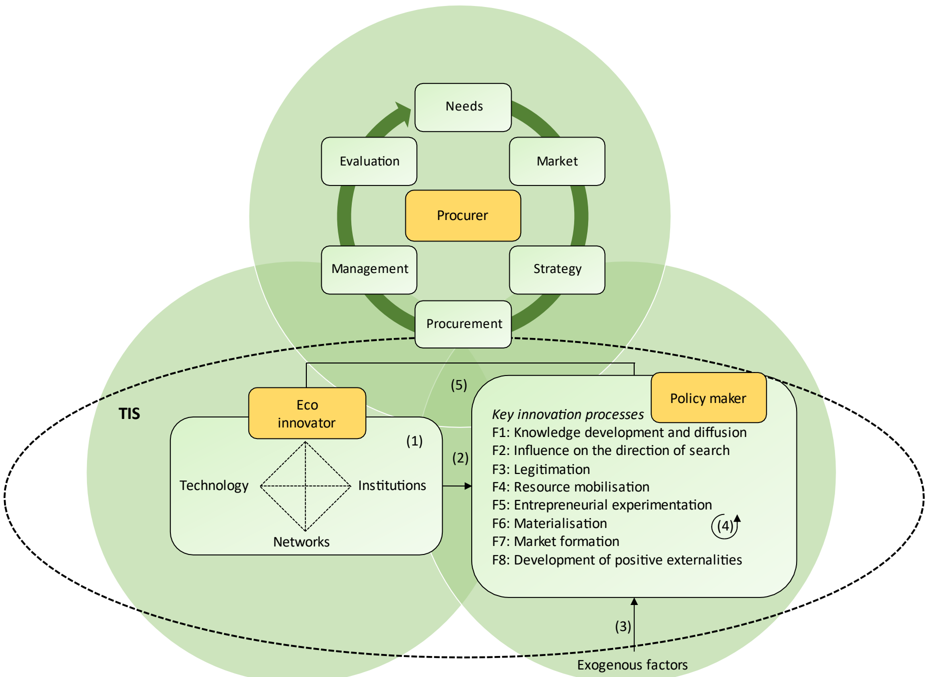

Figure 16: Procurement in relation to the Technology Innovation System (TIS). The model was first developed in the Ecopol project, adapted from Norefjäll (2019c).

To understand and influence this development, actors can use a Technological Innovation Systems (TIS) approach to build long term strategy and collaboration. In the TIS analysis the system components to analyse are called "structures". These structures are Actors, Institutions, Technology and Networks and they represent the static aspects of the system, as they are relatively stable over time.

Definitions in Technological Innovation Systems
According to Hekkert et al. (2011): "*The structure of the innovation system consists of innovation system components. We distinguish between four types of components:*

1. Actors: Actors involve organizations contributing to a technology, as a developer or adopter, or indirectly as a regulator, financer, etc. It is the actors of a Technological Innovation System that, through choices and actions, actually generate, diffuse and utilize technologies. The potential variety of relevant actors is enormous, ranging from private actors to public actors, and from technology developers to technology adopters. The development of a Technological Innovation System will depend on the interrelations between all these actors. We distinguish between the following actors categories:

a. Knowledge institutes
b. Educational organizations
c. Industry
d. Market actors
e. Government bodies and Supportive organizations

2. Institutions: Institutional structures are at the core of the innovation system concept. It is common to consider institutions as 'the rules of the game in a society, or, more formally as the humanly devised constraints that shape human interaction. A distinction can be made between formal institutions and informal institutions, with formal institutions being the rules that are codified and enforced by some authority, and informal institutions being more tacit and organically shaped by the collective interaction of actors. Even though informal institutions have a strong influence on the speed and direction of innovation, they are impossible to map systematically. Therefore, in the mapping of the innovation system structure, we focus on the formal policies that are in place that are likely to affect the development of the focal technology.

3. Networks: The central idea of the innovation system framework is that actors function in networks. In the case of networks it is interesting to map the geographical focus of the networks. Do the networks have a localized or globalized character?

4. Technological factors: Technological structures consist of artifacts and the technological infrastructures in which they are integrated."

The forces developing and creating direction for the innovation system are called "functions" and an overview is presented in **Fel! Ogiltig självreferens i bokmärke.**. The core concept of the functions (sometimes called processes) was developed in Technology Innovations Systems (TIS) research (Bergek et al., 2008a; Hekkert et al., 2007; Jacobsson and Bergek, 2006). The descriptions of the functions are continuously evolving (Bergek et al., 2008b; Dewald and Truffer, 2012) and the functions can change depending on the subject of the study (Perez Vico et al 2014, Planko et al 2017). A commonly used description of the functions and a manual for analysis is found in Hekkert et al (2011).

Table 5: Overview of System Functions, indicators and diagnostic questions for analysing the functions of the Innovation System Functions. Table adapted from Hekkert et al. (2011).

Functions and indicators	Diagnostic questions
F1 - Entrepreneurial Experimentation and production - Actors present in industry (from structural analysis)	- Are these the most relevant actors? - Are there sufficient industrial actors in the innovation system? - Do the industrial actors innovate sufficiently? - Do the industrial actors focus sufficiently on large scale production? - Does the experimentation and production by entrepreneurs form a barrier for the Innovation System to move to the next phase?
F2 - Knowledge Development - Number of patents and publications (from structural analysis)	- Is the amount of knowledge development sufficient for the development of the innovation system? - Is the quality of knowledge development sufficient for the development of the innovation system? - Does the type of knowledge developed fit with the knowledge needs within the innovation system? - Does the quality and/or quantity of knowledge development form a barrier for the TIS to move to the next phase?
F3 - Knowledge exchange - Type and number of networks	- Is there enough knowledge exchange between science and industry? - Is there enough knowledge exchange between users and industry? - Is there enough knowledge exchange across geographical borders? - Are there problematic parts of the innovation system in terms of knowledge exchange? - Is knowledge exchange forming a barrier for the IS to move to the next phase?
F4 - Guidance of the Search - Regulations, Visions, Expectations of Government and key actors	- Is there a clear vison on how the industry and market should develop? • in terms of growth? • in terms of technical design? - What are the expectations regarding the technological field? - Are there clear policy goals regarding this technological field? – Are these goals reliable? - Are the visions and expectations of actors involved sufficiently aligned to reduce uncertainties? - Does this (lack of) shared vision block development of the TIS?
F5 - Market Formation - Project installed (e.g. wind parks planned, site allocation and constructed)	- Is the current and expected future market size sufficient? - Does market size form a barrier for the development of the innovation system?
F6 - Resource Mobilization - Physical resources (infrastructure, material etc) - Human resources (skilled labour) - Financial resources (investments, venture capital, subsidies etc)	- Are there sufficient human and financial resources? • If not, does that form a barrier? - Are there expected physical resource constraints that may hamper technology diffusion? - Is the physical infrastructure developed well enough to support the diffusion of technology?
F7 - Counteract resistance to change/legitimacy creation - Length of projects from application to installation to production	- What is the average length of a project? - Is there a lot of resistance towards the new technology, set up of projects/permit procedure? • If yes, does it form a barrier?

10.1 Tool 15: TIS light workshop

TIS light (Technological Innovation Systems light) provides a platform for discussing the state of an innovation system for a technology, product group, value chain or urban area. In doing so, it helps create a common understanding and broaden the perspectives of the participants. This is a process that widens the scope for uptake of eco-technologies by expanding the red circle in Figure 15 and also drawing the three circles closer together. Unlike full-scale TIS, which traces the development of the system over time and prioritizes information collection and analysis, a TIS light provides a snapshot of the current state of the system and places the emphasis on the interaction between stakeholders. The tool revolves around answering the following three questions, with room for adjustment:

1. What are the elements of the system? Mapping the system structure – identifying the actors, networks, institutions and technologies that form part of the innovation system, as well as structural barriers and drivers for the development
2. How do the elements interact? Exploring the system dynamics – evaluating how well the system functions with regards to a set of critical processes borrowed from innovation research
3. What can be done to improve the system? Developing policy and governance recommendations to improve the functioning of the innovation system - on a local, regional or national level

At the core of the tool is a highly interactive workshop, where the participants, guided by facilitators, untangle the complexity behind the system. The preparatory phase includes scoping and desk research, where facilitators and the client decide on the appropriate scope for the analysis and make the necessary adjustments to the structure to accommodate for the specifics of the topic. At the end, a report is produced that synthesizes the learnings.

The workshop participants get the chance to exchange their knowledge on different parts of the innovation system, look at a familiar topic from a new angle, broaden their perspectives, break the silos and create a shared understanding of the way forward. While the workshop is the central deliverable, the accompanying solution-oriented report synthesizes the learnings of the main drivers and barriers and provides a set of tangible recommendations to improve the system, anchored in the information obtained through the workshop. The tool could be used in any situation where there is a technological development that needs to be explained or studied. It is particularly beneficial in situations where there is a broad range of actors with different interests and opinions, a lack of collaboration channels and/or a common understanding. The method is based on TIS analysis and has been further developed in the EU projects Fissac (Karltorp, 2018) and Ruggedised (RUGGEDISED, 2019), and in the Swedish “Feedstock recycling” project. It has been applied on a variety of topics from smart urban energy solutions to feedstock recycling and industrial symbiosis.

10.2 Tool 16: Policy planning for co-benefits

The co-benefits concept implies a ‘win–win’ strategy to address two or more goals with a single policy measure. The recognition of co-benefits opens a ‘window of opportunity’ for certain policy goals to be achieved as side effects of another goal that might be higher on the current political agenda. Based on the work by Mayrhofer and Gupta (2016), Table 6 summarizes three different ways of conceptualizing co-benefits in the climate change and environmental policy literature. This process of conceptualizing co-benefits widens the scope for market uptake of eco-technologies as shown earlier in this chapter. Conceptualizing co-benefits widens the orange circle of policy objectives in Figure 15 and directly opens the scope for market uptake. It also informs the functions shaping the Technological Innovation

System and indirectly shapes the policies and institutions creating incentives for the development of eco-technologies in line with the BSR challenges.

Table 6: Three different ways of conceptualizing co-benefits in the climate change and environmental policy literature (Mayrhofer and Gupta, 2016).

Approach	Definition
Development first	Conceptualizes co-benefits as the impact that development plans or sectoral policies might have on the environment.
Development co-benefits	Refers to co-benefits as primarily the local impacts that are the result of specific climate change and environmental policies. While policies thus have the primary goal of climate mitigation or adaptation, spill over effects on other policy goals such as employment or the improvement of public health are recognized
Co-impacts and co-benefits	Policy measures are a priori designed to achieve two goals simultaneously.

In each of these approaches, co-benefits are perceived as an opportunity to push a certain agenda—the specifics of the agenda make the difference between these three strands of usage. In the case of "development first" the main goal is to advance development while environmental or climate goals is only considered as secondary co-benefits. By contrast, in "development co-benefits" the main goal is the environment whilst secondary goals are sought for social development. In its third use, the question of primacy does not arise because goals are achieved even-handedly through an integrated approach and the 'window of opportunity' arises merely from the recognition of multiple benefits.

How "co-benefits" is approached, will determine the perspective taken when targeting "windows of political opportunity" which facilitate policy change. Windows of opportunity arise when simultaneously a problem is recognized, a solution is available, and the political climate is positive for change. Policy windows open occasionally and might not stay open very long. Thus, actors promoting a specific solution must act rapidly before the opportunity passes by (Kingdon and Stano, 1984).

Co-benefits are relevant not only for policy alignment, but also in economic terms. Co-benefits are said to diminish the costs of environmental impacts, like climate change, for society. Pearce and Barbier (2000) argue for instance, that policy evaluation should include cost–benefit analysis to justify policy action. Broadly speaking, scholars highlight that taking co-benefits into account shifts the focus from financial viability to include a larger number of policy options. Second, accounting for co-benefits decreases the costs of policy options from a political point of view because emphasizing co-benefits can increase the willingness to pay. Third, co-benefits can take the form of social benefits and hence legitimize governmental policy action to the wider public. This is, however, considered easier to achieve in less developed countries where infrastructural systems are less locked in than in industrialized countries, thus providing developing countries an opportunity to leapfrog (Mayrhofer and Gupta, 2016).

How to capture co-benefits in a circular economy?

Given the urgent need to reduce some environmental pressures, proactive policies are needed to accelerate the replacement of unsustainable products and practices with greener alternatives. Product and process innovations are technologically feasible to allow for improved resource efficiency and in turn decrease the amount of natural resources needed to produce the same unit of output. Despite this, efficiency has been quite modest, resulting in GDP growth globally having more than outweighed the efficiency gains (Jackson, 2016; Wiedmann et al., 2015). If economic development is to be sustainable, resource efficiency needs to increase at least at the same rate as economic output. Essentially, human well-being and economic progress need to be decoupled from non-renewable resource consumption and emissions (United Nations Environment Programme, 2011).

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. Circular economy models are being developed to minimize material and energy flows through industrial systems and make sure residuals of one production process are used as input for another (Ellen MacArthur Foundation, 2012). In terms of economic benefits, a circular economy could boost productivity, improve performance and reduce costs (Ellen MacArthur Foundation, 2015). A circular economy could help governments meet their climate targets; industries and food production systems could reduce their emissions; and at the same time, we could improve our resilience to the effects of climate change (Ellen MacArthur Foundation, 2019).

To accelerate progress and fully profit from the benefits and co-benefits from a circular economy, however, economic and policy incentives need to be set very differently than how they have been set up until today. Barquet et al. (2019) examined current policy instruments and governance structures in the BSR and how these affect the development, choice and implementation of circular innovations for phosphorus recycling. Based on their findings they argue that there is a need to increase policy steering towards phosphorus recycling and that there is a need for mainstreaming the idea of circular economy across society and local, national and supranational governance. Barquet et al. (2019) state that continuing efforts to simplify the legal framework for reused phosphorus products, particularly at the EU-level, is necessary to ensure wide-spread adoption of eco-technologies and that eco-technologies that ensure closed nutrient loops could be more actively implemented when municipalities and decisionmakers procure products and services from the private sector. Testbeds for innovations in municipalities should favour circular solutions with multiple benefits to society and reduced effects on the environment and that municipalities can create clearer guidelines and requirements that signal to innovators and entrepreneurs what type of solutions are necessary for the development of the municipality, while at the same time making it easier for the development of circular innovations to succeed. While Barquet et al. (2019) focused on phosphorus, the identified needs for policies are likewise relevant for re-circulation of other, oftentimes less prioritized, nutrients (e.g. N and K) as well as carbon. The journey towards a circular economy needs to be initiated by decisionmakers and sustainable policies and cannot be expected to come about purely through market-based forces.

Despite the many benefits from a circular economy, the analysis by Barquet et al. (2019) highlights that in order to attain the full range of co-benefits from a circular economy, additional action to close the loop is needed. A circular economy requires intervention in at least three areas: i) capacity development in technology and capabilities, ii) policy steering to foster circular practices and restrict linear models, and iii) market mechanisms and business models. This means, that creating a policy with one benefit in mind, will not automatically lead to attaining other co-benefits.

This is where industrial policy comes into play. Green industrial policy is important when markets do not reflect the full environmental costs of an investment or when market actors lack relevant information. Broadly speaking, industrial policy aims to reinforce or counteract the allocative effects of markets with the objective of restructuring economies towards a better societal outcome (Rodrik, 2004). This does not mean that industrial policy replaces the creative entrepreneurial process in a market-based economy. Rather, its purpose is to embed market productivity within broader social welfare processes to improve the outcomes for society at large.

11 CONCLUDING REMARKS

The principal objective of this deliverable has been to introduce a selection of support tools and methods, relevant for decision-makers, to aid the transition towards a circular economy by supporting the implementation of emerging eco-technologies. This toolbox has been framed to provide support in response to the challenges that decision-makers and local implementers in municipalities and regions can encounter when exploring the process of transitioning to a circular economy.

To successfully transition to a circular economy, it is necessary for both decision-makers and the general public to shift mindset when it comes to waste and by-products to enable efficient recovery of valuable resources in abundant waste streams. The development of circular solutions needs to be, at least partially, driven by a common agenda and a bottom up demand from end-users for increasingly sustainably produced products. Turning wastewater and agricultural by-products into suitable products will require cooperation in order to drive necessary technological development that results in eco-technologies that are economically feasible to invest in and to operate, that provide products with suitable properties, and that are socio-culturally accepted by the consumer who ends up willing to purchase the end-product. Social innovation approaches are increasingly advocated as they give stakeholders a voice and allows them to present their concerns and be part of the creative process. At the same time, involving stakeholders improves the identification of local problems, increases suggestions of feasible solutions, and increases the chances of acceptance and uptake of solutions. This is particularly of importance when implementing measures that introduce systemic changes in already firmly established structures.

In order to create real demand for a solution, the need must be met by policy and goals aligned with the need, a market or an innovation system in sync with that need and a procurement capacity of the procuring organisations. Given the urgent need to reduce pressure on the environment, proactive policies are needed to accelerate the replacement of unsustainable products and practices with greener alternatives. Product and process innovations are technologically feasible to improve resource efficiency and in turn decrease the amount of natural resources needed to produce the same unit of output. If economic development is to be sustainable, resource efficiency needs to increase at least at the same rate as economic output, fundamentally human well-being and economic progress need to be decoupled from non-renewable resource consumption and emissions.

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 the benefits and co-benefits from a circular economy, economic and policy incentives need to be set very differently than they do today. Continuing efforts to simplify the legal framework for reused phosphorus products, particularly at the EU-level, is necessary to ensure wide-spread adoption of eco-technologies. Eco-technologies that ensure closed nutrient loops could be more actively implemented when municipalities and decision makers procure products and services from the private sector.

12 REFERENCES

AHLSTRÖM, M., KÄRRMAN, E. & JOHANNESDOTTIR, S. 2019. Manual for Assessing Sustainability of Eco-technologies. (BONUS RETURN; Deliverable 3.4).

ALHOLA, K., SALMENPERÄ, H., RYDING, S. & BUSCH, N. J. 2017. *Circular Public Procurement in the Nordic Countries*, Nordic Council of Ministers.

AQUACARE. 2019. *Innovation in Phosphorus Removal* [Online]. Aquacare webbpage. Available: https://www.aquacare.nl/en/biophree-innovation-in-phosphorus-removal.html [Accessed 29 03 2020].

BARQUET, K. & CUMISKEY, L. 2018. Using participatory Multi-Criteria Assessments for assessing disaster risk reduction measures. *Coastal Engineering,* 134**,** 93-102.

BARQUET, K., JÄRNBERG, L. & MACURA, B. 2019. Report on Current Policy Instruments and Governance Structures in BSR. (BONUS RETURN; Deliverable 2.5).

BARQUET, K., OCHOLA, B. & LUNDH, M. 2018. Emerging Eco-technologies. (BONUS RETURN; Deliverable 3.7).

BERGEK, A., JACOBSSON, S., CARLSSON, B., et al., 2008a. Analyzing the functional dynamics of technological innovation systems: A scheme of analysis. Research Policy 37, 407–429.

BERGEK, A., JACOBSSON, S., SANDÉN, B., 2008b. 'Legitimation' and 'development of external economies': Two key processes in the formation phase of technological innovation systems. Technology Analysis & Strategic Management 20, 575–592.

CHACÓN, L. F., A., NOREFJÄLL, F., RIBIC, B., KRUHEK, M. & VALENZUELA, B. 2016. Roadmap for a Progressive Improvement. https://www.ppi4waste.eu/.

CIRCLE ECONOMY 2016. Master Circular Business with the Value Hill.

DEWALD, U & TRUFFER, B., 2012. The Local Sources of Market Formation: Explaining Regional Growth Differentials in German Photovoltaic Markets. European Planning Studies.

EAFIP. 2018. *eafip FAQ* [Online]. eafip webpage: European Commission. Available: https://eafip.eu/resources/faq/ [Accessed 27 02 2020].

EAFIP 2019. The eafip Toolkit: Module 2.

ELLEN MACARTHUR FOUNDATION. 2012. *Circular Economy Systems Diagram* [Online]. Ellen McArthur Foundation. Available: https://www.isb-global.com/wp-content/uploads/Ellen-McArthur-Foundation-Circular-Economy.jpg [Accessed 12 10 2019].

ELLEN MACARTHUR FOUNDATION. 2015. *Mapping the benefits of a circular economy* [Online]. Available: https://www.mckinsey.com/business-functions/sustainability/our-insights/mapping-the-benefits-of-a-circular-economy [Accessed 30 03 2020].

ELLEN MACARTHUR FOUNDATION. 2019. *Completing the Picture how the Circular Economy Tackles Climate Change* [Online]. Available: https://www.ellenmacarthurfoundation.org/assets/downloads/Completing_The_Picture_How_The_Circular_Economy-_Tackles_Climate_Change_V3_26_September.pdf [Accessed 30 03 2020].

ERIKSSON, A. 1998. Samverkansspiralen. Greppet - att Vända en Regions Utveckling. (SOU 1998:89).

EUROPEAN COMMISSION. 2019a. *Pre-Commercial Procurement* [Online]. Available: https://ec.europa.eu/digital-single-market/en/pre-commercial-procurement [Accessed 23 10 2019].

EUROPEAN COMMISSION. 2019b. *Public Procurement of Innovative Solutions* [Online]. Available: https://ec.europa.eu/digital-single-market/en/public-procurement-innovative-solutions [Accessed 23 10 2019].

HADDAWAY, N. R., MCCONVILLE, J. & PINIEWSKI, M. 2018a. How is the Term 'Ecotechnology' Used in the Research Literature? A Systematic Review With Thematic Synthesis. *Ecohydrology & Hydrobiology,* 18**,** 247-261.

HADDAWAY, N. R., PINIEWSKI, M. J., S., ANDERSSON, K. E., F. & KSIEZNIAK, M. O., P. KARCZMARCZYK, A. 2018b. Shortlist of Eco-technologies. (BONUS RETURN; Deliverable 2.2).
HEKKERT, M., SUURS, R, Negro, S., et al., 2007. Functions of innovation systems: A new approach for analysing technological change. *Technological Forecasting and Social Change* 74, 413–432
HEKKERT, M. & NEGRO, S., 2009. Functions of innovation systems as a framework to understand sustainable technological change: Empirical evidence for earlier claims. *Technological Forecasting and Social Change* 76, 584–594.
HEKKERT, M., NEGRO, S., HEIMERIKS, G. & HARMSEN, R. 2011. Technological Innovation System Analysis. A manual for analysts. Utrecht University.
HORIZON 2020. 2019. *Technology Readiness Levels* [Online]. European Commision. Available: https://ec.europa.eu/research/participants/data/ref/h2020/wp/2014_2015/annexes/h2020-wp1415-annex-g-trl_en.pdf [Accessed 23 10 2019].
HSY. 2018. *Phosphorus recovery in Finland Case RAVITA* [Online]. Available: https://bestbalticproject.eu/wp-content/uploads/2018/08/VILPANEN_Phosphorus-recovery-in-Finland-Case-RAVITA.pdf [Accessed 16 02 2020].
JACKSON, T. 2016. *Prosperity without growth: foundations for the economy of tomorrow*, Routledge.
JOHANNESDOTTIR, S., KÄRRMAN, E., LJUNG, E., ANDERZÉN, C., EDSTRÖM, M., AHLGREN, S. & ENGLUND, M. 2019. Report From the Multi-criteria Analysis. (BONUS RETURN; Deliverable 3.3).
KARLTORP, K. S., S. 2018. Report on Use of Adapted TIS Analysis in the FISSAC Project. FISSAC webbpage.
KINGDON, J. W. & STANO, E. 1984. *Agendas, alternatives, and public policies*, Little, Brown Boston.
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 Eco-technology Effectiveness. (BONUS RETURN; Deliverable 2.7).
MACURA, B., PINIEWSKI, M., JOHANNESDOTTIR, S. & MCCONVILLE, J. 2018. Systematic Map Report, Database and Interactive GIS. (BONUS RETURN; Deliveravle 2.3).
MAYRHOFER, J. P. & GUPTA, J. 2016. The science and politics of co-benefits in climate policy. *Environmental Science & Policy,* 57**,** 22-30.
MURRAY, R., CAULIER-GRICE, J. & MULGAN, G. 2010. *The open book of social innovation*, National endowment for science, technology and the art London.
NASA. *Technology Readiness Level Definitions* [Online]. Available: https://www.nasa.gov/pdf/458490main_TRL_Definitions.pdf [Accessed 22 10 2019].
NICHOLLS, A. & MURDOCK, A. 2011. *Social innovation: Blurring boundaries to reconfigure markets*, Springer.
NOREFJÄLL, F. 2019a. Barriers for Circular Procurement Development. Transition lab, RISE.
NOREFJÄLL, F. 2019b. The development of a new product. Transition lab, RISE.
NOREFJÄLL, F. 2019c. Procurement in Relation to the Technology Innovation System. Transition lab, RISE.
NOREFJÄLL, F. 2019d. Systematic View on Procurement and Innovation. Transition lab, RISE.
PEARCE, D. W. & BARBIER, E. 2000. *Blueprint for a sustainable economy*, Earthscan.
PEREZ VICO, E., JACOBSSON, S., HELLSMARK, H.,2014. The many ways of academic researchers: How is science made useful? *Science and Public Policy* (2014), p 1-17.
PLANKO, J., CHAPPIN, M. & CRAMER, J.M. & HEKKERT, M. (2017). Managing strategic system-building networks in emerging business fields: A case study of the Dutch smart grid sector. Industrial Marketing Management.
POWELL, N., OSBECK, M., LARSEN, R. K., ANDERSSON, K., SCHWARTZ, G. & DAVIS, M. 2013. *The Common Agricultural Policy Post-2013: Could Reforms Make Baltic Sea Region Farms More Sustainable? SEI and Baltic COMPASS Policy Brief.* [Online]. Stockholm Environmental

Institute webpage: Stockholm Environment Institute. Available: https://mediamanager.sei.org/documents/Publications/Air-land-water-resources/sei-bc-pb-2013-cap-reform.pdf [Accessed 24 02 2020].

PULLIN, A. S., FRAMPTON, G. K., LIVOREIL, B. & PETROKOFSKY, G. 2018. *Guidelines and Standards for Evidence Synthesis in Environmental Management, Version 5.0* [Online]. Collabortation for Environmental Evidence. Available: www.environmentalevidence.org/information-for-authors [Accessed 11 03 2020].

RISE. 2019. *Testbed Sweden* [Online]. Available: https://www.testbedsweden.se/en/?q&page=1&category=-1&area=-1&industry=-1&program=-1&region=-1&mode=list [Accessed 25 02 2020].

RODRIK, D. 2004. Industrial policy for the twenty-first century.

ROGERS, E. M. 2010. *Diffusion of innovations*, Simon and Schuster.

RUGGEDISED. 2019. *RUGGEDISED Project* [Online]. Available: https://ruggedised.eu/home/ [Accessed 26 03 2020].

SNYDER, H. 2019. Literature review as a research methodology: An overview and guidelines. *Journal of Business Research,* 104**,** 333-339.

STENBECK, S., KÄRRMAN, E. & NOREFJÄLL, F. 2019. Framework for facilitating pre-commercialization. (BONUS RETURN; Deliverable 5.1)

STENBECK, S. & QUISTGAARD, L. 2018. *The Innovation Developement Cycle* [Online]. Available: http://www.sustainnovaid.org/ [Accessed 19 09 2019].

SWEDISH AGENCY FOR HEALTH TECHNOLOGY ASSESSMENT AND ASSESSMENT OF SOCIAL SERVICES 2017. Utvärdering av metoder i hälso- och sjukvården och insatser i socialtjänsten.

SWEDISH MINISTRY FOR FOREIGN AFFAIRS 2019. Best Total Value. Sustainable Public Procurement for UN.

TERRANOVA ENERGY. 2018a. *Process flow TerraNova@ Ultra with integral Phosphorus-Recovery* [Online]. https://terranova-energy.com/en/: TerraNova Energy. Available: http://terranova-energy.com/pdf/TNEPrecoveryen.pdf [Accessed 21 02 2020].

TERRANOVA ENERGY. 2018b. *TerraNova® Ultra* [Online]. https://terranova-energy.com/en/. Available: https://terranova-energy.com/pdf/TNEkurz2017en.pdf [Accessed 20 02 2020].

TSANIDIS, V. 2016. *Innovation Procurement and H2020 support* [Online]. Available: http://www.kpk.gov.pl/wp-content/uploads/2016/04/Innovation_Procurement_H2020_support_Vassilis_Tsanidis_Warsaw_10_5_2016.pdf [Accessed 23 10 2019].

UNITED NATIONS ENVIRONMENT PROGRAMME 2011. *Decoupling natural resource use and environmental impacts from economic growth*, UNEP/Earthprint.

WIEDMANN, T. O., SCHANDL, H., LENZEN, M., MORAN, D., SUH, S., WEST, J. & KANEMOTO, K. 2015. The material footprint of nations. *Proceedings of the national academy of sciences,* 112**,** 6271-6276.

VINNOVA. 2018. *Testbed Sweden* [Online]. Available: https://www.vinnova.se/en/m/testbed-sweden/ [Accessed 25 02 2020].

VOORBERG, W. H., BEKKERS, V. J. J. M. & TUMMERS, L. G. 2015. A Systematic Review of Co-Creation and Co-Production: Embarking on the social innovation journey. *Public Management Review,* 17**,** 1333-1357.

13 APPENDIX A: STAKEHOLDER ENGAGEMENT WORKSHOP EXAMPLE

Format: 3 groups, 4-5 stakeholders in each. In each group a facilitator and a note taker.

10.45-12.15 Sustainability criteria for circulating innovations: which are important for Fyrisån?
Group exercise, facilitated by Erik Kärrman, RISE
Purpose: Stakeholder values and priorities to complement the sustainability criteria found in literature and get criteria that are adapted to the local context and reflects what is important to the stakeholders in the area

Methodology (groups and interests)

Introduction of sustainability assessment purpose, framework and process (10 min)

Individual stakeholder perspective on sustainability and criteria (10 min)

- Let each participant reflect for 5-10 min, in relation to their role, challenges and interest at the local level
- They are given an A4-sheet (Handout 1) with the question "**What sustainability criteria do you use in your profession?"** (side 1) on one side, on the other side "**What 5 sustainability criteria are most important?"** (side 2). This paper we want them to hand in after the exercise. If they are ok with writing their name on it, that's great. Otherwise, they can write their professional role (consultant, municipal, etc.)
- They write down reflections/answers/criteria on side 1. It is partly so that they start to think of the topic from their own perspective before the joint discussions, and partly because it is interesting for us to see how different stakeholders work with sustainability.

Group perspective on sustainability and criteria (4-5 persons) (40 min)

- Each group is given stack of post-it and a portable whiteboard. On this whiteboard, we have written the categories for criteria (environment, economy, health & hygiene, socio-cultural and technical function)
- The group shares their view on sustainability criteria and discusses. They write each criteria on a post-it and put it under fitting category. They are not allowed to put more than 20 criteria on the board, so they have to agree on the 20 most important ones
- After some time, maybe 15 min, the facilitator gives them an A4-paper (Handout 2) with the literature criteria. They can use it for inspiration and further reflection but it is up to them, it serves as an example of what criteria researchers use. They change/update their list if they want to.
- The result is 20 post-its, with one criteria on each, categorized in the pre-determined categories

Prioritization (10 min)

- Each stakeholder gets to choose the 5 most important criteria from the list of 20 criteria that they have put together. Preferably by writing a star or similar on the post-it of the criteria. They do not have to agree on this, or even discuss.
- Each stakeholder writes down the 5 criteria they chose on side 2 of their own sheet. This is because it is interesting for us to connect different stakeholders to their prioritized criteria.
- We collect their answers

<u>Reflection whole group</u> (10 min)
What did they think of the exercise? Are they satisfied with the list? Are their values reflected in the list?
Facilitator

Keep in mind:

- Individual stakeholder interest
- Group and local context interests (agriculture, wastewater and Rich picture)
- How dimensions and criteria can support identification/selection of eco-technology and multifunctional benefits
- The vision for circular economy (reduce and reuse perspective C/N/P)

12.15-13.00 Lunch

13.00-14.15 What circulating measures and technologies could be implemented in Fyrisån?
Group exercise, facilitated by Erik Kärrman, RISE
Purpose: Get stakeholder inputs on selection of technologies to assess in the multi-criteria assessment. This discussion is more "free".

Introducing a vision for circularity

Vision: "we have a circular economy, there are no eutrophying emissions because nutrients and carbon are recirculated". **How did we get there?** Which are the critical factors to getting there? To come to that vision, **do you know any tech that can address the vision**, that could overcome these critical factors?

Discussion about the vision for circularity

- Erik Kärrman, RISE introduces the vision – 5 min
- 5 min - each participant reflects on their own, what is their vision? Writes down notes if they want to.

<u>Group discussion</u> (same groups as before lunch) (45 min)

- We present the question "What critical factors are there for achieving this vision?" along with key-words that they can reflect upon in their discussion.
- They get a large sheet to write down their ideas, identified technologies, barriers, possibilities etc.

Facilitator can ask additional, more specific questions if needed:

- What technologies, practices or methods does the vision include and where are they implemented?
- What is required to get there?
- What role does you organization have in getting there?
- Which are the critical factors to come to that vision?
- What are the barriers to reach the vision?
- What are the possibilities?
- What areas/sectors are prioritized?
- What additional multifunctional benefits and values could appear?
- Do you know any tech that can address the vision?

<u>Reflection</u> whole group (15 min)

Handout 1
Side 1/2:

<u>What sustainability criteria do you use in your profession?</u>

Side 2/2:

What 5 sustainability criteria do you think are the most important?

Handout 2
Side 1/1:

Environment	Economy	Socio-cultural	Health and hygiene	Technical function
Climate effect	Life cycle costs	Acceptance	Work environment	Flexibility
Reuse of resources	Capital costs	Policy and legal issues	Health risks	Reliability
Emission of contaminants	Work demand	Promoting sustainable behaviour	Pathogens	Technical complexity
Biodiversity	Economic vulnerability	Cultural and aesthetic values	Toxic substances	Lifetime
Land use	Quality of products	Institutional requirements/capacity		Compatibility with existing infrastructure
Use of resources (energy, water)	Supporting local economy	Equity		Maintenance demand

14 APPENDIX B: SUSTAINABILITY CRITERIA USED IN WASTEWATER AND AGRICULTURE

A list of criteria previously compiled within BONUS RETURN by Johannesdottir et al. (2019) based on several studies for wastewater (Table B1) and agriculture (Table B2) applications is reprinted below.

Table B1. Sustainability criteria used in scientific literature to assess sustainability of wastewater systems

Criteria	Reference examples
Environment	
Water emissions	Hellström *et al.* (2000); Balkema *et al.* (2002); Diaper & Sharma (2007); Kalbar *et al.* (2012); Woltersdorf *et al.* (2018)
Air emissions	Hellström *et al.* (2000); Palme *et al.* (2005); Kalbar *et al.* (2012)
Impact on biodiversity and land fertility	Balkema *et al.* (2002)
Emissions to land	Hellström *et al.* (2000); Balkema *et al.* (2002); Palme *et al.* (2005); Diaper & Sharma (2007); Molinos-Senante *et al.* (2014); Woltersdorf *et al.* (2018)
Resource recovery	Balkema *et al.* (2002); Palme *et al.* (2005); Diaper & Sharma (2007); Molinos-Senante *et al.* (2014)
Use of energy/natural resources	Hellström *et al.* (2000); Balkema *et al.* (2002); Palme *et al.* (2005); Diaper & Sharma (2007); Molinos-Senante *et al.* (2014); Marques *et al.* (2015); Woltersdorf *et al.* (2018)
Land requirement	Balkema *et al.* (2002); Kalbar *et al.* (2012); Molinos-Senante *et al.* (2014)
Economic	
Total costs	Hellström *et al.* (2000); Balkema *et al.* (2002); Palme *et al.* (2005); Diaper & Sharma (2007); Kalbar *et al.* (2012)
Annual costs	Molinos-Senante *et al.* (2014); Woltersdorf *et al.* (2018)
Capital costs	Molinos-Senante *et al.* (2014); Marques *et al.* (2015); Woltersdorf *et al.* (2018)
Work demand	Hellström *et al.* (2000); Balkema *et al.* (2002); Diaper & Sharma (2007); Kalbar *et al.* (2012); Woltersdorf *et al.* (2018)
Social	
Acceptance	Hellström *et al.* (2000); Balkema *et al.* (2002); Palme *et al.* (2005); Diaper & Sharma (2007); Kalbar *et al.* (2012); Molinos-Senante *et al.* (2014); Marques *et al.* (2015); Woltersdorf *et al.* (2018)
Awareness and participation	Balkema *et al.* (2002); Kalbar *et al.* (2012); Marques *et al.* (2015)
Institutional requirements/capacity	Balkema *et al.* (2002); Marques *et al.* (2015); Woltersdorf *et al.* (2018)
Promoting sustainable behaviour	Kalbar *et al.* (2012)
Policy and legal issues	Marques *et al.* (2015); Woltersdorf *et al.* (2018)
Health	
Work environment	Hellström *et al.* (2000); Balkema *et al.* (2002); Palme *et al.* (2005)
Health risk	Hellström *et al.* (2000); Balkema *et al.* (2002); Palme *et al.* (2005); Diaper & Sharma (2007); Woltersdorf *et al.* (2018)
Technical	
Flexibility	Hellström *et al.* (2000); Balkema *et al.* (2002); Kalbar *et al.* (2012); Marques *et al.* (2015)
Reliability	Hellström *et al.* (2000); Balkema *et al.* (2002); Palme *et al.* (2005); Diaper & Sharma (2007); Kalbar *et al.* (2012); Molinos-Senante *et al.* (2014); Marques *et al.* (2015); Woltersdorf *et al.* (2018)
Robustness	Hellström *et al.* (2000); Balkema *et al.* (2002); Kalbar *et al.* (2012); Woltersdorf *et al.* (2018)
Lifetime	Balkema *et al.* (2002); Kalbar *et al.* (2012); Woltersdorf *et al.* (2018)
Compatibility with existing infrastructure	Diaper & Sharma (2007)

Table B2. Sustainability criteria used in scientific literature to assess sustainability of agricultural systems

Criteria	Reference
Environmental	
Fertiliser use	Carof *et al.* (2013); Latruffe *et al.* (2016)
Land use	Carof *et al.* (2013); FAO (2013); Latruffe *et al.* (2016)
Biodiversity	Carof *et al.* (2013); FAO (2013); Latruffe *et al.* (2016); Scharfy *et al.* (2017)
Resource use	Carof *et al.* (2013), Latruffe *et al.* (2016), FAO (2013)
Water use	Carof *et al.* (2013), Scharfy *et al.* (2017) / FAO (2013)
Air emissions	Latruffe *et al.* (2016), Scharfy *et al.* (2017), Carof *et al.* (2013), FAO (2013)
Soil effects	Latruffe *et al.* (2016), Scharfy *et al.* (2017), Carof *et al.* (2013)
Pesticides	Carof *et al.* (2013), Latruffe *et al.* (2016)
Water emissions	Scharfy *et al.* (2017), FAO (2013), Carof *et al.* (2013)
Animal welfare	FAO (2013)
Economic	
Productivity	Latruffe *et al.* (2016), Carof *et al.* (2013)
Subsidies	Carof *et al.* (2013), Latruffe *et al.* (2016)
Total costs	Carof *et al.* (2013), Scharfy *et al.* (2017)
Investment costs	Scharfy *et al.* (2017), FAO (2013)
Employment	Carof *et al.* (2013)
Product quality	FAO (2013)
Local economy	FAO (2013)
Amortization time	Scharfy *et al.* (2017)
Stability	FAO (2013), Latruffe *et al.* (2016)
Multifunctionality	Latruffe *et al.* (2016), Latruffe *et al.* (2016)
Quality of products	FAO (2013), Latruffe *et al.* (2016)
Social	
Livelihood	Latruffe *et al.* (2016), FAO (2013)
Acceptance	Latruffe *et al.* (2016), Scharfy *et al.* (2017)
Equity	Latruffe *et al.* (2016), FAO (2013)
Cultural and aesthetic values	Latruffe *et al.* (2016), FAO (2013)
Continuity	Scharfy *et al.* (2017), Latruffe *et al.* (2016)
Applicability	Scharfy *et al.* (2017)
Local economy	Latruffe *et al.* (2016)
Quality of products	Latruffe *et al.* (2016)
Uncertainties in crop cultivation	Carof *et al.* (2013)
Corporate ethics	FAO (2013)
Accountability	FAO (2013)
Participation	FAO (2013)
Rule of law	FAO (2013)
Holistic management	FAO (2013)
Health	
Health	Carof *et al.* (2013), FAO (2013)
Working conditions	Latruffe *et al.* (2016), FAO (2013), Scharfy *et al.* (2017)

References

Balkema, A.J., Preisig, H.A., Otterpohl, R. & Lambert, F.J.D. (2002). Indicators for the sustainability assessment of wastewater treatment systems. *Urban Water*, vol. 4 (2), ss. 153–161.

Carof, M., Colomb, B. & Aveline, A. (2013). A guide for choosing the most appropriate method for multi-criteria assessment of agricultural systems according to decision-makers' expectations. *Agricultural Systems*, vol. 115, ss. 51–62.

Diaper, C. & Sharma, A. (2007). Innovative sewerage solutions for small rural towns. *Water Science and Technology*. ss. 97–103.

FAO (2013). SAFA Sustainability Assessment of Food and Agriculture systems: Indicators. *Food and Agricultural Organization of the United Nations*.

Hellström, D., Jeppsson, U. & Kärrman, E. (2000). A framework for systems analysis of sustainable urban water management. *Environmental Impact Assessment Review*, vol. 20 (3), ss. 311–321.

Kalbar, P.P., Karmakar, S. & Asolekar, S.R. (2012). Selection of an appropriate wastewater treatment technology: A scenario-based multiple-attribute decision-making approach. *Journal of Environmental Management*, vol. 113, ss. 158–169.

Latruffe, L., Diazabakana, A., Bockstaller, C., Desjeux, Y., Finn, J., Kelly, E., Ryan, M. & Uthes, S. (2016). Measurement of sustainability in agriculture: a review of indicators. *Studies in Agricultural Economics*, vol. 118 (3), ss. 123–130.

Marques, R.C., da Cruz, N.F. & Pires, J. (2015). Measuring the sustainability of urban water services. *Environmental Science and Policy*, vol. 54, ss. 142–151.

Molinos-Senante, M., Gómez, T., Garrido-Baserba, M., Caballero, R. & Sala-Garrido, R. (2014). Assessing the sustainability of small wastewater treatment systems: A composite indicator approach. *Science of the Total Environment*, vol. 497–498, ss. 607–617.

Palme, U., Lundin, M., Tillman, A.M. & Molander, S. (2005). Sustainable development indicators for wastewater systems - Researchers and indicator users in a co-operative case study. *Resources, Conservation and Recycling*, vol. 43 (3), ss. 293–311.

Scharfy, D., Boccali, N. & Stucki, M. (2017). Clean Technologies in Agriculture—How to Prioritise Measures? *Sustainability*, vol. 9 (8), ss. 1–22.

Woltersdorf, L., Zimmermann, M., Deffner, J., Gerlach, M. & Liehr, S. (2018). Benefits of an integrated water and nutrient reuse system for urban areas in semi-arid developing countries. *Resources, Conservation and Recycling*, vol. 128, ss. 382–393.

15 APPENDIX C: ELEMENTS OF THE INNOVATION DEVELOPMENT CYCLE

The elements of the innovation cycle are built around the four phases of an innovation reaching the market. In each new phase, the development and testing environment becomes increasingly similar to the real environment the innovation is intended for. In a fourth phase, the innovation is introduced to the market and further developed based on the experience gained in the field where the innovation is applied. A product can be either a technical solution, a system solution or a service. In subsequent sections, the term product is used as a “catch-all”-term for all these types.

Phase 1: Formulate and challenge
Phase 1 takes place in and around the innovators laboratory or workshop and includes RL 1 to RL 4. In addition to formulating the innovation concept, the idea should be challenged to determine the suitability for continued development. An important step in this phase is to make the necessary contacts to successfully reach the goal of a demanded product in the market and define the requirements that the product must be able to meet in order to offer what the market needs.

Phase 1 covers the following Readiness Levels:
- RL 1: Basic principles are observed and the idea for the innovation is born,
- RL 2: The Innovation concept is formulated,
- RL 3: Experimental evidence and prototypes are developed,
- RL 4: Specification of requirements and test protocols are developed.

Examples of information sources and important contacts that should be made in Phase 1:
- “Lessons Learned” – experiences gained from reviewing the market,
- Researchers and research findings,
- Funding/finance infrastructure,
- Legal framework and involved authorities,
- Consultants and advisors (technical, financial and legal),
- Standards and certification schemes.

RL 1: Basic principles are observed and the idea for the innovation is born
At this first stage, the basic principles that form the basis for the innovation are discovered or observed. Ideas for innovations can arise in many ways, for example from field experience or from discoveries reported in literature.

RL 2: The Innovation concept is formulated
Based on the discovery or observation, an innovation concept can be formulated. It is valuable for the continued development that the formulation takes off in a needs and market analysis at an early stage to evaluate the sustainability of an innovation and identify the challenges that must be addressed. Developing an innovation into a product can take many years and requires a lot of effort and funding. Therefore, it can be valuable to enter a partnership with a future client and to contact various authorities, organizations and players in the industry who may have relevant information for the development of the innovation. Furthermore, there are legal, cultural and social challenges in the countries and environments in which the product is intended to be used. This is also an opportunity to form a project group with stakeholders, technology developers, large companies, etc. with the common interest in getting a functional and profitable product out on the market, which can drive the development of the product forward.

As more emphasis is placed on the sustainability of innovations, procurement of products in the future is likely to be characterized by increased sustainability requirements. It is therefore strongly recommended that already at the stage of needs and market analysis, the innovator relates to and benefits from the sustainability assessment framework developed within BONUS RETURN for this purpose. It is important to note that a solution will never be more sustainable than the context or the user environment allows for. For example, if a technical solution requires sustainable energy in order to be considered sustainable and sustainable energy is not available where the product is to be used, the sustainability value of the product is lost. Therefore, it is important that there is a clear understanding of the context and environment in which the solution is to be applied.

RL 3: Experimental evidence and prototypes are developed
When the needs and market analysis is complete, the mechanisms and functions needed for the innovation to be developed are investigated. Hypothesis and theories are confirmed or refuted, and the function of the product is validated. These tests could be done in a laboratory environment of some kind and/or in a workshop. At this stage, a first prototype is likely to be developed for further development and testing.

RL 4: Specification of requirements and test protocols are developed
At RL 4 there is now a basis provided by the needs and market analysis, and there is evidence that mechanisms and functions of the prototype are working, which gives impetus to the innovation formulation. In the next phase, the prototype will be developed into a functioning product. Ultimately, the completed prototype should be tested for the desirable properties and features of the final product, in other words what the product should be tested to make sure that it offers what the customer wants to buy. Therefore, a specification of requirements and test protocols to which the prototype can be developed and tested (validated) against are necessary. The idea is that the client and the innovator, and possibly other stakeholders, together produce the specification of requirements and test protocols for the final validation tests at RL6 and RL 7. The specification of requirements and the test protocols should be reviewed by a third party to ensure that appropriate content and sufficient quality have been achieved. Consultation may be needed to find appropriate standards and metrics for product validation and evaluation as well as for formulating the appropriate documentation. High ambitions are required when the specification of requirements and the test protocol are drawn up so that the validation really becomes a receipt for the buyer of the that the product is finished and in compliance with the requirements to enable the product development to proceed to phase 3 and be tested and demonstrated in a sort of real environment.

Phase 2: Develop and validate
Phase 2 covers the following Readiness Levels:

- RL 5: The prototype is developed in a relevant environment
- RL 6: The prototype is validated in a relevant environment by a third party

Phase 2 takes place in a competent isolated testbed and comprises RL 5 to RL 6. A competent isolated testbed is a test site that is similar to a real environment for which the product is intended for and with access to high innovation-development support competence (including good technical support) that is isolated from the surrounding environment such as competitors, clients, media etc. The purpose of tests in this phase is development and not demonstration for potential clients or stakeholders, thus an *isolated* testbed where the innovator can develop and fix problems that arises without having to explain or defend the shortcomings of the prototype.

A competently isolated testbed can either be *open or site-specific*. An open testbed is often built for innovation development support by offering a test environment for innovators with a fee for service. A site-specific testbed is a site which the innovator finds by own means and where the innovator can test the invention thanks to unique conditions and proximity to a service or competence (i.e. a university). For wastewater applications it could be at the site of a wastewater treatment plant. For a site-specific testbed the innovator and the site owner need to agree on the terms for the test. A site owner could be any kind of organization (e.g. an institute, university, municipality, industry, farm owner), private company or person.

RL 5: The prototype is developed in a relevant environment
Equipped with the developed specification of requirements and the test protocol as a roadmap, the concept is developed into an applicable prototype of a product (or a service) for tests in a competent isolated testbed. The tests are likely an iterative process (i.e. trial and error) where discoveries and challenges force the development of the prototype back and forth until a final working configuration or solution is achieved.

RL 6: The prototype is validated in a relevant environment by a third party
In RL 6, the prototype is validated by a third party against the specification of requirements and the test protocols developed in RL 4 in phase 1. The validation is done by a third party for the sake of obtaining an unbiased independent evaluation. The prototype should now be sufficiently ready and functionally validated to become a product unless the innovator chooses to first make additional tests in cooperation with a potential client in phase 3 and after that make further minor revisions before producing the first version of the final product.

There are international standards for verification and validation. ISO17020 and ISO17025 establish general principles, procedures and requirements for technical verification. Environmental technology verification according to ISO14034 applies specifically to the verification of environmental technologies (i.e. technologies that either provide environmental added value or measure environmental impact). Within the framework of its Environmental Technology Verification pilot program, the European Commission offers a free general verification protocol (Environmental Verification Protocol) for environmental technology.

Phase 3: Demonstrate and qualify
The completion of Phase 2 with a validation test means that the clients can now trust that the product works against the requirements identified by the stakeholder group (who were identified in phase 1), which is close to a reality application. In phase 3, the product is now ready to be implemented in a real end-user setting/environment.

Phase 3 covers the following stages of Readiness Levels:

- RL 7a: The prototype is *tested* and developed in an operational environment
- RL 7b: The prototype is *demonstrated* in an operational environment

Both of these procedures are favourably carried out in cooperation with clients or potential clients.

RL 7a: The prototype is tested and developed in an operational environment
At RL 7a the product is tested in an operational environment very similar to the client environment. The purpose is to give the development team the opportunity to test, adjust and fine-tune the product in a real setting to monitor and manage unforeseen challenges. For example, a scenario may be that a connection to the internet does not work due to local conditions and the project team now gets a

chance to address this shortcoming. Hopefully, socio-cultural aspects have been dealt with in the earlier phases, but there is now a chance to fine-tune aspects of such issues. The development team is responsible for the activity, but collaboration with client staff is necessary to identify the, hopefully small, remaining unsolved issues.

RL 7b: The prototype is demonstrated in an operational environment
At RL 7b, the product is finalized and can be demonstrated together with a client in a real operational environment. This is probably done at the same environment as RL 7a if no other purpose is achieved by changing the test environment. The purpose is now shifted from development and adjustments to give the development team the opportunity to show and demonstrate the innovation for the client and other stakeholders. Initially the development team could be responsible for the activity but over time and with a purchase agreement it should be delivered and handed over to a client. The client then takes over the responsibility for final validation and evaluation if that is possible. The results of the validation and evaluation should, for the benefit of the seller/innovator, be documented in a demonstration report that can be further disseminated to other potential clients.

Phase 4: Market introduction
The market introduction is the final phase for the development of the product. The prerequisite for moving to Phase 4 is that the product is fully developed and that there is now a manufacturer producing and perhaps even distributing the innovation into the market. The manufacturer can be a larger company that manufacture on order or who has bought the patent or license. The product is now qualified, purchasable and used in the market.

Market introduction includes the following Readiness Levels:
- RL 8: The product is qualified for use
- RL 9: The product is purchased and used

RL 8: The product is qualified for use
RL 8 is defined as the period when the product, system or service begins to be manufactured and even series manufactured. It can, for example, be that a sanitation solution, such as a humus, starts to be manufactured in larger sizes to be sold upon request. The marketing work has begun long before during Phase 1 with early contacts and collaborations with clients and other players in the market, but at this stage the work is being intensified to achieve success in procurement. To help, there are networks and collaborations established during the development.

RL 9: The product is purchased and used successfully
RL 9 defines the initial period when the product has been procured by clients and used successfully. The product has thus proven its usefulness in real operations and has been refined in continued development into an attractive product that has a demand by the market.

16 APPENDIX D: MARKET SURVEY QUESTIONNAIRE

1. Do you have any determined plans regarding an increase in capacity at your WWTP in the near future?
   □ No
   □ Yes, currently happening
   □ Yes, within 1–5 years
   □ Yes, within 5–10 years
   □ Yes, within 10–15 years

2. Do you have any determined plans on incorporating a phosphorus post-precipitation step at your WWTP?
   □ No
   □ Yes
   □ Maybe

3. How are you preparing for the upcoming 2020 phosphorus recovery regulations in Sweden?

4. What is your opinion on recovering phosphorus in a partial stream (chemical sludge) separated from sewage sludge?

5. If you would implement a phosphorus recovery technology integrated with your wastewater treatment process.

   a) What factors are important for your daily overall operation?
   b) What factors are important for your operators?

6. What is the current state of space flexibility at your WWTP?
   □ Completely flexible
   □ Quite flexible
   □ Quite inflexible
   □ Completely inflexible

7. From your point of view, are there any drawbacks associated with the RAVITA technology?

8. From your point of view, are there any advantages associated with the RAVITA technology?

9. What would you say are the conditions for you to consider implementing/investing in the RAVITA technology?

10. Consider the case where you would be implementing the phosphorus recovery method conducted by RAVITA. Would you prefer to invest in the necessary process equipment itself or buy it as a service?

11. Considering your current knowledge of the RAVITA technology. What would you say about the probability of implementing the RAVITA technology at your WWTP in the future?
    □ Very likely
    □ Quite likely
    □ Quite unlikely
    □ Very unlikely

12. Based on your answer of question 11, why do you feel that way?