D T6.3 Opening a direct nutrient exchange component in the NutriTrade Platform

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Nutrient Offsetting for the Baltic Sea

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1 Introduction

Given the challenges with eutrophication in the Baltic, measures are needed to reach the environmental targets associated with the Marine Strategy Framework Directive (MSFD; EC 2008), the Water Framework Directive (WFD; EC 2000) and the Helcom Baltic Sea Action Plan (BSAP; Helcom 2007). The NutriTrade project evaluates how nutrient trading can work as an instrument to financing and implementing new measures for capturing nitrogen (N) and phosphorus (P) or by other means mitigating the effects of eutrophication. As part of the project, a market platform for nutrient reducing measures has been created. Examples of measures include biomass harvesting, such as mussels, reed, ascidians, algae, and fish. These measures can, if designed efficiently, contribute to reducing the concentrations of N and P in the marine ecosystem and hence help alleviating eutrophication effects.

Several challenges are associated with the N & P cycles: For P, a particular challenge is, apart from eutrophication, the finite stocks (EcoSanRES, 2003). P from mineral resources is a scarce resource and studies suggest that the stocks may be exhausted within this century if measures are not taken to reuse P or lower the input in e.g. mineral fertilizers (Steen, 1998; Vaccari, 2009). N is, unlike P, not a finite resource, but input of N to the cycle generates a number of negative environmental impacts beyond eutrophication, in what is referred to as the nitrogen cascade (Galloway et al., 1995; Galloway et al., 2003). These effects include global warming, acidification, biodiversity loss and increase of ground-level ozone (Sutton et al., 2011). Studying measures not only in terms of e.g. avoided leakage or uptake from the recipient (Baltic Sea) is thus important. Measures that contribute to a lower input to the system have the potential of generating a long-run effect on eutrophication mitigation as well as other environmental impacts and reducing the need for input of new mineral P to the system. Hence, there is a need for studying not only nutrient capture in measures but also the destiny of the captured N and P in a cycle perspective. Evaluating the secondary products generated from measures with this in mind is challenging but key to generating long-run effects on several environmental pressures including eutrophication.

Nutribute (http://www.nutribute.org/) is a digital platform for channelling financing into efficient eutrophication mitigation measures in the Baltic Sea region by matching financers with project initiators. The platform currently focuses on stimulating funding for N and P reduction per se, i.e. not providing a market platform for the secondary products being generated by the project, such as biofuel, organic material, fertilizers, etc. In order to stimulate N and P sequestration activities, it is important that these secondary products can be marketed to various user groups to a) lower the cost of measures by generating side-benefits, and b) establish a channel for recycling N & P upstream in the N & P cycles to make sure that the measures have a long run effect on eutrophication. Secondary products are highly diverse, ranging from the biomass itself for e.g. food or feed to high tech material derived in a biorefinery, and hence the commercialization of secondary products needs to be tailor-made to the specific products and their associated markets.

A key question being addressed in this report is whether a particular marketing- and matching platform could support the commercialization of secondary products and in that case what characteristics such a platform would need. We here identify secondary products from a range of potential NutriTrade measures to inform a discussion of this question.

Additionally, we use the information on secondary products to address the issue of nutrient recovery vs. nutrient uptake. Where do the N and P being captured through the measures end up in the N and P cycles after being transformed into different products and how does this impact the inflow of new N and P to the system? Ideally, measures and their associated products should contribute to closing the N and P loops to avoid a continuing enrichment of N and P in the system.

The report is organized as follows. Chapter 2 identifies secondary products for a few nutrient-reducing measures. Chapter 3 identifies current marketing/matching platforms for these kinds of products and discusses the potential for a new platform which is overarching for the NutriTrade measures. Chapter 4 discusses the role of the measures and their associated products for the N and P cycles. Chapter 5 provides recommendations.

2 Potential measures and their secondary products

This chapter describes a few planned or implemented eutrophication measures in Sweden and Finland. The measures presented are not necessarily included in Nutribute at the moment but are used as examples that could be included. Different kinds of measures are presented, including harvesting of aquatic biomass (plants or animals), treatment of wastewater, targeted fishing and treatment of sediment and clay. There are both commercial and non-commercial incentives. Most of these measures create some kinds of nutritious side products, such as biomass for biogas production, fertilizers, organic material for food or feed, and material for high value products. Table 1 summarizes the information about the measures and their side products.

Table 1. List of measures to reduce eutrophication in Sweden/Finland and possible use of secondary products.

Company/agency	Description of measure	Side product	Possible use of side product
Agrosea AB	Harvesting of reed and other aquatic plants	Organic material (e.g. reed)	Biogas and fertilizer
Algoland (Linné universitet)	Treating wastewater with microalgae	Algae Biomass	Biogas or high value products
Ecofiltration Nordic AB	Treating wastewater with Polonite filter	Saturated Polonite	Fertilizer
Marin Biogas	Cultivation and harvesting of ascidians	Ascidian Biomass	Biogas and fertilizer
Musselfeed	Production of mussel meal	Mussel meal	Food and feedstuff
Pilot Fish	Targeted fishing of cyprinid fish	Fish	Human consumption, livestock/fish feed and energy production
Pilot Gypsum	Treating clay fields with gypsum	None	-
Pilot Mussel	Cultivation and harvesting of	Mussel biomass	Feed for poultry and fish

	blue mussels		
Swedish Algae Factory	Cultivation of algae for solar cells, waste treatment, fish feed and fertilizer	Algae Biomass	Solar cells, fish feed and fertilizer
Teknikmarknad AB	Dredging of sediment	Sediment	Fertilizer on farmland and woodland

Agrosea AB is a company that has developed a concept for harvesting reed and other aquatic plants from lakes and bays (Biotal, 2018). The plants are then collected and used as raw material for biogas production. Biogas production also creates biomass that can replace conventional fertilizers. The company is located in the city of Linköping in Sweden, but the method could possibly be used anywhere. The reed should be harvested during the summer since that is the time when it grows the most and most nutrient is bound to the plants.

Algoland is a research project that combines marine science research with industrial expertise in order to achieve solutions that reduce carbon dioxide and nutrient emissions while producing valuable products, in the form of animal feed and biofuels (Linnéuniversitetet, 2018). One part of the project investigates the potential to purify landfill leachate water from nitrogen by using microalgae. The project is located in Kalmar and uses ash from a nearby combined power and heating plant as a nutrient source for the algae. The algal biomass is used for bioenergy or high value products.

Ecofiltration Nordic AB is a cleantech company that develops reactive filter media (made of calcium silicate) for purifying phosphorus rich water (Ecofiltration, 2018). The filter can be used for wastewater treatment, both on large scale and in individual sewages, as well as in ponds, wetlands and drainage ditches to limit phosphorus leaching. The goal is to recycle the used saturated nutrient rich filter and use it as fertilizer.

Marin Biogas cultivates and harvests ascidians on the Swedish west coast (Marin Biogas, 2018). The production implies absorption of nutrients that have been bound in the ascidians tissues and the biomass can then be used in biogas production and as fertilizer. The business is still in an early phase. Marin Biogas has been involved in a research project (financed by the Swedish Energy Agency) in which they during three years cultivated and harvested ascidians, and then delivered them to a biogas plant in Falkenberg, Sweden (Energimyndigheten, 2015.). The location of ascidian farms is dependent on the distance to biogas plants. One of the project objectives was to investigate whether the method also could work in the Baltic Sea since brackish water is not a natural environment for ascidians.

Musselfeed is a company that has developed an industrial process for separating the mussel meat from the shells and produce mussel meal. The flour can be used as raw material for food or feed products. Musselfeed is involved in a research project financed by the European Agricultural Fund for Rural Development to try the concept. Currently they are only active on the Swedish west coast (Musselfeed, 2018).

Pilot Fish is one of the pilot projects in NutriTrade and includes targeted fishing of cyprinid fish. The aim is to remove a significant amount of nutrients from the marine ecosystem that is bound to the fishes to solid ground in Finland (NutriTrade, 2018a). Targeted cyprinid fishing might also have a positive impact on the fish stock and the food web. The Pilot Fish seeks to increase the utilization of cyprinid fish in foods consumed by humans.

Pilot Gypsum is another pilot project in NutriTrade and implies gypsum application of fields to reduce phosphorus and suspended solid loads from agricultural soils (NutriTrade, 2018b). 1,500 hectares of clay fields have been treated with gypsum in the catchment area of a river in south-western Finland. The impacts on water quality are then monitored and analysed.

Pilot Mussel aims at compensating blue mussel farmers on the Swedish east coast for removing nutrients through harvesting of mussels from the Baltic Sea (NutriTrade, 2018c). There is currently no commercial market for blue mussels from the Baltic Sea but it could be used as feed for poultry and fish.

Swedish Algae Factory cultivates a microscopic alga called diatom. It can be used for wastewater treatment, to produce organic biomass and to extract nanomaterial that enhance the efficiency of solar panels (Swedish Algae Factory, 2018). The material can also be used in cosmetics since it takes up sunlight, but not ultraviolet radiation. The business is still in an early phase. Currently the method is used in a land-based fish farm on the Swedish west coast. The idea is to reach zero emissions of nutrients through controlled algae blooms in the fish farm. The algae are then used for fish feed while the excess can be used for biogas.

Teknikmarknad AB is a spin-off company from the Royal Institute of Technology in Stockholm (KTH) with whom they cooperate closely (Teknikmarknad, 2018). Teknikmarknad matches local investments with new environmental technologies and offers municipalities investigations, pre-studies and pilot projects in environmental technology-related fields. One of their concepts is dredging of the nutrient rich top sediment in order to reduce the eutrophication. The removed sediment can after a process be used as a fertilizer.

3 Marketing of secondary products

It is important to take care of the secondary products in a way that the measures actually decrease the nutrient load in the sea. A commercialization of the secondary products could lead to a sustainable and efficient utilisation of the recycled nutrients. However, a functioning market requires no legislative or financial barriers. The product also needs to be of the same quality, alternatively, have a lower price than the conventional options. This chapter investigates whether a platform for marketing and trading secondary products could support the commercialization, and in that case, what characteristics such a platform would require.

3.1 Existing platforms for secondary products

As a basis for taking a decision whether NutriTrade should develop a marketplace for nutrient exchange or if there are already existing platforms to join, an analysis has been made of existing platforms. The information about the platforms has been collected through internet search and contact with people working with the platforms.

The **Nutrient Platform** is a network of Dutch organizations in the water sector, agriculture, waste sector and chemical industry, representing businesses, knowledge institutes, NGOs and the government. The aim is to create a market for recycled nutrients. This is, according to the Nutrient Platform (2016), done by developing cross-sectoral business cases on nutrient recycling, improving Dutch and European legislation that helps turning waste into resources, creating awareness about sustainable nutrient management and linking a joint knowledge agenda to business demand.

The Nutrient Platform also initiated the non-profit **European Sustainable Phosphorus Platform (ESPP)** in Belgium 2013. ESPP is a knowledge sharing and networking platform for phosphorus management. It enables discussions between the market, stakeholders and regulators. ESPP addresses regulatory barriers, makes policy proposals and defines a long-term vision for phosphorus sustainability in Europe. It also spreads information about the participants' activities, publications and conferences (ESPP, 2018).

ESPP has, in cooperation with P-REX, developed a platform called **eMarket** (www.e-market.phosphorusplatform.eu), which is an online matchmaking platform between suppliers and users of recovered nutrients in Europe. eMarket is not in operation at the moment due to lack of funds (Christian Kabbe, Project Manager P-REX, pers. comm.), but the website is still running. It is a marketplace where companies that can offer recovered phosphorus can register and fill in a form with information about e.g. what material they have, the amount they supply and how it can be delivered. Figure 1 shows exactly what kind of information is requested. The company is then shown as a pointer on a map with contacts to the supplier. Potential users of the recovered nutrients can either find registered suppliers via the website or create their own ad. The companies on the demand side fill in similar information as the companies on the supply side.

1. **Material status:**
   - ☐ Fertilizer ready for application
   - ☐ Fertilizer to blend
   - ☐ Secondary raw material
   - ☐ Soil improver

2. **Is this product consider "processed manure" under the nitrated directive?**
   - ☐ Yes
   - ☐ No

3. **Is this product certified as a fertilizer under national or EU legislation?**
   - ☐ Yes
   - ☐ No

Country: ____________

4. **Physical form:**
   - ☐ Solid
   - ☐ Liquid
   - ☐ Sludge/Slurry

5. **Material source**
   - ☐ Not sewage
   - ☐ Not manure
   - ☐ Other

6. **Special types**
   - ☐ Strutive
   - ☐ L-strutive
   - ☐ Ash
   - ☐ Treated ash
   - ☐ Organo-mineral
   - ☐ Digestate

7. **Material composition**

% nitrogen: _______________

% phosphorus: _______________

% potassium: _______________

% sulfur: _______________

% iron: _______________

8. **Material provided as:**
   - ☐ Waste
   - ☐ Product

9. **Quantity, liquids**

   Please select the wanted unit of measurement for your liquid demand:
   - ☐ Liters
   - ☐ Cubic metre

Tonnage production/available per month: ____________

Maximum order quantity per month: ____________

Enter your address: ____

Figure 1. Information requested about suppliers and users of recycled nutrients at eMarket (www.e-market.phosphorusplatform.eu).

Sustainable Phosphorus Alliance is an American non-profit organization that advocates for sustainable use, recovery, and recycling of phosphorus (Arizona State University, 2018). It is a forum where public- and private-sector organizations can share experiences, network, and develop and implement phosphorus reducing measures. However, the organization does not offer any trading or match-making between suppliers and users of recovered nutrients.

The **UK Nutrient Platform** is a nutrient-focused forum for information and networking. It is, however, in limbo at the moment, seeking sustainable funding to allow it to progress (Andrew Gadd, pers. comm.).

The **Baltic Sea Action Group (BSAG)** is a Finnish non-profit organization, founded in 2008. BSAG works to find solutions to the environmental problems in the Baltic Sea and brings together business, scientists, decision makers and other parties. It is an information sharing and lobbying organization. One part of their work is to bring together companies related to nutrient recycling in order to create innovations, new cooperation and concepts that can create business opportunities (BSAG, 2018).

The **German Phosphorus Platform** is a network of stakeholders from science, industry and public sector to establish sustainable phosphorus management in Germany. They try to identify and implement technologies for recycling of phosphorus, both for increasing the production efficiency and for re-using production waste as input material (Deutsche Phosphor-Plattform, 2018). They organize events, initiates and coordinates projects, provide networking, develop regulation proposals and recommendations etc. However, the German Phosphorus Platform is not a platform for recycled products (Daniel Frank, Deutsche Phosphor-Plattform, pers. comm.).

SYNERGie is a resource reuse software system launched in 2009 by International Synergies Limited. The software enables companies to identify reuse opportunities and minimize their waste through a database. It allows companies to characterise, search and match resources (International Synergies Limited, 2018). Currently, the software is being used in nine countries. Today, the database is mainly used for waste material from e.g. construction sites but could potentially also be used for nutrients.

Table 2 shows a summary of the information about existing platforms that was found. Most of the platforms are forums for information/networking/lobbying. The opportunities for joining existing marketplaces for nutrients are limited since the only actual market for recycled nutrients (eMarket) is not in operation. However, SYNERGie is an interesting alternative if it can be used for nutrient exchange.

Table 2. List of existing platforms for secondary products.

Name	Origin	Type of platform	In operation?
Nutrient Platform	Netherlands	Information spreading, lobbying. Initiated the European Sustainable Phosphorus Platform (ESPP).	Yes
European Sustainable Phosphorus Platform, ESPP	Belgium	Knowledge sharing and networking platform.	Yes
eMarket		Match making between suppliers of recovered nutrients and potential end-users. Initiated by ESPP.	Not in operation, needs funding
Sustainable Phosphorus Alliance	US	Knowledge sharing and networking platform.	Yes

The UK Nutrient Platform	UK	Forum for information and networking.	Not in operation, needs funding
Baltic Sea Action Group (BSAG)	Finland	information sharing and lobbying organization	Yes
German Phosphorus Platform	Germany	A supportive and information-sharing platform.	Yes
SYNERGie	UK	A resource reuse database	Yes

3.2 Developing marketing for secondary products

Since there are no suitable existing platforms to join, there could potentially be room to create one. However, it is also important to investigate the companies'/agencies' demand for such a marketplace. We have talked to representatives from three of the companies listed in table 1 (Ecofiltration, Swedish Algae Factory and Musselfeed) to get information about whether a platform for secondary products would be useful for them or not.

The demand for Ecofiltration's side product (saturated Polonite) is low. Currently the company has to give it away or even pay companies to receive the material. According to Wangler[1], the conventional alternatives are too cheap. This suggests that the quality of their side product is lower than the conventional fertilizers or that customers choose the conventional alternatives for some other reason. Wangler thinks that in a few years they will be able to sell their side product as the phosphorous might get more expensive due to peak phosphorus, but also because the public's increasing interest in circular economy. A platform for secondary products could, according to Wangler, benefit the company since they have no customers at the moment. But if they in the future get some long-term customers nearby, they would not use that kind of platform.

Swedish Algae Factory currently has activities only on the Swedish west coast but are planning to expand their business to the Baltic Sea, according to Allert[2]. If they do, they will have to use another type of algae that grows better in a brackish environment. At the moment the company is not interested in a platform for secondary products since the business is still in an early stage and the algae they cultivate is directly used as fish feed. However, in the future when business is more developed, the company could be interested in using a potential platform.

Musselfeed processes a number of tons of mussels per day and there is a demand both for the product (mussel meal) and the technology. The reason why people want to buy the product is because of its high quality and because it is considered a green product. The company finds its customers through business networks and are not in a need for a marketplace to sell the products (Kocher[3]). However,

[1] Fredrik Wangler, CEO Ecofiltration AB. Interview 2018-02-07

[2] Sofie Allert, Swedish Algae Factory. Interview 2018-02-09

[3] Sofia Kocher, Musselfeed. Interview 2018-02-12

they could be interested in a platform such as Nutribute to finance their measures (mussel farms). But Kocher is skeptical to this kind of one-time funding and would rather get more continuous contributions for a more sustainable financing of the production.

The result from the interviews suggest that some companies would benefit from a marketplace for secondary products, especially in the start-up phase when they have no customers yet. However, since the products are so different, there might exist other more specialized marketplaces for each one of them. The companies also seem more interested in finding customers through their own business networks than via a research platform. Some of the products cannot be transported long distances due to high transport costs, which implies that an international website would be less useful for these products. Common for the three respondents is that they think that one reason why people buy their products is because they consider it as a green product. This suggests that marketing these products on a "green" website would benefit them.

There are mainly three ways NutriTrade could stimulate trading of secondary products:

1. Create a new website/platform for trading recycled nutrients
2. Create a platform under the Nutribute website for trading recycled nutrients
3. Add descriptions of the secondary products on the Nutribute website

Since some of the existing platforms in table 2 are not in operation due to lack of funds, it is important that a potential new platform can run on its own without too much maintenance. Anyone should be able to create an account, find necessary information and buy or sell without involving an administrator. It is also important that it is free to use. Another question is whether it should be possible to order via the platform or just contacts and link to their website. A person visiting the platform should also be able to select the region of interest as a search criterion in order to find the most relevant products.

The information needed on a potential website could be the following:

- Type of secondary product
- Quantity
- Quality
- Location
- Whether the measure is limited to a time period
- Price (if not free)

4 Closing the loop through N and P removal – substitution effects and cycle impacts

In a sustainable and resource-intensive society, nutrient rich materials from the ocean become a resource that can be recycled and replace conventional alternatives. This chapter first describes the nutrient cycles and then the explores how nitrogen and phosphorus, captured through potential

NutriTrade measures, impact the nutrient cycles.

4.1 The phosphorus cycle

Naturally, phosphorus moves in a cycle through rocks, soil, water, sediments and organisms. Over time, wind and rain erode phosphate rich rocks and phosphates leach into soil and water. Phosphate ions in soil are absorbed by plants and then transferred to animals through consumption. Decomposers break down plant and animal matter into soil and phosphorous leaches into water bodies. Dissolved phosphate and silt becomes sediment. Eventually, the sediment forms new rocks and geological uplift pushes the new rocks to the surface. The phosphorus cycle is slow compared to other biogeochemical cycles – the geological uplift takes millions of years (Figure 2).

The impacts of human activities on this cycle lead to at least two major consequences. First, mining of mineral phosphorus for e.g. fertilizer manufacturing implies that the resource is becoming increasingly scarce (Steen, 1998; Vaccari, 2009). Second, input of P to the cycle leads to eutrophication effects. The production and consumption of food, detergents, pulp- and paper industries, bio energy production, and extraction of iron ore are among the most significant sources of P inputs in Sweden (Naturvårdsverket, 2013).

Recovering P through secondary products such as feed, food, biofuel, fertilizers, etc. has the potential for contributing to lower P concentrations in the Baltic Sea, but in order for mitigation measures to have an effect in the long run, the destiny of P atoms being captured in the secondary products is important to consider. Secondary products that contribute to substitution of e.g. other agricultural production, or even more directly, to substitution of mineral fertilizer use, have the potential to contribute to lowering the inputs of P to the system.

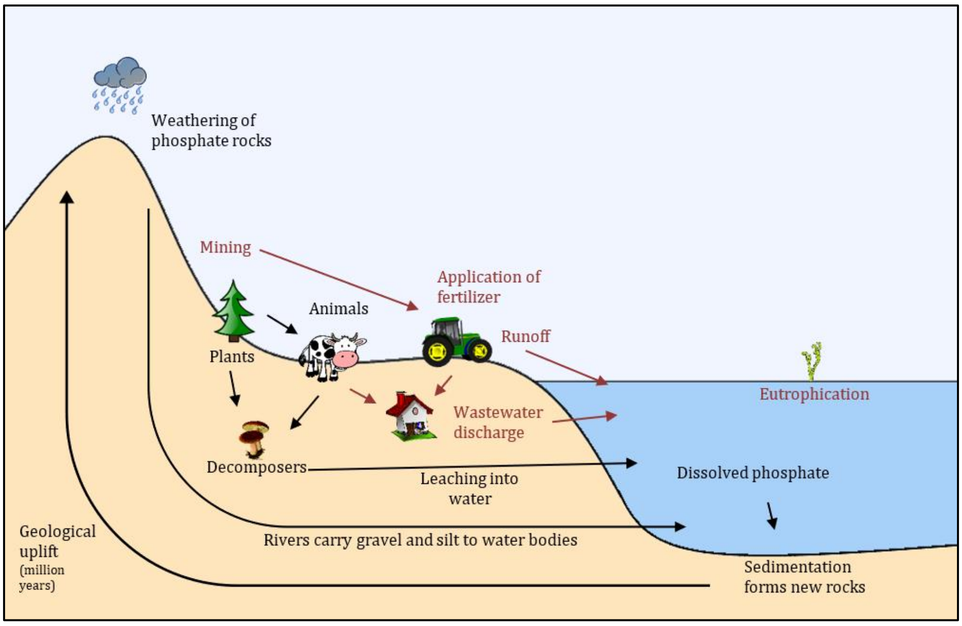

Figure 2. The phosphorus cycle.

4.2 The nitrogen cycle

Figure 3 shows the nitrogen cycle. In contrast to phosphorus, nitrogen is not a limited resource. The air in the atmosphere consists of 78 % nitrogen and N is naturally fixed by bacteria and transformed to other forms. N can also be fixed as nitric oxide by lightning and ultraviolet rays. All organisms need nitrogen, but the gas form (N_2) cannot be used as a nutrient. Instead, plants take up nitrogen from soils in the form of ammonium (NH_4) and nitrate (NO_3). Nitrogen reacts with other chemicals to form new compounds (nitrogen cascade; Galloway et al., 1995; Galloway et al., 2003), which include nitrogen oxides (NO_x), nitrous oxide (N_2O), ammonia (NH_3) and nitrate (NO_3), which contribute to a range of environmental impacts (Figure 4). For example, reactive nitrogen causes biodiversity loss in forests and water, contributes to respiratory and cardiovascular diseases for humans, as well as bowel cancer from nitrates in drinking water, and contributes to global warming and acidification (Sutton et al., 2011).

Human activities such as combustion of fossil fuels and the use of manufactured fertilizers contribute to an enrichment of the nitrogen cycle. Each year, manufactured fertilizers add 11 million tonnes of reactive nitrogen in the EU agricultural landscape (Sutton et al., 2011). Damages costs caused by nitrogen pollution has been estimated to between 70 and 320 billion euros per year in the EU.

Eutrophication mitigation measures need to consider this cascade. Secondary products from measures which contribute directly or indirectly to e.g. less use of manufactured fertilizer or less combustion of fossil fuels have the potential for generating long-run effects in terms of mitigating eutrophication as well as many other environmental impacts caused by reactive nitrogen.

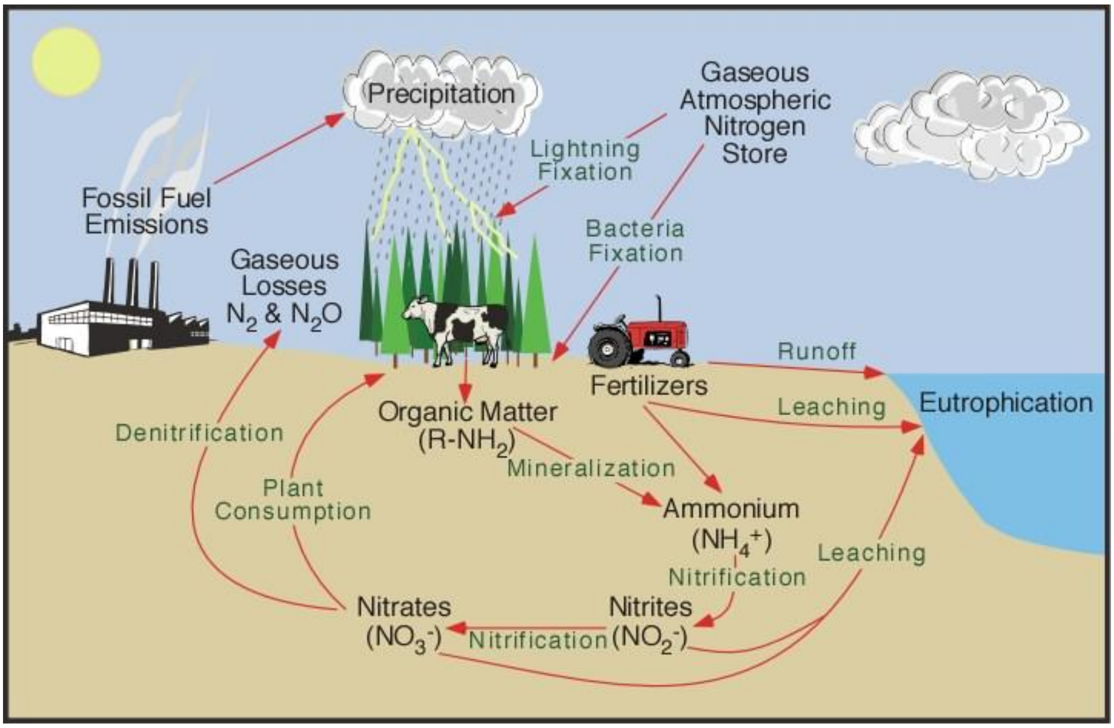

Figure 3. The nitrogen cycle. Source: Pidwirny, M. (2006). "The Nitrogen Cycle". Fundamentals of Physical Geography, 2nd Edition. Accessed March 2 2018. www.physicalgeography.net/fundamentals/9s.html

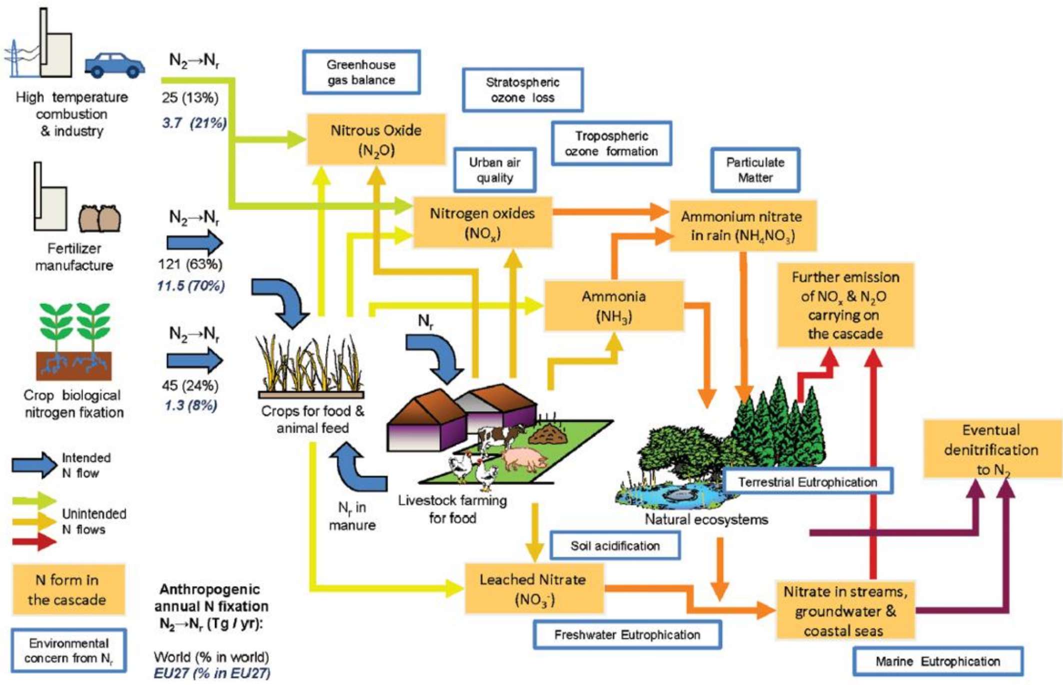

Figure 4. The nitrogen cascade - environmental impacts caused by reactive nitrogen. Source: European Nitrogen Assessment, 2011.

4.3 Secondary products in a nutrient cycle perspective

Two key sources of input of N and P to the cycles need to be particularly considered when secondary products are evaluated in terms of their long-run effects on eutrophication as well as impacts related to the nitrogen cascade: artificial fertilizers (N&P) and combustion (N). Concerning artificial fertilizer, there are three strategies to reduce environmental impacts (Konjunkturinstitutet, 2014):

1) to increase nitrogen efficiency
2) reduce the environmental impact of supply at different stages of the nitrogen cycle
3) to reduce the input

Increased nitrogen efficiency reduces both excess and leakage but moves nitrogen to other parts of the cycle. For example, if nitrogen efficiency leads to a larger nitrogen uptake of the plant, this fraction will eventually end up in the manure or waste water treatment plant. Measures that reduce the environmental impact in one step only move the nitrogen to another step in the nitrogen cycle. These strategies are therefore insufficient in the long term because nitrogen accumulates in nature as long as there is an imbalance between supply and conversion. In order to reduce the problem in the long run it is necessary to reduce the nitrogen input to the system in question.

Since most of the crops are produced for animal feed use, the vast part of the nutrients goes through the animal husbandry. This means a constant nutrient surplus in animal husbandry and the nutrients end up as pollutants in air and water. By recycling the nutrients on animal farms back to crop production, the need for artificial fertilizers can be limited or eliminated. This requires that the manure is of good quality and that the cost for transport is not too high (Einarsson 2012). In areas with intense crop agriculture, there is however a deficit of nutrients in the soil and mineral fertilizer is a key source of new introduction of N and P to the system.

Nitrogen from combustion, e.g. in energy production and transports, is also a significant source of input to the cycle. Similar to artificial fertilizers, the reduction of input from the source is key to mitigating eutrophication as well as other environmental impacts in the long run.

Below, a brief overview of the different products (c.f. table 3) in terms of their role for the nitrogen and phosphorus cycles is presented. As secondary products are developed and used/consumed, nitrogen and phosphorus follow the product life cycle. Factors such as life length and type of product influences the way nutrients are being recovered and their destiny in relation to the cycles, as well as their potential to substitute other products which may be associated with nitrogen and phosphorus effluents or emissions.

Biogas

Biogas being produced from marine biomass moves N and P to a different stage in the cycle, but N and P are eventually entering the cycle again in various forms after combustion. However, when utilizing biogas from marine biomass instead of relying on e.g. land-based biomass production, which may require fertilization, a net positive impact can be achieved. Similarly, if the bioenergy substitutes fossil fuel combustion, a reduced net input of nitrogen can be expected. Additionally, organic "waste" products from biogas production may be developed into fertilizers, which may replace other manufactured fertilizers. Hence, several possible indirect effects may lead to a lower input of N and P to the system.

Fertilizer
The production of fertilizers from different nutrient removal measures has the potential for providing a new alternative to mineral fertilizers. By substituting mineral fertilizers with fertilizers based on nutrient recovery, the inflow of N & P to the system can be reduced. The quality of these fertilizers is key to actually replacing conventional fertilizers factors such as heavy metal content and nutrient composition is a challenge to this development. Additionally, different agricultural regions and different crops require different fertilizer composition. Hence, refinement of fertilizers to suit the right fertilizer market while also avoiding long transports is key to success.

Human consumption
Food production from marine biomass transports N & P first to humans, then to sewage treatment, then further to sewage sludge, which is mainly used as landfill. Depending on location and specific use of the sludge, it can be expected that a share of the N & P leaches back into the system, however with a significant time delay. Additionally, marine-sourced food may substitute other food, which in turn is dependent on nutrient input to the system in terms of application of fertilizers. This effect is rather direct when substituting e.g. crop production for marine-sourced food, but not the less significant when substituting meat production given the substantial N & P inputs required in this supply chain.

Livestock and poultry feed
N & P in livestock feed eventually end up in manure (and in the meat, which is then consumed by humans), which in turn can be used in different ways. If the manure is used as a substitute for mineral fertilizers, a net reduction of the N & P input to the system can be achieved. Additionally, substituting feed produced from land-based agriculture with feed based on marine-sourced biomass has an indirect contribution to lowering the inputs of N and P to the system.

Fish feed
Feed for aquaculture is a significant driver of eutrophication. Typically, e.g. fish meal and fish oil are main ingredients, but also crops such as wheat, e.g. for binding material. Substituting traditional fish feed for locally sourced biomass can have an impact on a) the net imports of N & P to the Baltic Sea when fish meal and fish oil is being sourced from other basins or sea areas, and b) the input of N & P based on fertilized agricultural production.

High value products
A range of more advanced products can be produced from marine biomass, such as beauty products, pharmaceuticals, plastics, glue, etc. Each of these products in turn has the potential to substitute other products. Given the many types of products involved and the many possible substitute goods, it is difficult to conclude on the impacts in the N & P cycles on an overarching level. However, the life span of these products may be an important factor. Although e.g. nutrients bound in materials such as plastics eventually enter the system again when the product is discarded (through e.g. incineration), N & P is being stored during the product’s life span.

Table 3. Overview of the different side products in terms of their role for the nitrogen and phosphorus cycles.

Possible use of side products	How can it reduce the input to the N or P cycles?
Biogas	Substitution of other energy production.
Fertilizer	Enabling lower mineral fertilizer use.
Human consumption	Substitution of other food production.
Livestock and poultry feed	Substitution of other feed production.
Fish feed	Lowering imports of other marine-sourced biomass from other regions to the system.
High value products (e.g. solar cells, sunscreen)	Uncertain.

5 Recommendations

In order to obtain long-run improvements for marine eutrophication, it is necessary to not only capture nitrogen and phosphorus through the NutriTrade measures, but also to use the secondary products in a way which contributes to lowering the imports of nutrients to the cycles. Since mineral fertilizer application is one of the main sources for these inputs, finding products which directly or indirectly contribute to lowering the need for applying mineral fertilizers is thus a key factor. The most obvious solution is when marine biomass is used to produce fertilizer, since it may provide a substitute for mineral fertilizers. However, challenges in this product development, e.g. heavy metal content, need to be overcome. Less obvious contributions to lowering the use of mineral fertilizers are however when marine-sourced products are a substitute for other production which in turn are reliant on land-based cultivation in need of fertilization. Such products may include biogas, food and feed.

In order to strengthen the possibility to tackle eutrophication in the long run through capture of nutrients at sea, the challenges with fertilizer production, such as logistics, suitability for different crops and heavy metal content needs to be prioritized in future research. Moreover, the systems for food, feed and biogas need further exploration with regards to how marine-sourced products may provide suitable substitution opportunities for land-based production and how this in turn may affect the need for agriculture using mineral fertilizers.

A key question being addressed in this report is whether a particular marketing- and matching platform could support the commercialization of secondary products and in that case what characteristics such a platform would need. The analyse of existing platforms shows that there are no good opportunities for joining platforms specialized on nutrient exchange. However, an opportunity is to join a platform not only specialized on nutrient exchange such as SYNERGie, which is a software that matches suppliers of waste with companies that can reuse the resource. Today, it is mainly used for waste material from e.g. construction sites but there is no limitation for using it for nutrient exchange. We thus recommend to further explore the possibilities of using this (or a similar) platform for nutrient exchange. A question that needs to be answered is if this platform would attract nutrient suppliers and users with regards to application handiness, geographical relevance etc. It also needs to be assessed how the platform could be included or marketed on the Nutribute platform.

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