Local runoff sources and wastewaters in the Baltic Sea Region

Deliverable 5.1

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Imprint

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Background

The Baltic Sea – a fragile aquatic ecosystem – consists of several basins with brackish and slow renewal waters. Freshwater inflows in combination with a relative small exchange of water from the North Sea determine the salinity levels of the basins. The stratification of the basins in combination with differences in salinity levels between bottom and top layers slows the circulation of water. Major inflows from the Belt Sea and the Sound continuously renew the superficial water in the Baltic Proper, one of the most deteriorated basins in the Baltic Sea. However, the deep water circulates every eleven years while the bottom waters remains for even longer periods. The stagnation of bottom waters in combination with the infiltration of nutrient and pollution loads through riverine inflows, direct discharges and atmospheric deposition are reasons to the lack of oxygen, extensive eutrophication and contamination. Dead bottoms areas vary over time. However the recovering of extremely damage basins is slow. Surface water layer instead is most exposed to meteorological conditions. Precipitation and wind play an important role in the distribution of nutrients and pollutants while seasonal temperature fluctuations in combination with nitrogen and phosphate concentration make the Baltic Sea vulnerable to algal blooming.

Centuries of anthropogenic activity in the Baltic Sea drainage basin (Figure 1) have converted the unique environment of the Baltic Sea into a threatened ecosystem. Pollution can be dated back to Middle Ages when humans settled down in coastal areas. However, pollution in the Baltic Sea region was first recognized as a human driven environmental problem in the 1950's. After World War II, industrialization in the catchment areas was followed by rapid population growth, excessive consumption and waste discharges. Special are the intensification of agricultural systems and the discharge of municipal and industrial wastewaters originating directly from coastal zones and catchment areas as well as atmospheric deposition of pollutants transported from long distant sources.

Differences in persistent eutrophication levels between the basins of the Baltic Sea can be explained by the relation between the resilience and recovery of local aquatic ecosystems in cohesion with regional variation of anthropogenic and natural nutrient loads. Large forestry and extensive rural areas surround the Gulf of Bothnia making it as one of the basins with lowest human induced eutrophication. The conditions are completely different for the Gulf of Finland and the Baltic Proper. This part of the Baltic Sea is high densely populated with runoff from intensive agriculture with large livestock holdings and insufficiently pretreated municipalities wastewaters. Heavy toxic and hazardous pollution originates principally from industrial activities settled directly in coastal zones and catchment areas. Atmospheric load from long distant sources and riverine loads from catchment areas also contribute to the bad water quality and decreasing fish stocks during the last decades. In the Gulf of Riga the biological incapability to absorb nutrient loads depends most of the particular low salinity and shallow bay of the basin. Besides, the nutrient loads contributing to an accelerated eutrophication rate, the main problem is the industrial discharge of heavy metals from the catchment area. Finally, in the South basins, Belt Sea, the Sound and Kattegat conditions on coastal waters depend principally on nitrogen and phosphate concentration where the harm of eutrophication is seasonally related. During winter the major nitrogen runoff reaches the open waters and algal production is a common phenomenon occurring during the spring. As a result of eutrophication marine life has suffered large-scale damage.

Figure 1: The Baltic Sea drainage basin

A significantly progress in the reduction of nutrients towards a healthier Baltic Sea have been leading by marine research, regional collaboration, national action plans, resulting in the development of policy instruments, international laws and agreements (*i.e.* HELCOM, EU Framework Directives, EU Policy instruments, UNFCCC, Helsinki Convention). The overall phosphorus loads into the Baltic Sea have been reduced in about 50 % since the 1970's. The main reasons behind the reduction of phosphorus loads are the identification of pollution Hot spots in the early 1990's, leading to major investments in improved municipal and industrial wastewaters directly located in coastal zones and catchment areas, especially from the city of St. Petersburg, Baltic countries and Poland. About 95 % of the phosphorus load is waterborne (e.g. riverine and direct load), for which 56 % originates from point sources and municipal wastewaters treatment plants stand for 90 % of the total pollution originating from point sources (Figure 2).

Unfortunately, figures on the reduction of nitrogen inputs are not as encouraging as those for phosphorus. Waterborne nitrogen loads is estimated to be 75 % of the total nitrogen inflows (Figure 2) for which 71 % originates from diffuse pollution sources and agriculture stands for 80 % of it. Atmospheric nitrogen deposition arising from long distance source, transport, shipping and agriculture stand for 25 % of the total nitrogen inputs (Figure 3). During the last decade nitrogen input is slightly increasing due to increased use of fertilizers in agricultural activities.

Eutrophication expressed as an excessive algae bloom is one of the most serious environmental threats facing the Baltic Sea

Hence requirements on good agro-environmental practices and new investments in wastewater abatement technologies are needed to achieve a good ecological and environmental status of the Baltic Sea.

According to the nutrient reduction target agreement at the HELCOM meeting in 2013, particularly the Baltic Proper and the Gulf of Finland are in need of further phosphorus and nitrogen reductions while the Kattegat and the Danish straits are in need of nitrogen reduction and the Gulf of Riga of phosphorus reduction. Country allocated reduction targets including EU-20 for transboundary emissions, suggest that major nutrient reductions are required from Poland and Russia, followed by Sweden, Lithuania and Germany.

Figure 2: Waterborne nutrient inputs into the Baltic Sea according to HELCOM 2009

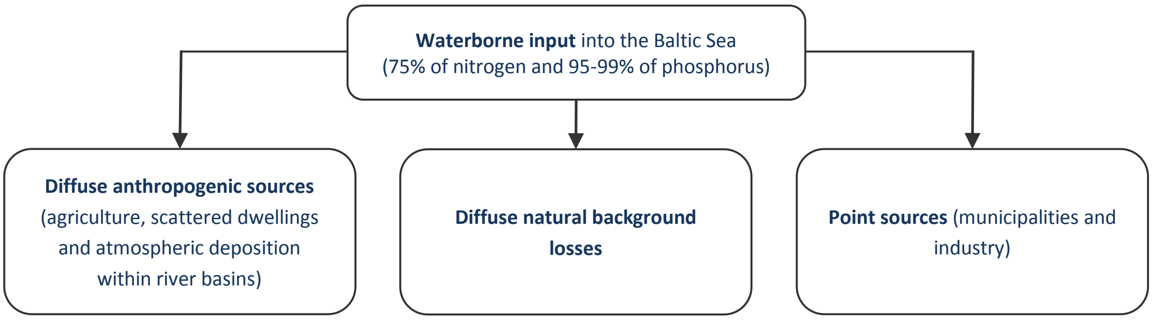
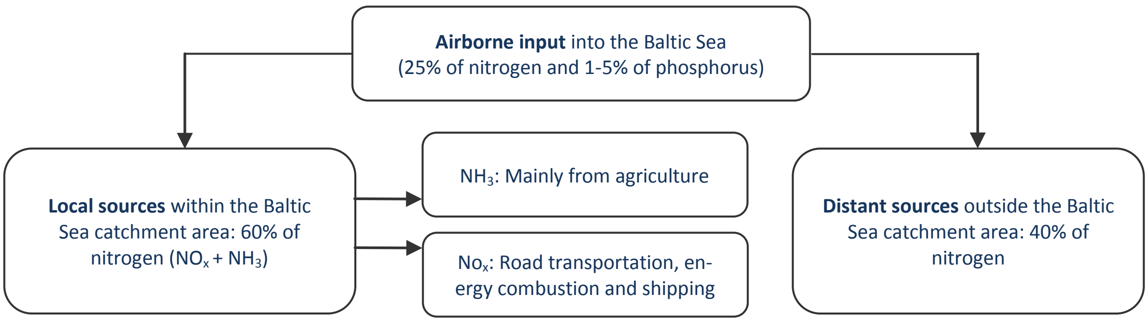


Figure 3: Airborne nutrient inputs into the Baltic Sea according to HELCOM 2009



Diffuse pollution sources

Agriculture

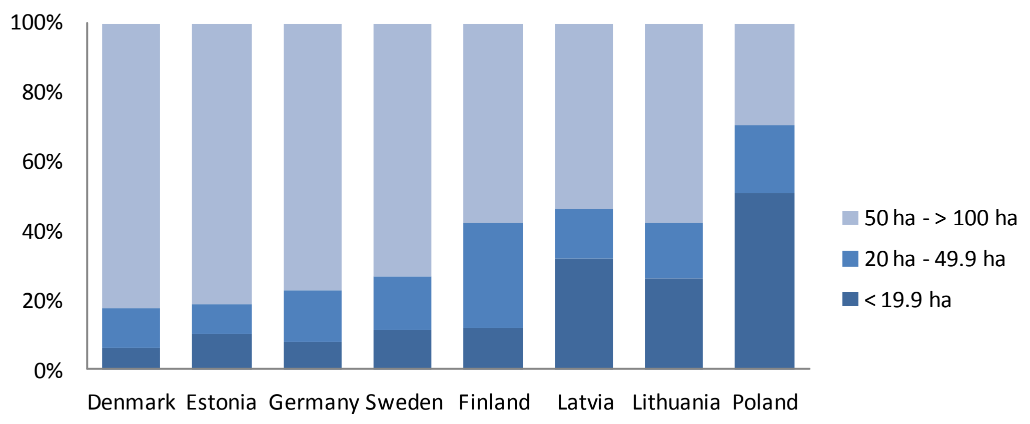
The intensification of the agricultural industrialism in Europe started after the World War II. The European Common Agricultural Policy was officially institutionalized in the early 1960's stating as main priorities to produce enough of food and to strength farmers' economic feasibility by protectionism. Policy regulations were directly aiming to increase land productivity through farm specialization. In practice, measures involved the use of inorganic fertilizers and pesticides in order to raise yields and a high concentration of livestock holdings. Conclusively, policy subsidies were compensating an excess use of nutrient inputs, surplus of agricultural products and environmental unsustainability. Today the agricultural sector is the main diffuse source of pollution in the Baltic Sea region.

The increasing demand on agricultural goods including the production of renewable energy such as energy crops has intensified the pressure on local and global ecosystems claiming the recognition of environmental impacts in policy statements. From the early 1990's several reforms on the Common Agricultural Policy in cohesion with EU's directives have been taking place. Environmental quality-oriented policy regulations and incentives have been outlined basically based on the relationship between agricultural management and ecosystem protection to provide an indication of the pressure on the environment. The implementation of good agro-environmental practices promotes efficient utilization of resources to limit local and global environmental pressures as well as investments in environmental protection allowing economic sustainability in the Baltic Sea region.

While a similar trend on agricultural production among the region facilitates the support of local ecosystem services, differences in structural, institutional and socioeconomic features between countries are a barrier to achieving common agreements. The wide diversification of farming systems, small vs. large farms using intensive vs. extensive productions, has given rise to major structural changes in reaching common targets to prevent the emergence of an industrialized mono-cultural agriculture as a result of a cost efficient oriented farming. Especially is the discrepancy between agricultural and environmental goals on farm structures. Agricultural policy emphasizes large farms to attain economies of scale while small farms are seen as an obstacle for agricultural development and for the implementation and control of good agro-environmental practices. However, a greater biodiversity in small farms than in large farms, even between organic small and large farms (Belfrage, Björklund and Salomonsson, 2005; Weibull, Bengtsson and Nohlgren, 2000; Chamberlain, Wilson, and Fuller. 1999).

Among Baltic Sea countries agricultural land cultivation area is distributed between farms in a range of less than 2 ha and far more than 100 ha. Large farms between 50 ha and over than 100 ha stand for 58 % of agricultural land use. Particularly Denmark, Estonia, Germany and Sweden are characterized by large agricultural holding that utilize most of the agricultural land in these countries (Figure 4). In Finland most of the land is used by farms are in the range of 20 ha – to over than 100 ha. Latvia and Lithuania show a mixture of small and large farms while in Poland quite small field parcels still stand for 51 % of the utilization of agricultural area.

Figure 4: Utilization of agricultural land area as a share of size of agricultural holdings in the Baltic Sea region, 2010. Source: Based on data from Eurostat, http://appsso.eurostat.ec.europa.eu.



Structural changes in the agricultural sector, as changes in the number of farms and size, have been a major reason to socioeconomic impacts in some countries without major impacts on the total utilization of agricultural land. Between 2007 and 2010, in Poland the number of holdings has decreased by 37 % reducing the utilized agricultural area by only 7 %. Simultaneously the number of workers in small farms has decreased by 39 % where only 12 % of them were reallocated into large farms (Figure 5). In Estonia, Latvia and Lithuania the number of holdings decreased at a slightly increasing of the utilization of agricultural area, where only Lithuania successfully reallocated labor force from small into large farms. For Sweden a slightly opposite trend is observed, farm workers are reallocated from large farms into small farms.

Figure 5: Changes in labor force in three different farm sizes and number of agricultural holdings in the Baltic Sea region, 2007-2010. Source: Based on data from Eurostat, http://appsso.eurostat.ec.europa.eu.

Changing agricultural practices from intensive to more extensive production requires knowledge on efficient use of input resources and appropriate technology to prevent pollution from agricultural sources. One successful institutional regulation is the designation of nitrate vulnerable zones by the EU directive. Denmark, Finland, Germany and Lithuania have designated 100 % of the territory as sensitive to agricultural nitrate pollution while regional designations are in Estonia 7.18 %, Latvia 12.8 %, Poland 4.54 % and Sweden 22.08 %. The EU directive works in consolidation with national action plans towards the implementation of good agro-environmental practices regulated by country specific official goals, legislation and subsidies. However, the degree of implementation between countries differs primarily on the relationship between incentives and legal requirements but even on traditional agricultural practices. Although, measures regulated by legislation and economic subsidy are also decreasing agricultural nutrient loads. However, the degree of implementation at farm levels is highly dependent on individual investment capacity, willingness to invest as well as farmers' skills and engagement on agro-environmental practices. Some examples of successful regulations towards agro-environmental practices with different levels of legal restrictions (national, regional and none) and different degrees of economic subsidies (more than 100 %, less than 100 % or 50 %, or none) undertaken by countries in the Baltic Sea region are presented below (Tables a-f):

Tables a-f: Managerial practice has a direct effect on the reduction of both nitrogen and phosphorus from surface run-off.
Source: Baltic Sea report, April 2012

a. Vegetative cover in autumn and winter on arable land

	DK	EE	FI	DE	LV	LT	PL	SE
Legislation	National	National	no	Regional	Regional	no	Regional	Regional
Subsidy	no	<100%	>100%	<100%	>100%	100%	<100%	100%

b. Adapting the amounts of chemical fertilizer and manure applied

	DK	EE	FI	DE	LV	LT	PL	SE
Legislation	National	National	no	National	Regional	National	Regional	Regional
Subsidy	no	<100%	>100%	no	yes	no	<100%	<100%

c. Avoiding the spreading of chemical fertilizers and manure during high-risk periods

	DK	EE	FI	DE	LV	LT	PL	SE
Legislation	National	National	no	National	National	National	Regional	Regional
Subsidy	no	no	>100%	no	yes	no	no	no

d. Avoiding the application of chemical fertilizers and manure to high-risk areas

	DK	EE	FI	DE	LV	LT	PL	SE
Legislation	no	Regional	National	National	National	National	Regional	Regional
Subsidy	yes	no	>100%	no	no	no	no	no

e. Manure storage

	DK	EE	FI	DE	LV	LT	PL	SE
Legislation	National	National	National	Regional	National	National	National	Regional
Subsidy	no	<50%	no	no	<50%	<50%	no	<50%

f. Buffer zones along water areas and erosion sensitive field areas

	DK	EE	FI	DE	LV	LT	PL	SE
Legislation	National	National	no	Regional	National	no	Regional	no
Subsidy	yes	no	100%	<100%	<100%	<100%	<100%	100%

The governance of institutional regulations is highly dependent on farmers' physical and economic ability to perform changes in production. Indicators on the intensification and specialization of agriculture at farm levels are frequently measures on changes in cropping patterns and livestock patterns. Agricultural practices may be beneficial or harmful depending on the resilience of local ecosystems. Mono-cultural agriculture is more dependent on chemical fertilizers with a high risk for nutrient loss, while in organic farming the risk of nutrient leaching is smaller. One of the major threats to waters and air quality is livestock density in interaction with manure practices and pastoral land since the dependence on import of animal fodder. Permanent grassland is most important for nature conservation given that the land is extensively managed.

Between the years 2007 and 2010, the general agricultural development in the Baltic Sea region is positively changing towards less environmental pressure. For countries in the Baltic Sea region there is a reduction in the utilized agricultural area, except of in Estonia, Lithuania and Poland. The area of arable land in Lithuania increased by 17% and in Poland decreased by 8 %. Slightly reductions in arable land are observed in Denmark, Germany and Sweden while in Estonia, Latvia and Finland arable land is slightly increasing.

However, major changes are in the conversion of minor areas from permanent grassland and meadow to permanent crops. Denmark, Germany, Lithuania, Poland and Finland show a similar trend for decreasing permanent grassland and meadow at an increasing rate of permanent cropland. In Estonia and Sweden both permanent grassland and meadow and permanent cropland are decreasing. Interesting is the trend in Latvia where permanent grassland and meadow increases by 44% reducing permanent cropland area by about 52 %. It has been a reduction on livestock density, indicating a less intensive animal breeding, in all countries except of Denmark and Germany, while grazing livestock is decreasing in Germany, Lithuania, Poland, Finland and Sweden. Another sign of a more extensive production is the share of organic farming area, which is increasing in the entire region, especially in Poland, Estonia and Sweden. Figure 6 and Figure 7 illustrate changes in agricultural patterns for countries in the Baltic Sea region.

Figure 6: Changes in utilization of agricultural area in the Baltic Sea region, 2007-2010
Source: Based on data from Eurostat, http://appsso.eurostat.ec.europa.eu.

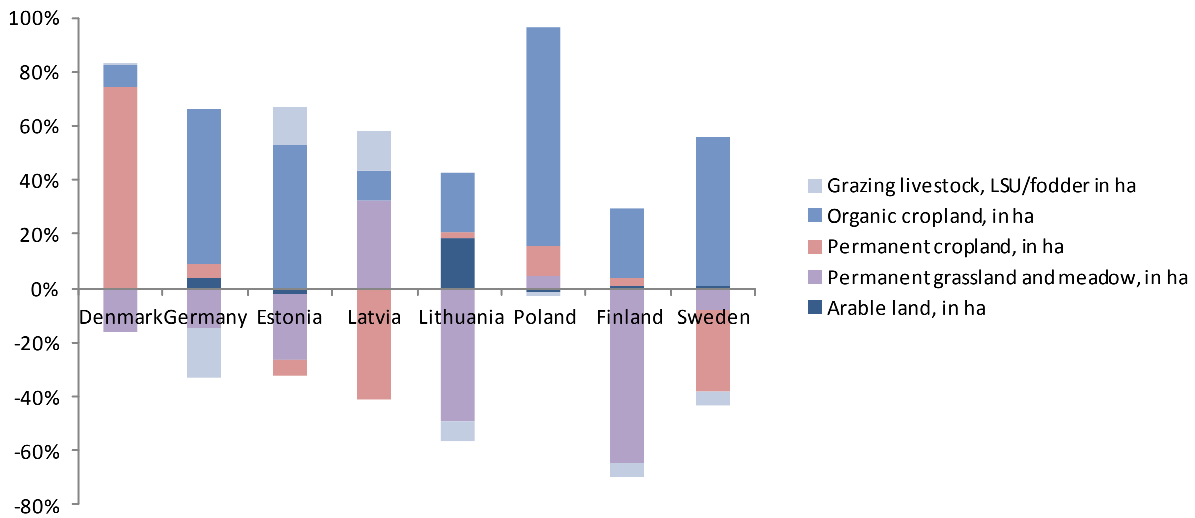
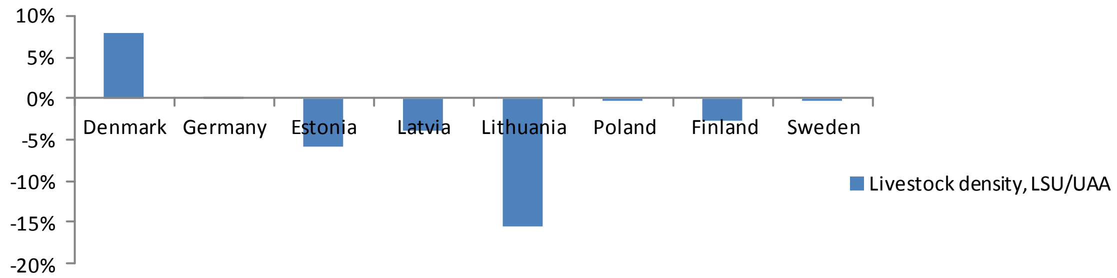
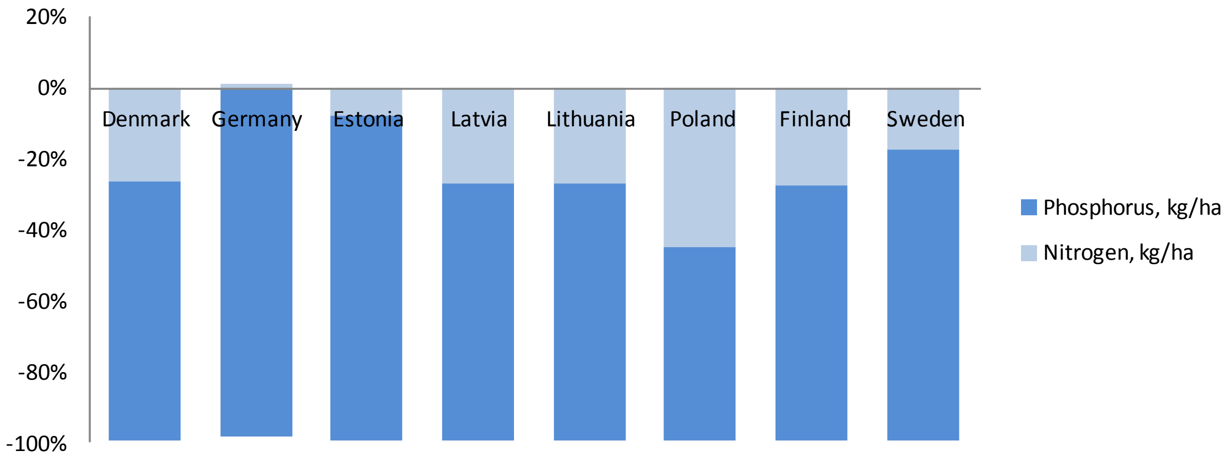


Figure 7: Changes in livestock density in the Baltic Sea region, 2007-2010
Source: Based on data from Eurostat, http://appsso.eurostat.ec.europa.eu.



Even if there is not a clear pattern on the changes in agriculture the amount of nitrogen and phosphorus application onto agricultural land is decreasing in the Baltic Sea region during the period 2007-2010, (Figure 8). Nutrient surplus is a potential threat to water and air quality while a lack of nitrogen and phosphorus may be a reason of soil degradation. Information on nitrogen and phosphorus applications includes inorganic fertilizers and manure as well as various types of crop productions in arable land, permanent crops and permanent grassland.

Figure 8: Changes in nitrogen and phosphorus application in kg/ha of arable land area in the Baltic Sea region in 2007-2010. Source: Based on data from Eurostat, http://appsso.eurostat.ec.europa.eu.



Atmospheric deposition

Due to travelling distances and a variety of sources, airborne pollutants are a complex matter. Approximately one third (AirClim, 2014) of the pollutants, nutrients and hazardous substances, entering into the Baltic Sea are also transported through atmospheric deposition. The main airborne nutrient contributing to eutrophication is nitrogen. Nitrogen compounds directly affect human's health and ecosystems. The residence time of nitrogen in the atmosphere varies depending on nitrogen components and their availability to transform before these are removed from the atmosphere by precipitation. Nitrogen is released into the air as nitrogen oxides and ammonia in equally portions. The origin of nitrogen oxides is mainly from fuel combustible, shipping and road transportation but also from other point pollution sources such as manufacturing and energy industries, wastewater treatment plants and households. High concentration levels of nitrogen oxides causes acid rain affecting nutrient concentration in the sea and in extensive areas nitrate deposition infiltrates into the groundwater. Most of the ammonia is coming from the agricultural sector. Especially from concentrated livestock holdings in connection with manure storage, slurry spreading and the use of inorganic fertilizers. However, ammonia is not transported long distances and most of the pollution arises from catchment areas, while nitrogen oxides originate from both catchment areas, Baltic shipping and thousands of kilometers long distant sources.

The concern on atmospheric deposition can be traced back to the 1960's. First by the recognition of the interrelationship between sulphur emissions in Central Europe and the acidification of Scandinavian lakes followed by the proof of long distant air pollutants travelling several kilometers before deposition and damage. Several decades of international cooperation between political systems and the introduction of international environmental laws have resulted in the introduction of agreements on emission ceilings among EU-member states and HELCOM-partners to reduce damages from transboundary air pollution. Between 1990 and 2010 nitrogen oxides and ammonia in atmospheric deposition has decreased by 47 % and 28 %, respectively.

Nutrient deposition is constantly changing over time and positively correlated with changes in economic activities and regulations towards point sources related to the Baltic Sea catchment areas as the rest of the world. The growing scientific understanding about airborne emissions and the access to monitoring data on emission loads and sources has facilitated the definition and implementation of policy regulations. Both economic growth and population growth has followed the same trend during the last decades. However, actual growth has been at higher rates than in forecasting national environmental ceilings, while the use of fossil fuels increased only 7.5 %, which is less than the 20 % applied for the projections used at that time leading to higher environmental benefits from actions applied. That is since the accelerating increasing in technology advance in many economic sectors including the increasing substitution of fossil fuels with renewable energy sources in combustion engines. Similar outcomes credit the agricultural sector where the use of inorganic fertilizers and the livestock numbers were also lower than the ones assumed in the projections. In this case reductions in nutrient loads are attributed to good agro-environmental practices and new technology investments.

Even if overall atmospheric nitrogen deposition has been reduced during the last decades, there are still countries having difficulties in achieving national environmental ceilings. For the Baltic Sea catchment area Germany and Poland are the largest emitters of nitrogen. However Poland is among the countries meeting the national environmental ceilings (see Table 1).

Table 1: Emissions of nitrogen oxides (NO_x), ammonia (NH_3) and National Emission Ceilings (NEC), measures in Gg, from EU-member states in the catchment area of the Baltic Sea, 2012. Source: EEA Technical report No 10/2014

Country	NOx	NOxNEC	NH_3	NH_3NEC
Denmark	115	127	71	69
Estonia	32	60	11	29
Finland	154	170	37	31
Germany	1273	1051	545	550
Latvia	35	61	19	44
Lithuania	58	110	38	84
Poland	817	879	263	468
Sweden	131	148	51	57

Long distant nitrogen sources affecting eutrophication in the Baltic Sea stands for around 40 % of the total nitrogen deposition. France, the United Kingdom, the Netherlands, Italy and the Czech Republic are main contributors to emission loads on the Belt Sea and Kattegat sub basins of the Baltic Sea. Table 2 presents some of the emissions loads from long distant sources.

The accelerated technological progress in finding new renewable energy sources during the last decades and agro-environmental practices in the agricultural sector in cohesion with institutional regulations are one of the major explanations to the reduction of nitrogen depositions from governing sources.

Table 2: Emissions of nitrogen oxides (NO_x), ammonia (NH_3) and National Emission Ceilings (NEC), measures in Gg, from long distant sources EU-member states to the Baltic Sea, 2012. Source: EEA Technical report No 10/2014

Country	NOx	NOxNEC	NH_3	NH_3NEC
France	983	810	679	780
United Kingdom	1062	1167	277	297
Netherlands	248	260	120	128
Italy	909	990	405	419
Czech Republic	210	286	63	80

Point pollution sources

Aeration tank – a structure in which wastewater and activated sludge are mixed and aerated

Industry

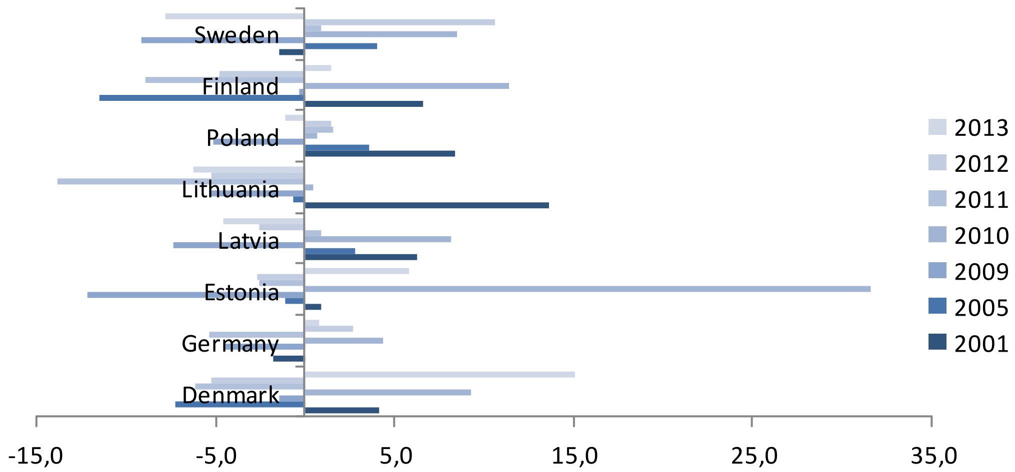
Point sources, mixed industrial and municipal discharges, contribute for total waterborne load by 12 % of nitrogen and 20 % of phosphorus with municipalities as the main pollution source 90 % (HELCOM, 2014). This positive development since the 1990's is the improvement by monitoring and controlling point-pollution sources in the Baltic Sea region, so called "Hot Spots". The definition of Hot Spots is based on three criteria; the economic importance of the industry, the impact on environmental pressure and human health.

The industry sector confronts a significant challenge in environmental management depending on their scale, diversity and locality. Poland, Russia and Finland have made major investments on wastewater treatment plants, food processing as well as pulp and paper industries, reducing nitrogen and phosphorus load with 32 % and 36 %, respectively between 1994 and 2013 (HELCOM, 2014).

Industrial production plays an important role in the economic development of the Baltic Sea region. The industry sector is the main contributor to national income and a major source of employment. The development pattern in the industry sector has been relatively constant during the last 20 years, where the service industry stands for the main contribution to GDP followed by the manufacturing industry. Considering the contribution to environmental pressure in relation to economic output, the primary industry as agriculture, forestry and fisheries, manufacturing, transportation and communication services as well as the energy industry in the supply of electricity, water and gas are the main contributors to environmental emissions.

For the production of homogenous goods such as transportation and communication services as well as the supply of electricity, water and gas differences between countries can be observed due to different levels of technology and energy sources. In Germany transportation services show a negative relationship between an increased vehicle fleet at a decreasing emission rate. Similar is the low environmental pressure from the Swedish production of electricity depending on the use of nuclear and hydropower, while in Denmark, Germany and Poland the use of coal in the energy sector is still relatively high. However, the introduction of wind power and natural gas is taken place in many European countries, such as Denmark and Germany. The energy industry is positively correlated with the development of manufacturing, where Figure 9 shows a recently great expansion in Estonia, Finland, Denmark and Sweden.

Figure 9: Volume index of production in the supply of electricity, gas and water. Percentage change compared to same period in previous year. Source: Based on data from Eurostat, http://appsso.eurostat.ec.europa.eu.



The primary industry, transportation and energy industries play a minor role in the contribution to national income with a modest contribution to employment at high emission loads. However, the manufacturing industry that is also contributing to airborne and waterborne emissions has an important role for the GDP and employment in each country.

A typical explanation to high emission loads from the manufacturing industry is a low-output level produced by low-technology where the contribution to total emissions is high per unit produced while high-output levels produced by high-technology also contributes to total emissions due to a total higher produced quantity.

Also significant economic recessions experienced in Europe and the rest of the World has contributed to lower industrial emission loads as a general decrease on industrial production at increasing unemployment rates. Especially painful for many countries in transition to market economies was the necessity of technology replacements by new private financed investments.

Figure 10 shows the volume index of high and low technology production in the manufacturing industry as the percentage change compared to the previous year. The above figure shows the high-technology manufacturing industry in 2001-2013. Most of the countries remain constant production volumes, except of Estonia showing increasing high-technology manufacturing outputs in 2010 and 2011. Interesting is the effect of the recently economic crisis in the low-technology (the below figure) manufacturing industry where Estonia has probably shift from low-technology to high-technology between 2009 and 2010. There is however a general production decline between 2009-2010 where Sweden and Germany were having minor effects of the economic crisis.

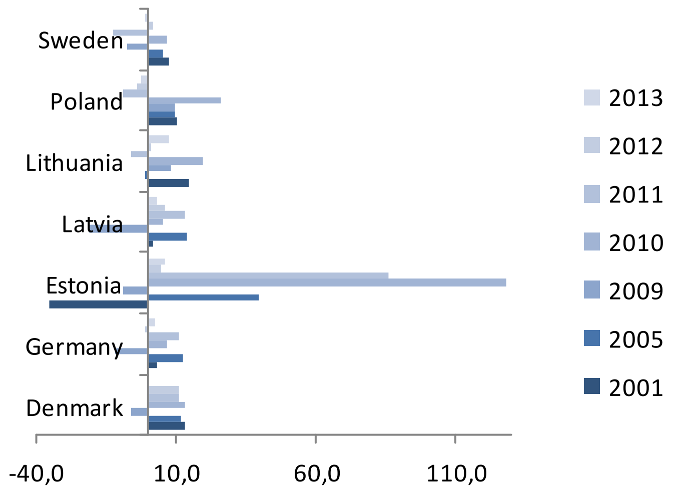
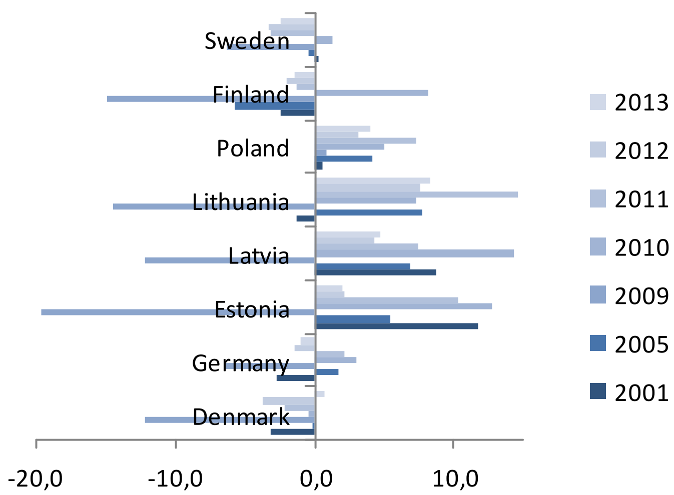


Figure 10: Volume index of production in percentage change compared to same period in previous year, high-technology (above) and low-technology (below) manufacturing. Source: Based on data from Eurostat, http://appsso.eurostat.ec.europa.eu.

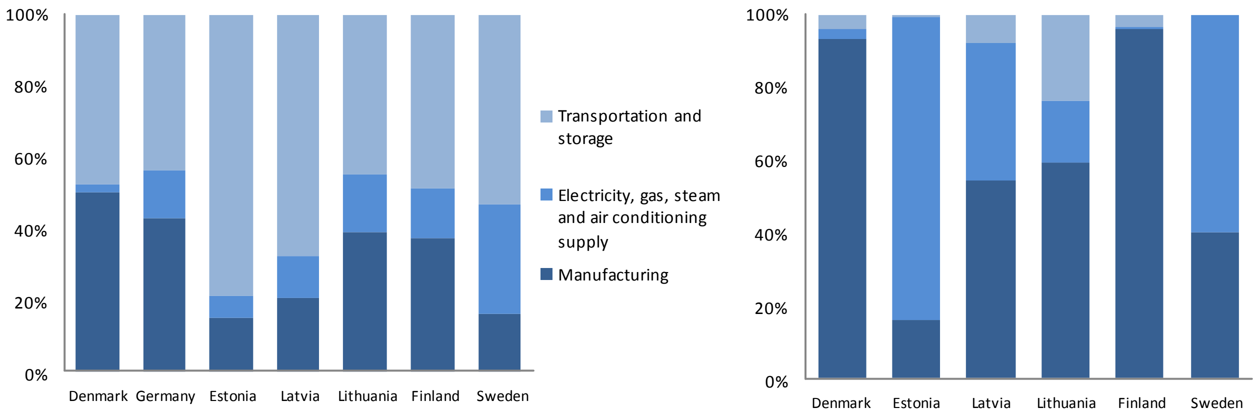


Policy instruments *i.e.* taxes, charges and tradable permits – promoting new investments on abatement technologies and revenues for environmental protection – are easy to implement on point-pollution sources.

Figure 11 shows the share of implementation in three categories of industrial sectors: the manufacturing, electricity, gas, steam and air conditioning supply, and transportation and storage of energy taxes and pollution taxes in 2011. Energy taxes include CO_2 taxes. The tax for transport using petrol and diesel and for stationary purposes the use of fuel oils, natural gas, coal and electricity (European Union, 2010). Energy taxes differ between countries and industry sectors depending on each countries taxation policies but also on several driving forces. A low energy tax can be attributed to technological advances making production less energy intensive.

The pollution taxes include estimated emissions to the air and water as well as on the management on waste and on noise (European Union, 2010). These are more frequently implemented in the manufacturing industry in Denmark and Finland as well as in the supply of electricity, gas, steam and air conditioning in Sweden and Estonia. Low tax revenue can be a sign of a stringent environmental protection, where changes in tax revenue can be attributed to a more environmental friendly production.

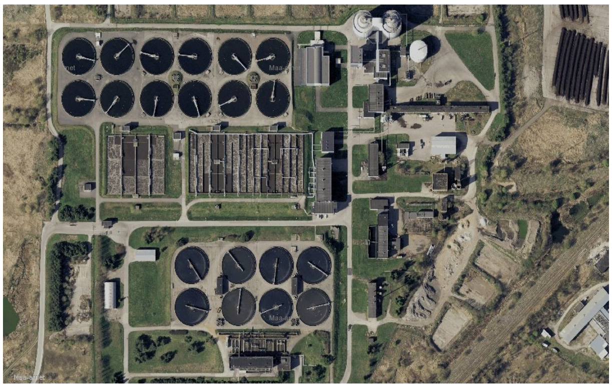
Figure 11: Shares of implementation in the manufacturing, electricity, gas, steam and air conditioning supply and transportation and storage of energy taxes (left) and pollution taxes (right) in 2011.
Source: Based on data from Eurostat, http://appsso.eurostat.ec.europa.eu.



Wastewater treatment plants

Most of the population is concentrated to only 0.8 % of the total Baltic Sea catchment area. Denmark, Poland and Germany are the most densely populated. High-populated urban areas in combination with industrial production are major sources of pollution. Although, rural areas with poor or no treatment of sewage discharges also contributes to pollution loads into the Baltic Sea.

In general there are three different treatments of wastewater. The primary treatment is a mechanical removal of coarse debris and part of the suspended solids, while secondary treatment uses biological decomposition. By aerobic or anaerobic microorganisms organic matter can be decomposed up to 90 % retaining nutrients up to 20-30 %. The advanced tertiary treatment removes the organic matter more efficiently where more than 80 % of phosphorus and 50-90 % of nitrogen can be removed. Most of the countries show a higher share of tertiary treatments implying a high level of the recovering of nutrients (Table 3).



Large-scale WWTPs commonly involve various processes for handling of large amounts (hundreds of thousands of PEs) of wastewaters

However, the most advanced removal of phosphorus and nitrogen by using the tertiary treatment is most commonly in Germany, Sweden and Denmark. The total number of urban wastewater treatment plants and the share of three treatment methods are presented in Table 3.

Table 3: Total number of urban wastewater treatment plants and the share treatment methods (in %) for countries in the Baltic Sea catchment area, in 2011. Source: Based on data from Eurostat, http://appsso.eurostat.ec.europa.eu.

Country	Total Urban WWTPs	Primary treatment	Secondary treatment	Tertiary treatment	Unspecified treatment
Denmark*	4 998	2.7%	2.7%	94.8%	0%
Germany*	78 857	0%	3.1%	95.8%	1%
Estonia	1 086	0.7%	16.3%	83.1%	0%
Latvia**	1 431	0.5%	38.6%	58.8%	2%
Lithuania	2 228	0%	4.4%	84.8%	11%
Poland	25 314	0.2%	20.2%	79.5%	0%
Finland	4 461	0%	0%	100%	0%
Sweden*	8 126	0%	4.6%	95.4%	0%

Information is for the years * 2010 and ** 2007

Wastewater treatment plants are considered to be one of the most cost efficient measures to reduce pollution loads, in both the removal of phosphorus and nitrogen. However, municipalities plants are one of the largest contributors of waterborne nutrient input to the Baltic Sea, accounting for 70-90 % of total direct nitrogen and phosphorus discharges. The HELCOM classification of Hot Spots includes 75 wastewater treatment plants, where 52 municipal and industrial facilities have been already deleted from the list. Still, there are plants in need of upgrading.

The effectiveness of wastewater treatment varies significantly between cities and countries. One of the reasons is the difference in financing wastewater management. The government, business sector, private and the public specialized producers of environmental protection services are held responsible for environmental expenditures on wastewater management. The private and public specialized producers of environmental protection services finance 54% of the expenditures while the government and the business sector stand for 23 % each, indicating a high degree of privatization of wastewater treatment plants among countries in the Baltic Sea region. Germany is the country with the highest environmental expenditure on wastewater management, followed by Poland and Finland. In Sweden wastewater management is primary financed by the business sector while in Denmark are the private and public specialized producers of environmental protection services. The investments in Estonia, Latvia and Lithuania are modest compared with the other countries, where the major expenditures are from the government and private and public specialized producers of environmental protection services. The business sector is less representative in water management probably due to the lack of investment capital. Experiences about privatization are mixed among countries depending on the investment capacity in the private sector. However, new investments require capital funding but also knowledge.

The value added of the sewage sludge generated in wastewater treatments plants provides several uses as inputs in the production of energy, fertilizer and nutrient recycling. However, there are differences among national legislation and policies restricting the use of sewage sludge depending on the content of various hazardous substances in the wastewaters and on how to recycle nutrients. Besides, legal restrictions, main factors affecting the recycling of sewage sludge are the applied technology for recovering of nutrients depending on the quality of incoming wastewaters. The market demand for sludge is also a determining factor. However, recycling nutrients is an international debate since the world's mineral resources of phosphorus are depleting. In the countries of the Baltic Sea region the production of sewage sludge arising from urban wastewaters treatment plants has been relatively constant during the last ten years. Most of the uses are in agriculture, compost and incineration (Table 4).

Table 4: Sludge production (in thousand tons of dry matter) and sludge disposal (in %) from urban wastewater treatment plants, for countries in the Baltic Sea catchment area, in 2011.
Source: Based on data from Eurostat http://appsso.eurostat.ec.europa.eu.

Country	**Sludge Production**	**Sludge Disposal**				
	TOTAL	Agricultural use	Compist and others	Landfill	Incineration	Other
Denmark*	141	52%	0%	1%	24%	4%
Germany*	1 780	32%	18%	0%	60%	0%
Estonia	18	6%	83%	11%	0%	0%
Latvia**	22	36%	9%	9%	0%	50%
Lithuania	52	19%	21%	0%	0%	0%
Poland	519	22%	6%	10%	8%	54%
Finland	149	5%	89%	3%	0%	0%
Sweden*	204	25%	32%	4%	1%	38%

Information is for the years * 2010 and ** 2007

Concluding remarks

The vast research literature related to anthropogenic activities and theirs environmental effects on the status of the Baltic Sea shows major actions, legislations, policy measures and market-oriented solutions having significantly positive results on the environmental health of aquatic ecosystems as pollution is notably reduced.

The biological complexity of the Baltic Sea is in need of long- and short-term recovery measures, which are equally complex as the solutions required on pollution sources for a reduction of emission loads. Major measures are unfortunately directly in discrepancy between productivity- and environmental international and national targets needed to attain social welfare at a competitive economic growth in the region.

The positive development in the industry sector in a competitive market regulated by environmental regulations and consumers' demand on environmental friendly production depends on the own embedded economic incentives for new investments in abatement technologies. The changes in the industry sector create employments and capital formation, which are needed for social welfare and economic growth.

The major sources of pollution are the agricultural sector, municipalities and industries. Structural changes in the agricultural sector and in urban infrastructures require high capital investments in new technologies and knowledge transfer. Both can be attained under market competitive conditions however at different social costs. The agricultural sector contributions to the GDP as well as the employment opportunities are very modest in relation to other industry sectors in the economy. In regard to how our society has developed from an agricultural, to industrial and now to a service society, the value of the agricultural sector accredits not only a contribution to the GDP but also a cultural traditional value.

Most of the structural changes in the agricultural sector towards environmental improvements require capital investment and knowledge on new production processes. The consequences in the agricultural sector in those countries where society changes directly from an agricultural to a service society strikes against low-income classes creating gaps in social welfare. The investment capacity, especially for parcels where there is a big need in human capital, is one of the more restricted against intensive-oriented farms. However, the implementation of good agro-environmental practices in combination with economic incentives is an efficient and market competitive solution. In a situation of free market competition, production externalities can be internalized at cost efficient solutions.

Under the last ten years considerable investments have taking place on wastewater treatment plants. There is however a broad variation between countries and cities on reaching abatement targets. That is, depending on the available technology in coherence with the incoming nutrients and hazardous substances in wastewater inflows. However, there is a general need among countries of upgrading existing facilities. The necessity of upgrading treatment plants in combination with new competitive innovations on abatement technologies makes wastewater management to a potential competitive market.

Wastewater treatment is already considered as one of the major cost effective abatement techniques. That is, having relative low abatement costs compared with other industry sectors in the economy, e.g. control of diffuse agricultural losses, and high benefits on aquatic ecosystems in the Baltic Sea. The privatization of wastewater treatment plants requires human capital. Also capital investments on new technologies can bring private economic profits to the industry by the recovering of nutrients from sewage sludge. Recycling nutrients as input factors in the production of renewable energy and agriculture reduces the use of fossil fuels and commercial fertilizers. The process is a closed recycling system. One of the major problems today is however solutions on how to separate nutrients from hazardous waste. The economic incentive in finding cost efficient abatement processes brings not only environmental benefits in terms of higher levels of abatement but also capital formation for new investments and creating jobs' opportunities. Overall lower emission loads, including other industries securing a sustainable economic growth as the population and thereby consumption in catchment areas is increasing.

A cost effective solution will be where the abatement costs are low and the impact of the abatement on the state of the sea is large. A cost effective solution for the recovering of the Baltic Sea with a multitude of different ecosystems requires locally adjusted technical solutions depending on the status and resilience of local ecosystems as well as on socioeconomic consequences of the implemented measures.

The need of on going research on abatement and recycling technologies is required in the development of cost efficient solutions, both for a sustainable economic growth, social and environmental benefits in the Baltic Sea region. There is also a need of better statistical data in order to see the effects of measure implementation to facilitate determining productivity and environmental goals in catchment areas.

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