Costs of nutrient reductions to the Baltic Sea- technical report.

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Abstract: This paper presents calculations of costs for measures reducing nitrogen and/or phosphorous loads to the Baltic Sea and minimum cost solutions for different nutrient reduction target formulations. In total, 14 measures are included for nitrogen (N) reductions and 12 for phosphorous (P) reduction, out of which six measures affect both nutrients. Calculations show that land use measures provide low cost measures for N reductions and P free detergents and improved sewage cleaning for P reductions. Two types of targets are chosen for calculation of minimum cost solutions: overall reductions of nutrient to the Baltic Sea and reductions to specific basins. Three different assumptions on adjustments among basins to exogenous load changes are made for basin specific targets; no adjustment, partial first-order adjustment, and total steady state adjustment. For a given nutrient reduction in percent, both estimated total cost and cost effective allocation of reduction in loads to different basins vary considerably depending on target setting. However, costs of different measures, and thereby estimated minimum cost solutions are sensitive to parameter values on leaching, retention, and abatement cost and capacity. Sensitivity analyses show that minimum costs of nitrogen reductions are mainly affected by changes in assumed abatement capacity of land use measures, and costs of phosphorus reductions are sensitive to cleaning cost at sewage treatment plants.

Key words: cost effectiveness, nutrient reductions, Baltic Sea, heterogeneous marine basins

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1. Introduction

Damages from eutrophication in the Baltic Sea have been documented since early 1960s by a number of different studies (e.g. Wulff et al. 2001). The riparian countries also showed concern by, among other things, the manifestation of the administrative body Helcom in charge of policies for improving Baltic Sea since 1974, and ministerial agreements in 1988 and 2007. However, in spite of long-term monitoring, political concern, and improved scientific understanding of the functioning of the sea, degradation of the sea continues. One important reason for the hesitation to reduce nutrient loads to the Baltic Sea is by all likelihood associated costs, which now start to increase at a higher rate than earlier since the low cost options, such as improvement in nutrient cleaning at sewage treatment plants located at the coastal waters of the Sea, have been implemented in several countries. Therefore, careful cost calculations are now likely to more important than earlier. This implies, in turn, precision in target formulation since minimum cost of nutrient reductions depends on abatement cost of different measures and their location in the drainage basins. The purpose of this study is to present calculations of costs of measures reducing nutrient loads to the Baltic Sea for different target formulations as expressed in, among others, the Baltic Sea Action Plan presented at the ministerial meeting in November 2007 (Helcom, 2007).

Cost effective nutrient reductions are defined as minimum cost solutions to pre-specified targets, which can be expressed in nutrient reductions to different basins in the Baltic Sea or as overall decreases. This implies calculations of costs and impacts of a number of different measures affecting the nutrient loads to the Baltic Sea, and a minimum cost solution most often implies a combination of different measures located in different drainage basins. In spite of the relatively large scientific research on the Baltic Sea there are surprisingly few large scale empirical economic studies that analyse and calculate such cost effective nutrient reductions to the Baltic Sea (Gren et al., 1997; Elofsson, 1999; Turner et al., 1999; Gren, 2001; Gren and Folmer, 2003; Elofsson, 2006; Gren, 2007). None of these studies calculate and compare minimum costs for different target formulations with respect to overall nutrient reductions or decreases in loads to one or several specific basins.

This study makes use of all possible previous studies for calculation of costs of different measures reducing water and airborne nitrogen and phosphorous loads from agricultural, industry, and sewage (Gren et al., 1995; Gren et al., 1997; Elofsson, 2000; COWI, 2007; Shou et al., 2007). One difference as compared to Gren et al. 1995 and 1997 is the extension of measures reducing phosphorous loads, which is due to the relatively recent recognition of the role of phosphorous for eutrophication (Boesch et al., 2006). This study differs from COWI (2007) and Shou et al. (2007) with respect to consideration of linkages among different types of measures, such as the impact of changes in airborne deposition on the abatement capacity of land use measures. Furthermore, this study includes additional abatement measures, such as private sewers.

The paper is organised as follows. First, calculations of emissions and nutrient loads to the Baltic Sea are presented. Next, costs and impacts of different measures are presented, which is followed by a chapter presenting cost effective solutions to different targets. Specific attention is given to impacts on costs of different assumptions on adjustment processes in the Baltic Sea basins to changes in external nutrient loads. Furthermore, cost calculations are made for targets recently suggested by Helcom, which specifies nitrogen and phosphorous reductions to specific marine basins (Helcom, 2007). The report ends with a brief summary and main conclusions.

2. Emission sources and nutrient loads to and within the Baltic Sea

The entire drainage basin is divided into 24 basins (see Figure 1) for which nutrient emissions, costs and impacts of different measures are calculated. The choice of drainage basins is based on availability of data on emissions, leaching into waters, transports from the emission sources to the coastal waters of the Baltic Sea, division of marine basins in the Baltic Sea, and on costs of alternative measures.

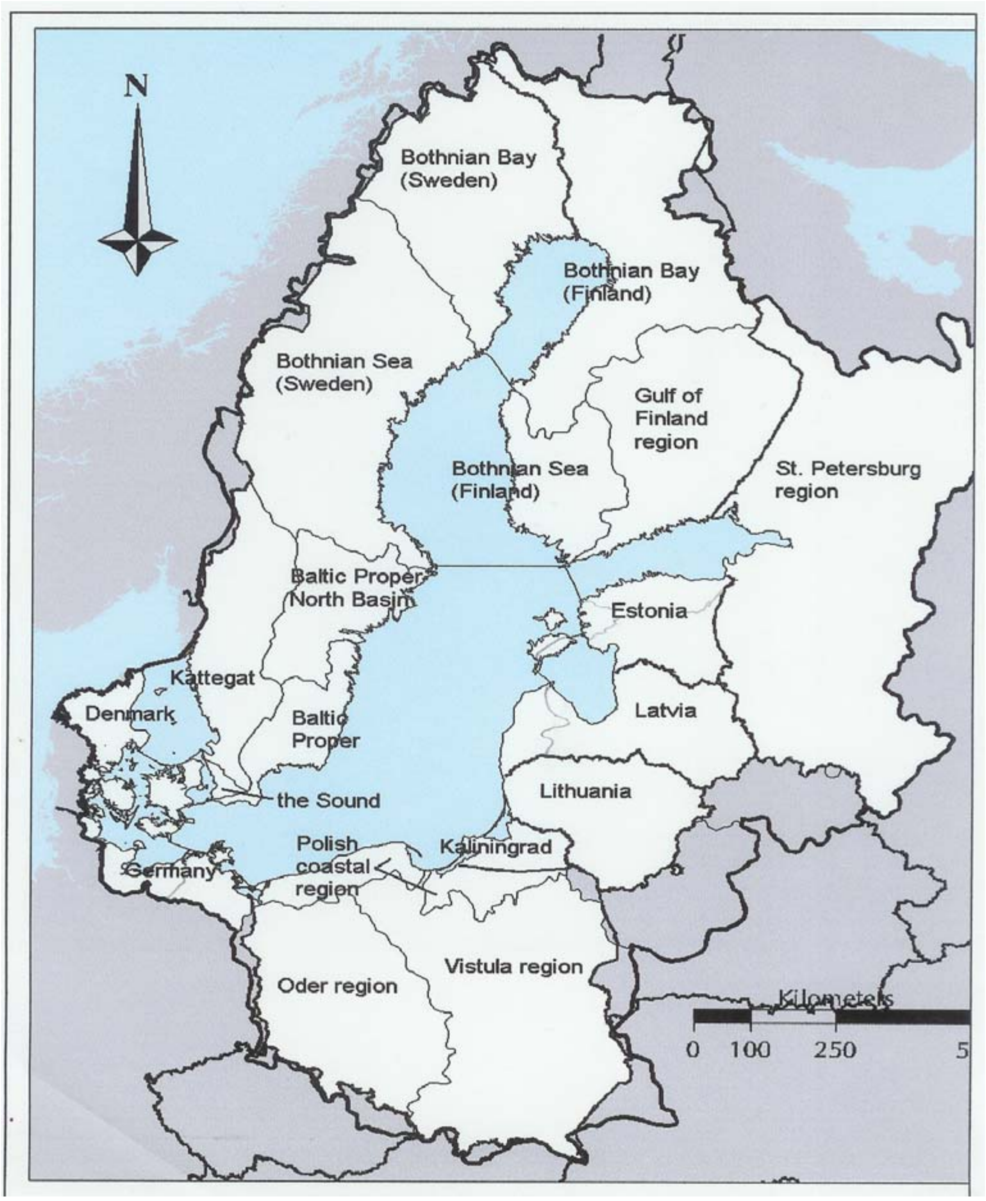


Figure 1: Drainage basins of the Baltic Sea (originally from Elofsson, 2003). (Drainage basins in Denmark (2), Germany (2), Latvia (2), and Estonia (3) are not provided with names, but are delineated only by fine lines)

Loadings of all emission sources to the Baltic Sea are calculated by means of data on emissions, which is sufficient for sources with direct discharges into the Baltic Sea, such as industry and sewage treatment plant located by the coast and air deposition. For all other sources further data is needed on the transformation of nutrients from the emission source to the coastal waters. This requires data on transports of airborne emissions among drainage basins, leaching and retention for all sources with deposition on land within the drainage basins, and on retention for upstream sources with discharges into water streams. Following Gren et al. (1997) the main emission sources included in the report are stationary combustion sources, traffic, ships, agriculture, industry, and sewage from households.

Airborne emissions are obtained from EMEP (2007), which reports transnational transports, direct discharges into the Baltic Sea, emission of N from the Baltic Sea, and deposition of N from nitrogen oxides and ammonia on the Baltic Sea and on the territories of riparian countries in 2005. A limitation is made in this study by including nutrient loads which can be affected by measures implemented in the drainage basins of the Baltic Sea. This includes all air deposition on land, but only air deposition on the Baltic Sea that originates from Baltic Sea drainage basin. In total, approximately 60 per cent of all total nitrogen load on the Baltic Sea drainage basin originates from riparian countries. When calculating leaching and final transports of nitrogen into the Baltic Sea, it is assumed that the leaching from non-arable land corresponds to half of the leaching from arable land. EMEP (2007) presents transboundary nitrogen oxides and ammonia emissions among countries, and not drainage basins. In order to obtain transport coefficients for drainage basins, the national coefficients for nitrogen oxides are divided among drainage basins within a country according to total area of land, and the national coefficients for ammonia are allocated according to area of arable land. All used data for calculation of airborne loads entering Baltic Sea is presented in Tables A1, A4-A7 in Appendix A.

Emissions from the agricultural sector is calculated from data on use of fertilizers per ha, holdings of livestock – cattle, pigs, and poultry, per ha, nutrient content in the different animals, and land use in the 24 different regions (see Tables A1 and A2 in Appendix A). Loads from arable land are then estimated by means of leaching and retention data presented in Table A1, Appendix A.

Discharges of N and P from households are estimated based on data on annual emission per capita in different regions, and on connections of populations to sewage treatment plants with different cleaning capacities (Table A3, Appendix A). Associated loads to the Baltic Sea are then calculated by combining emission data with nutrient retention in Table A1, Appendix A.

Calculated loads of nitrogen and phosphorous from all sources are presented in Table 1.

Table 1: Calculated allocation of N and P discharges into Baltic Sea from different Sources and countries, thousand tons of N and P in 2005

Country	*Nitrogen:*				*Phosphorous:*		
	Air	*Sewage*	*Agriculture*	*Total*	*Sewage*	*Agricult.*	*Total*
Denmark	20	3	21	44	0.5	0.6	1.1
Finland	18	9	22	49	0.8	0.9	1.7
Germany	11	4	31	46	0.2	0.3	0.5
Poland	71	41	206	318	11.0	10.0	22.0
Sweden	22	14	37	74	1.0	0.6	1.6
Estonia	6	4	46	56	0.3	1.3	1.6
Latvia	9	4	31	44	1.0	2.0	3.0
Lithuania	17	4	72	93	1.1	2.4	3.5
Russia	47	15	22	83	2.7	1.3	4.0
Baltic Sea[1]	18			18			
Total	*239*	*98*	*487*	*824*	*19.6*	*19.3*	*38.9*

1) Direct deposition on the sea from emission sources operating at the sea.
Sources: see Tables B1 and B2 in Appendix.

The largest single source of nutrient load is the agricultural sector in Poland, which accounts for approximately 25 per cent of total load of both nitrogen and phosphorous. In total, nitrogen load from Poland accounts for almost 40 per cent of total load. The next largest country source is Lithuania, followed by Russia. The main reasons for the relatively large load from Lithuania are high levels of airborne deposition, intensive agriculture, and low retention of nitrogen.

The estimated results reported in Table 1 can be compared with two other sources of similar estimates, but for other time periods (Helcom, 2004, 2007). Helcom (2004) presents calculations of nutrient loads for the year 2000 and Helcom (2007) show average loads for the period 1997-2003. This is one reason why both estimated total loads of nitrogen and phosphorous and allocation of loads between countries differ among the three estimates, which are presented in Table B3 in Appendix B. Another reason is the difference in calculation methods. Our total estimates are most close to the Helcom (2004) results, but the allocation of loads among countries is more similar to the Helcom (2007) calculations. A common result to all three calculation sources is the dominance of Polish loads of nitrogen and phosphorous.

In order to calculate cost effective solutions to targets on maximum load to different basins of the Baltic Sea, associated calculated loads are required. However, depending on assumptions of adjustments among basins to exogenous changes in loads from any drainage basins three different loads to basins are identified in this study; direct loads from own drainage basins, relatively rapid first-order adjustment and long-term final adjustment. Direct loads from own drainage basins are reported in B1 and B2 in Appendix B. However, due to the responses in the Baltic Sea to exogenous changes in loads to one or several of the basins, direct loads are not sufficient for assessing biological responses as measured in sigh depth changes due to exogenous load changes. Since total adjustments to a change in nutrient loads may take decades, it can be of interest to look at loads in different basins after first-order adjustments which occur relatively rapidly. Such loads after first-order adjustment are calculated by means of transport coefficients between basins. These coefficients show the shares of transport to a basin *j* of total load in basin *i*. The final adjustment, so called steady state, represents final adjustments where spread of impacts and repercussions among basins are accounted for.

Coefficients of first-order adjustments are obtained from Gren and Wulff (2004) and transport coefficients for final adjustment are found in Savchuk (2005) (see Tables A13 and A14 in Appendix A). Coefficients of airborne direct dischargers into different basins are obtained from Helcom (2005) and presented in Table A7 in Appendix A). Calculated direct discharges, and allocations of nutrients from first order responses and steady state solutions are presented in Table 2.

Table 2: Calculated nutrient load transports to different basins of the Baltic Sea under different response scenarios of the Sea.

Basin	*Nitrogen; Direct kton N*	*%*	*First-order response %*	*Steady state %*	*Phosphorous; Direct kton P*	*%*	*First-order response %*	*Steady state %*
Bothnian Bay	25.4	3.1	0.7	2.4	0.66	1.7	1.30	0.8
Bothnian Sea	35.8	4.4	19.4	12.1	0.91	2.4	19.9	11.8
Baltic Proper	504.3	61.2	36.1	46.1	27.3	71.0	19.5	26.6
Gulf of Finland	116.7	14.2	10.3	9.1	5.08	13.2	22.2	5.8
Gulf of Riga	46.4	5.6	3.8	3.3	2.67	7.0	3.5	2.0
The Sound	54.2	6.6	23.0	16.3	0.74	2.9	30.7	29.7
Kattegat	41.0	5.0	6.7	10.7	1.13	1.9	2.9	23.4
Total	823.7	100	100	100	38.91	100	100	100

The direct loads reported in Table 2 show that approximately 61 percent of total nitrogen load and 71 per cent of total phosphorous loads enter the Baltic Proper. When comparing these shares with similar estimates from two similar Helcom sources, the estimated shares in Table2 to the Baltic Proper are relatively high, while the shares to Bothnian Bay, Bothnian Sea and Kattegat are relatively low (see Table B4 in Appendix B). It is interesting to note the considerable change in shares when accounting for the first-order adjustments. Since Baltic Proper is a relatively open basin with transports of nutrients to and from several other basins, its share of total load is reduced after first-order adjustment, but it is increased after all adjustments have taken place.

3. Costs of alternative measures

One purpose of this paper is to calculate cost effective solutions for different nutrient targets to the Baltic Sea, where cost effectiveness is defined as that allocation of abatement measures in different countries which generates the target at the least overall cost. The condition for this is that marginal costs of all measures are equal. As long as marginal costs differ it is always possible to reallocate abatement and obtain the same target but at a lower cost. This is made by reducing cleaning at the relatively high cost measure and increasing it by the same amount by the low cost measures.

Marginal costs of nutrient reductions to the Baltic Sea or any of its basins consist of two main parts: cost for the measure and its impact on the Sea target. The importance of both this components is illustrated in a simple example. Assume two sewage treatment plants, A and B, which are exactly the same and thereby have the same cost of increased cleaning of nutrients, say, SEK 50/kg N reduction. The plants differ only with respect to their locations, where A is located at the coast of the Sea and B is located upstream. The nitrogen retention rate for the upstream located plant B is assumed to be 0.5. The marginal cost for 1 kg N reduction to the Sea is now determined by the marginal cost at the source divided by the impact. The impact of 1 kg N reduction from plant A is 1, and for plant B it is 0.5. This means that the marginal cost for nitrogen reductions to the Sea from plant A is SEK 50/kg N reduction and from plant B SEK 100/kg N reduction. The larger the impact for a given marginal cost at the source, the lower is the marginal cost of nitrogen reductions to the Sea, and vice versa.

In the simple numerical example, impacts of the two plants were given. However, since there is a dependency in impact on the Baltic Sea between different types of measures, the measures included in this study is divided into three main classes: reductions in nutrients at the source, reductions in leaching of nutrients into soil and water for given nutrient emission levels, and reductions in discharges into the Baltic Sea for given emissions at sources and leaching into soil and water. The first class includes, among others, reductions in nitrogen fertilizers, reductions in livestock, and changed spreading time of manure from autumn to spring time. Examples of the second class of measures are land use measures such as increased area of grass land and cultivation of catch crops. The third class of measures consists of construction of wetlands at river mouths along the coastal waters of the Baltic Sea.

The costs for the second and third classes consist of management cost and opportunity cost for a given area of land, which is independent of the leaching impacts. The cost of nutrient reductions then depends on the deposition of nutrient on land or nutrient load to a downstream wetland. The deposition, in turn, depends on the emissions from the sources, i.e. first class of measures, and, for wetlands, leaching into waters entering the wetland. The cost for leaching reduction, or nutrient abatement by wetlands, is then lower the higher is the emission if there is a positive correlation between leaching and deposition on land. This, in turn, means that marginal cost for nutrient reductions to the Baltic Sea increases for measures implemented at the emission sources since a decrease in emissions reduces the leaching impact, and hence cost of abatement, at the second and third classes of measures (see Gren et al. 1997 and Byström 1998 for formal derivations of these cost linkages). Such cost linkages have not been accounted for in studies such as Schou et al. (2006), and COWI (2007) and it is therefore likely that their estimates of marginal costs of single measures are biased.

This study includes 14 measures affecting nitrogen loads and 12 measures changing phosphorous loads, where a majority of the measures belong to the first class of measures affecting emissions at sources. However, before presenting calculations of costs for nutrient reductions at sources and to the Baltic Sea, a brief presentation is made on the approaches applied for the calculations.

3.1 General approach for cost calculations

Ideally, when calculating cost of an abatement measure, data is available of total costs for different reduction levels where total costs include two main components: net cleaning cost at the source and dispersion of impacts on the rest of the economy. Examples of cleaning cost at the source are expenses for increased cleaning at sewage treatment plants, foregone profits from decreases in the use of nitrogen fertilizers, and expenses for creation of wetlands. Net cleaning cost implies that all positive impacts in addition to the effect on nutrient reductions to the sea are included. For example, wetlands may act as sinks, not only for nutrients, but also for other pollutants such as heavy metals and they may also enhance biodiversity. This study does not account for any such side benefits of included measures, and the cost calculations can therefore be regarded as overestimate of actual costs.

Cleaning activities at firm levels in different sectors of the economy may give rise to impacts on other sectors and adjustments within the whole economy. So called computable general equilibrium (CGE) models can be applied for calculating final costs, including all adjustments among production sectors in the economy (e.g. Bergman, 2005). Such model approach is indeed appropriate for calculation of costs in sectors with relatively large shares of the total production in the economy which generate considerable dispersion impacts on the economy. However, the usefulness of the CGE is questionable for cost calculations of activities in primary production sectors with relatively small shares of total production, which is the case for agricultural sectors in several Baltic Sea countries (Brännlund and Kriström, 1996). Furthermore, another advantage with CGE models, consideration of trade linkages among the Baltic Sea countries, may not be applicable due to the small trade volume among the riparian countries (Johannesson and Randås, 2000).

An alternative to CGE models is then partial equilibrium approach which is a more simple and less data consuming approach, and can be carried out by using information on demand for inputs goods such as nitrogen fertilizers. Minimum costs for abatement by means of a measure, say fertilizer reduction or changes in land use, are then derived by imposing abatement requirements, such as restrictions on the use of an input, at different levels for the representative profit maximising firm. Adjustments take place, and the resulting reduction in profits show the minimum cost of obtaining different levels of cleaning. Adding abatement by a specific measure by all firms for different cost levels gives minimum cost curve as illustrated in Figure 2.

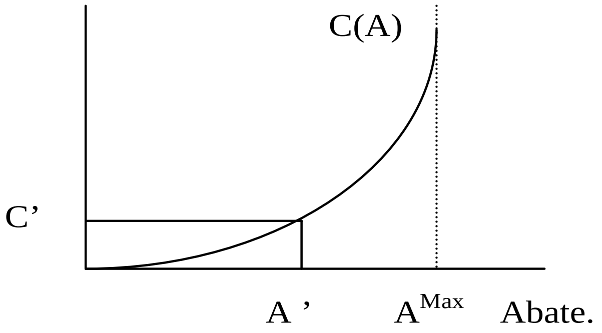


Figure 2: Illustration of minimum costs for different abatement levels by a specific measure

The curve $C(A)$ illustrates the cost curve for different levels of abatement requirement, and reflects the minimum cost solutions for each abatement level. For example, the minimum cost for obtaining A' corresponds to C'. The level A^{Max} shows the maximum level of abatement that is possible to obtain. This level depends on technological constraint and on the time perspective. In this paper, assumptions are made on no radical structural changes within the agricultural sectors which imply restrictions on decreases in livestock and fertilisers and changes in land use.

A third approach for calculations of cost for measures at the sources is the so-called engineering method, which calculates cost for a specific measure, say increased cleaning at sewage treatment plants or installation of selective catalytic reductions at combustion sources, based on the measures’ need for different inputs such as labour and capital, and given prices of these inputs. Constant unit abatement costs are then assumed, which results in linear cost curve as compared to the convex cost function as illustrated in Figure 2. In this study, partial equilibrium analysis is applied for reduction in fertilisers and engineering methods are applied for calculations of costs of all other measures.

In order to calculate marginal cost of measures for reductions in nutrient loads to the Baltic Sea, the estimated costs of cleaning measures are combined with data on impact on the Baltic Sea which occurs by nutrient transports in soil and water, in air, and, depending on target formulation, in marine basins. A common impact of all measures is that determined by nutrient transports in the Sea. Measures affecting airborne emission have the most involved ‘chain of impacts’, where reductions in airborne emissions have direct and indirect impacts on the Sea. The direct impacts consists of the share of emission that would have been deposited on the Sea, and the indirect impacts occur through decreases in dispersal of deposition on land within the entire drainage basin, which, in turn, generate less leaching and final transport to the Baltic Sea. Measures with direct impact on the Sea, such as increased cleaning at sewage treatment plants located by the coast, has the most simple ‘chain of impacts’, where the impact on the Sea corresponds to the reduction at the source.

3.2 Calculated marginal costs of reductions at emission sources

The first class of measures, reduction of nutrient at the emission sources, includes 9 nitrogen emission reduction measures and 7 measures for corresponding phosphorous reductions, see Table 3.

Table 3: Included measures reducing nutrient emissions at sources

N reduction (9 measures)	*P reduction (7 measures)*
Selective catalytic reduction (SCR) on power plants	
SCR on ships	
SCR on trucks	
Reductions in cattle, pigs, and poultry	Reductions in cattle, pigs, and poultry
Fertilizer reduction	Fertilizer reduction
Increased cleaning at sewage treatment plants	Increased cleaning at sewage treatment plants
Private sewers	Private sewers
	P free detergents

Costs for reductions in airborne emissions by SCR, change in spreading time of manure, increased cleaning at sewage treatment plants and private sewers in rural areas are calculated as annualised investment costs, which are obtained from (COWI, 2007) and (Shou et al., 2007). Cost estimates are documented in Tables A9 and A11 in Appendix A. Reduction in livestock holdings and decreases in nutrient fertilizers are calculated as associated losses in profits, and costs of P free detergents as increased production cost. Costs of P free detergents and reduction in livestock holdings are found in COWI (2007). Costs of reductions in nutrient fertilizers are calculated as associated decreases in producer surplus, which correspond to the cost curve illustrated in Figure 2. The costs have been calculated by means of estimated demand elasticities for nitrogen and phosphorous, data on price and use of fertilisers and assumption of linear demand curve. The slope of the linear demand function has been estimated by assumption of constant slope derived at actual price and purchases of fertilizers and the demand elasticities obtained from other studies (see Tables A2 and A9 in Appendix A).

Marginal costs for nutrient reductions to the coastal water of Baltic Sea are obtained by dividing the marginal costs at the sources with their impacts on the sea. The latter is determined by spread of airborne emissions of nitrogen oxides and ammonia, leaching from soils, and retention of nutrients during transports from the emission source to the Baltic Sea, for data see Tables A1, A4-A6 in Appendix A. Calculated marginal costs for reductions of nitrogen to the Baltic Sea are presented in Table 4.

Table 4: Calculated marginal costs per kg N reduction to the Baltic Sea from emission reduction measures at sources

	NOx	*Livestock*	*Fertiliser*	*Sewage*	*Private sewers*
Denmark	243 – 387	540 – 613	0 – 1451	141 – 331	509 – 565
Finland	246 – 396	282 – 552	0 – 394	141 – 419	509 – 717
Germany	444 – 755	532 – 634	0 – 410	141 – 451	509 – 771
Poland	314 – 528	314 – 416	0 – 108	113 – 448	429 – 766
Sweden	218 – 373	214 – 493	0 – 472	141 – 745	509 – 766
Estonia	224 – 374	213 – 325	0 – 65	113 – 325	429 – 557
Lithuania	254 – 418	64 - 134	0 – 24	113 – 386	429 – 780
Latvia	228 – 351	208 – 407	0 – 156	113 – 456	429 – 660
Russia	267 – 604	208 – 384	0 – 414	113 – 627	429 – 1072
Minimum cost per unit N reduction by SCR in ships including direct impact on the Baltic Sea and indirect on deposition on land in all drainage basins is SEK 19/kg N reduction.					

Sources: Tables C1, C2 in Appendix C. See Tables A9, A11, in appendix A for assumed capacity constraints

Both highest and lowest marginal costs are found for fertilizer reductions. The second lowest marginal cost occurs for sewage reductions and selective catalytic reduction on ships. It is also noted that marginal costs are relatively large for private sewers.

Corresponding calculations of marginal costs for phosphorous reductions to the Baltic Sea are reported in Table 5.

Table 5: Calculated marginal costs for phosphorous reductions to the Baltic Sea from emission reduction at sources

	P free detergents	*Livestock*	*Fertiliser*	*Sewage*	*Private sewers*
Denmark	104 – 434	23796 – 45189	0 – 102649	573 – 1271	2397 – 2445
Finland	138 – 493	9561 – 16288	0 – 11215	573 – 1683	2397 – 3239
Germany	255 – 1256	40451 – 56401	0 – 93506	573 – 3115	2397 – 5992
Poland	165 – 270	4673 – 5527	0 – 5180	385 – 1335	2013 – 3246
Sweden	102 – 941	11183 – 42687	0 – 38884	573 – 2350	2397 – 4522
Estonia	159 – 279	7271 – 8680	0 – 2613	385 – 1293	2013 – 3145
Lithuania	133 – 190	1120 – 1670	0 – 1503	385 – 1182	2013 – 2875
Latvia	170 – 340	4344 – 6106	0 – 2752	385 – 1380	2013 – 3355
Russia	124 – 426	9000 – 19570	0 – 19000	385 – 2070	2013 - 5032

Sources: Tables C3, C4 in Appendix C. See Tables A9 and A12 in Appendix A for capacity constraints

Similar to calculated marginal costs of nitrogen reductions, fertilizer reductions provide both low and high cost option depending on the level of fertilizer reduction. However, marginal costs of phosphorous decreases by livestock reductions are larger than corresponding costs for nitrogen reductions. Removal of P in detergents is a relatively low cost measure.

3.3 Marginal costs of measures affecting leaching and retention of nutrients.

This study includes five measures of the second and third classes, which affect leaching and retention of nitrogen and/or phosphorous, see Table 6.

Table 6: Included measures affecting leaching and retention

N reduction (5 measures)	*P reduction (5 measures)*
Catch crops	Catch crops
Energy forestry	Energy forestry
Grassland	Grassland
Creation of wetlands	Creation of wetlands
Changed spreading time of manure	
	Buffer strips

Costs of change in spreading time for manure from autumn to spring are calculated as annualised costs of investment in manure storage capacities. Costs for all other measures are calculated as profits, or rents, foregone from alternative land use. These costs are calculated as annualised values of market prices of arable land. Additional operational costs occur for energy forestry, catch crops, and creation of wetland, see Tables A8 and A10 in Appendix A. However, the marginal costs for nutrient reductions to the Baltic Sea by these measures are determined by their abatement capacity, which in turn depend on nutrient loads to the land use in question, which is endogenous in the model. Marginal costs for these measures are therefore calculated for the maximum load where no other measures are undertaken, and constitute therefore the minimum marginal costs, see results in Table 7.

Table 7: Calculated minimum marginal costs for nitrogen reductions to the Baltic Sea from measures affecting leaching and retention.

	Catch crop	*Grass land*	*Change spread of manure*	*Energy forest*	*Wetlands*
Denmark	290 – 299	974 – 1007	75	1036 – 1071	66 – 66
Finland	146 – 317	313 – 317	52	822 – 1022	11-139
Germany	113 – 327	324 – 327	136	583 – 588	23-25
Poland	82 – 106	88 – 96	71	118 – 139	10-11
Sweden	46 – 376	75 – 302	44 – 71	544 – 3487	75-2764
Estonia	58 – 80	57 – 58	58	107 – 109	48-67
Lithuania	71	20	55	107	20
Latvia	139 – 204	139 – 140	66	280 – 283	64-93
Russia	156 – 193	156 – 169	56 – 69	235 – 255	94-143

Sources: Tables C1 and C2 in Appendix C, and Table A10 for capacity constraints

The pattern of marginal costs is less clear for measures affecting leaching and retention than for emission oriented measures presented in Table 5. Although increased areas of grass land and energy forest seem to be relatively expensive for several countries, these options can also be relatively inexpensive in Poland, Estonia, and Lithuania. The relatively low marginal costs of nitrogen reductions by wetland construction is determined by the load to wetlands which includes airborne emissions and water borne nitrogen transports from all land leaching (not only arable land) and from sewage. These loads are in turn determined by leaching and retention in the drainage basin, which is one explanation to the low marginal costs in Lithuania where nitrogen retention is low.

When comparing the marginal costs of measures affecting leaching and retention with measures reducing nitrogen emission at source it can be seen that the former provides low cost option. This is not the case with measures and leaching and retention of phosphorous, which instead are large as compared to the emission oriented measures, see Table 8.

Table 8: Calculated minimum marginal costs for phosphorous reductions to the Baltic Sea from measures affecting leaching and retention.

	Catch crop	*Buffer strip*	*Wetlands*
Denmark	7455 – 9899	31067 – 37713	6992 – 8677
Finland	4933 – 5095	7419 – 8060	751 – 2363
Germany	1444 – 1873	6716 – 8529	2999 – 3870
Poland	2941 – 3239	2941 – 3239	456 – 679
Sweden	7366 – 66649	6784 – 66649	25805 – 63801
Estonia	19055 – 88657	2377 – 2574	6158 – 9127
Lithuania	4206	891	2405
Latvia	8074 – 62177	2156 – 2675	4232 – 5119
Russia	1417 – 1994	1786 – 2624	9010 – 10020

Sources: Table C4 in Appendix C, and Table A10 for capacity constraints

Buffer strips in Lithuania and wetland creation in Finland and Poland constitute the only measures for which marginal costs are in the same order of magnitude as the marginal cost of P free detergents and increased cleaning at sewage treatment plants.

A general conclusion when comparing marginal costs of N and P reductions for the two classes of measures is that marginal costs of measures affecting leaching and retention are relatively low for nitrogen while marginal costs of emission oriented measures are relatively low for phosphorous reductions. It is important to emphasise the sensitivity of the cost estimates with respect to data on leaching, retention, and discount rate when annualising investment costs, which is revealed by the sensitivity analyses carried out in Chapter 5.

4. Minimum cost of alternative nutrient reductions

Based on the data on load presented in Chapter 2 and on the cost estimates reported in Chapter 3, cost effective solutions for different targets are presented in this chapter. Two types of targets are then identified: overall reductions in nutrients to the Baltic Sea and reductions to specific target basins of the Sea. As will be demonstrated in this chapter, minimum costs can differ significantly for the same reduction as measured in per cent nutrient reductions depending on target formulation.

4.1 Cost effective reductions to coastal waters of the Baltic Sea

Minimum cost solutions for reduction targets ranging between 0 and 50 per cent for nitrogen and between 0 and 70 per cent for phosphourous reductions are presented in Figure 3

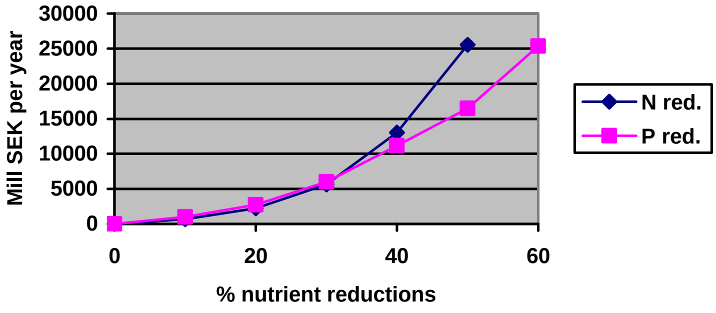


Figure 3: Minimum costs for different nitrogen and phosphorous reduction targets

Minimum costs for N and P reduction are in the same order of magnitude for reductions not exceeding 30 per cent. At larger reduction levels N decreases become more expensive and are approximately 60 per cent larger at the 50 per cent reduction requirement level. However, although the costs are almost the same for lower reduction levels, the cost effective allocation of measures differ. As reported in Chapter 3, fertilizer reductions and wetland creation are the least costly options for small nitrogen reductions, and at larger decreases installation of SCR on ships and cultivation of catch crops become cost effective measures. This can be seen from the reported marginal cost estimates of measures in Tables

4 and 7 in Chapter 3 and the shadow costs of the restriction obtained in the minimum cost solution, which is interpreted as the marginal cost at the targets and presented in Figure 4.

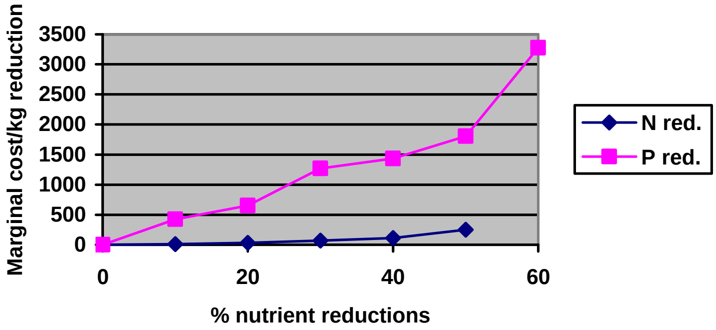


Figure 4: Shadow cost per kg N or P at different targets for nutrient reductions (source: see Table D1 in Appendix D)

As can be seen from Figure 4, shadow costs of phosphorous reductions are considerably higher than for the same nitrogen reduction as measured in per cent. The lowest cost options, which are included in cost effective solutions at less than 20 per cent P reductions, are increased cleaning at sewage treatment plants with direct discharges into the sea, fertiliser reductions, and removal of P in detergents. Land use changes such as wetland creation and cultivation of catch crops are part of the cost effective solutions at a minimum of 30 per cent reductions.

Common for cost effective solutions for both N and P reductions is that Poland makes an important cleaning contribution, and face the largest cleaning cost, see Table 9.

Table 9: Country nutrient reductions in per cent of initial loads and costs, in millions of SEK/year, for 20 per cent and 50 per cent overall reductions in N and P respectively.

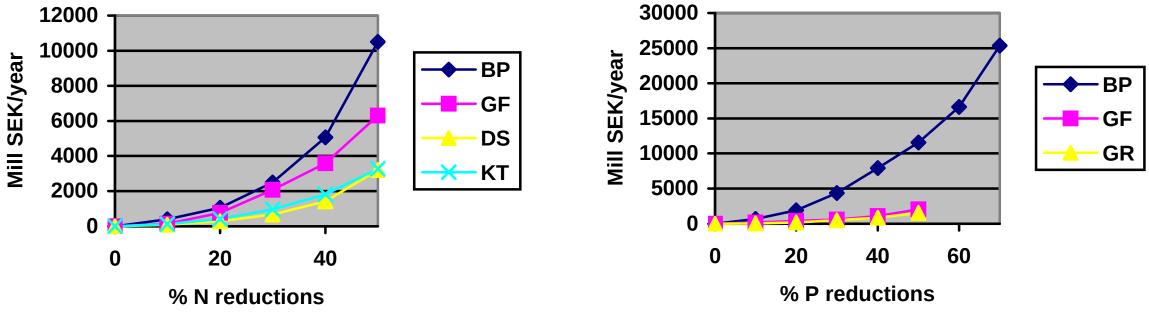
	Nitrogen:				*Phosphorous:*			
	20 %		*50 %*		*20 %*		*50 %*	
	% red	*Costs*	*% red*	*Costs*	*% red.*	*Costs*	*% red.*	*Costs*
Sweden	5.7	52	42.5	3843	20.2	186	48.1	512
Denmark	2.6	12	30.8	1182	3.4	45	58	574
Finland	8.7	58	37.7	1965	6.3	37	25.2	271
Poland	27.1	1197	55.5	12773	19.2	1444	56.4	11369
Estonia	24.7	329	63.1	2857	16.8	98	41.2	574
Latvia	8.6	54	48.4	2035	19.8	203	44.2	1179
Lithuania	38.4	729	55	2421	14.7	135	51	1242
Germany	10.3	111	44.1	1396	0.9	2	4.8	29
Russia	2.8	6.7	42.5	4313	39.5	692	44.2	941
Ships	0	0	50	250				
Total	20		50		20		50	

Poland, Estonia and Lithuania carry out reductions above the average requirement for both 20 and 50 per cent nitrogen decreases, which is due to the low cost options of wetland creation and nitrogen fertilizers reductions in these countries. Russia accounts for the relatively largest reductions of phosphorous discharges at the 20 per cent reduction level, and Poland meets the largest reductions in its own load at 50 per cent reductions. It is interesting to note that reductions of nutrients in all countries are required for cost effective solutions to both nutrients and reduction requirements.

4.2 Reductions to marine basins

However, it is unlikely that overall reductions of nutrient are the ultimate aim of eutrophication policies. Instead, the purpose is to achieve improvements in different basins of the Sea. According to Helcom (2007), nitrogen reductions are required to Baltic Proper, Gulf of Finland, Danish Straits, and to Kattegat. Phosphorous reductions are needed in order to improve the biological conditions in Baltic Proper, Gulf of Finland and to Gulf of Riga. As reported in Chapter 2, calculations of nutrient loads to these basins can be made under three different assumptions of adjustments among the basins; no adjustment which includes direct discharges from the own drainage basins, accounting for first-order adjustments between basins, and the steady state solution where all adjustments are made to changes in nutrient loads. As will be shown in this chapter, consideration of adjustment among basins can have considerable impacts on cost effective solutions with respect to total cost, shadow cost, and allocation of nutrient reductions among basins.

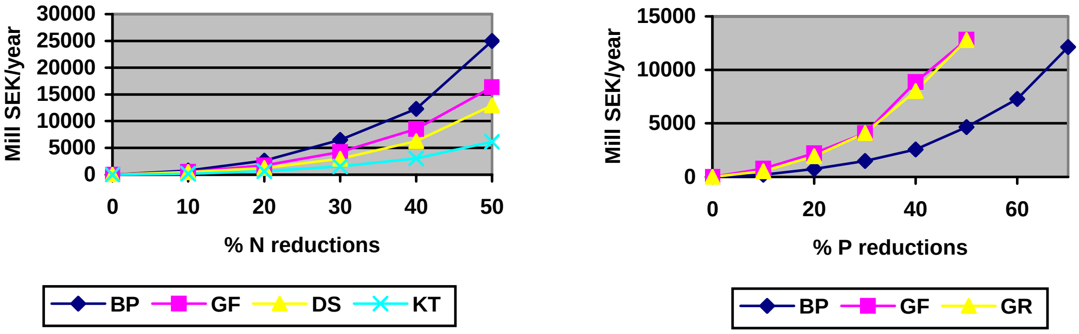
Starting with the consideration of only discharges to target basins from their own drainage basin, calculated minimum costs for N and P reductions show large differences for targets above 10 per cent reductions, see Figures 5 and 6 for presentations of minimum cost solutions for nitrogen and phosphorous reductions respectively.



Figures 5 and 6: Minimum costs of nitrogen and phosphorous reductions in direct discharges to target basins (source: see Table D2 in Appendix D)

Except for phosphorous reductions to the Baltic Proper, minimum costs are calculated for nutrient reductions up to 50 per cent. The choice of higher reduction levels of phosphourous to Baltic Proper is based on the required reductions pointed at in Helcom (2007). Costs are largest for nutrient reductions to the Baltic Proper, which is explained by the magnitude of loads to this basin from its drainage basins, see Table 2 in chapter 2. It can also be noted that the costs of N and P reductions to Baltic Proper are similar for the same reductions as measured in percent, which can be seen more clearly in Table D2 in Appendix D. However, nitrogen reductions to Gulf of Finland are approximately three times as expensive as corresponding phosphorus reductions which is explained by the availability of low cost options for phosphorous reductions by sewage treatment in the drainage basins of the Gulf.

When we instead calculate cost of nutrient reductions to the basins and account for the first-order adjustments to exogenous load changes among basins, which occur relatively rapidly, the cost patterns change, see Figures 7 and 8.

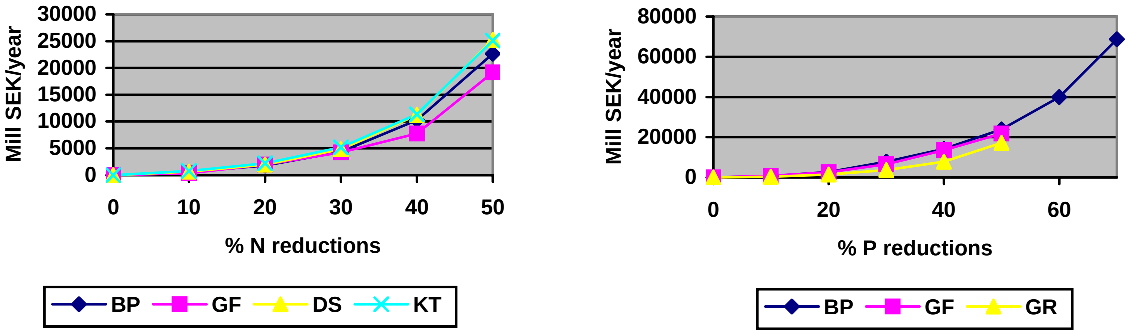


Figures 7 and 8: Minimum costs of nitrogen and phosphorous reductions to target basins when accounting for first-order adjustments among basins. (Source: Table D2 in Appendix D.)

Minimum costs for nitrogen reductions to all basins are now increased and those of phosphorous reductions are decreased as compared to the costs of reductions from the basins' own drainage areas. Another interesting feature is that the cost of phosphorous reductions to the Baltic Proper is less costly than corresponding reductions to Gulf of Finland and Gulf of Riga. The reason is that the large share of transports to other basins, which reduces the reduction requirements as measures on tonnes of phosphorous, see coefficients of transports among basins in Table A13 and A14 in Appendix A.

Not only do minimum costs for nutrient reduction change when moving from targets of reductions in basins' own drainage basin to consideration of first-order adjustments among basins, but also the cost effective allocation of reductions among basins. Cost effective reductions to the Baltic Proper at both 20 and 50 per cent reduction levels imply decreases in nitrogen discharges to all basins except for Bothnian Bay and Kattegat, see Table D3 in Appendix D where shadow costs of reduction requirements in the different basins are presented. These shadow costs vary between SEK 26/kg N reduction (Baltic Proper) and 73/kg N reduction (Bothnian Sea) for 20 per cent reduction to the Baltic Proper. It is interesting to note that targets of phosphorous reductions to the Baltic Proper is achieved by measures implemented, not in the drainage area of Baltic Proper, but in the drainage regions of Bothnian Sea, Gulf of Finland, Gulf of Riga, and Danish Straits. The reason is that all discharges of phosphorous to the Baltic Proper from its own drainage region are transported to other basins, see Table A14 in Appendix A. When considering nutrient targets to other basins than the Baltic Proper, such as nitrogen reductions to Kattegat and phosphorous decreases to Gulf of Riga, cost effective allocations of measures are more concentrated on fewer basins (Table D3, Appendix D).

When instead requiring reductions in final steady state, when all adjustments are made among basins, the costs for given percentage reductions are similar for different basins, see Figures 9 and 10.



Figures 9 and 10: Minimum costs of nitrogen and phosphorous reductions to target basins when accounting for first-order adjustments among basins.

The cost of N reductions are now slightly more expensive than corresponding P reductions. This is due to the fact that basins become more interconnected, and measures are therefore implemented in most of the basins for reaching targets in one of the basins. Measures for obtaining targets of nitrogen reductions to Baltic Proper or Kattegat should now be introduced in all Baltic Sea basins, see Table D3 in Appendix D. Shadow costs for nitrogen reductions by 20 per cent to the Baltic Proper vary between SEK 2/kg N reduction (Kattegat) and SEK 26/kg N reduction (Baltic Proper). Note that these shadow costs are considerably lower than those under the assumption of first-order adjustments, and also that their relative levels between basins differ.

However, so far separate targets for each basin have been considered where costs are minimized for achieving certain percentage reduction in one basin at the time. It would be misleading to sum the costs for target achievements in separate basins when considering achievement of target in several basins. In Figure 11, total minimum costs are presented for achievements of different percentage reductions of N and P reductions in all targeted basins simultaneously under different assumptions of adjustments among basins.

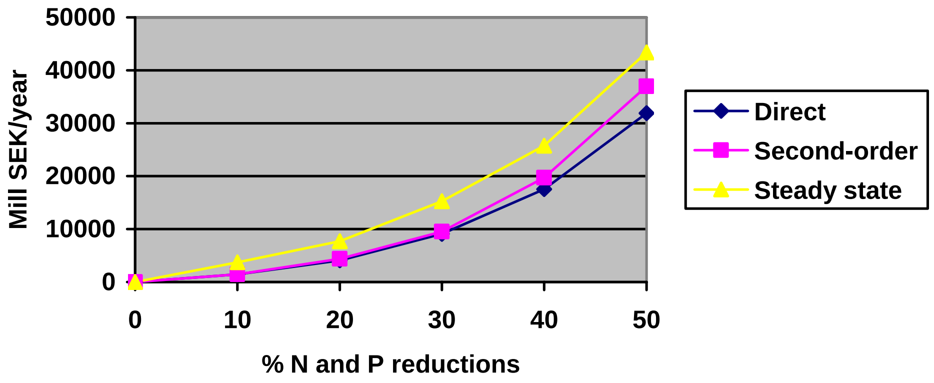


Figure 11: Minimum costs for constraints on all target basins under different assumptions of adjustments among basins in the Baltic Sea (Direct: discharges from the drainage area of the basins, Second-order: first adjustment among basins to changes in nutrient loads, Steady-state: final adjustments to nutrient load reduction.).

At reductions exceeding 10 per cent the minimum costs for reductions in steady state loads of nitrogen are approximately 30 per cent higher than the costs for reductions in discharges from the own drainage basins. Another difference between the two assumptions of connections among basins is that cost effective allocation of measures are implemented in all basins for nitrogen and for all basins but Danish Straits and Kattegat for phosphorous reductions under the assumption of steady state adjustments (see Table D4, Appendix D). It is also interesting to note the significant change in shadow cost for nutrient reductions to the different basins when moving from separate to simultaneous targets (Tables D3 and D4 in Appendix D). Under assumption of steady state adjustment the shadow costs of N and P to Baltic Proper is decreased by approximately 70 and 75 per cent respectively for 20 per cent reductions. On the other hand, shadow costs of nitrogen reductions to Danish Straits and Kattegat are increased at the 20 per cent reduction target. The reason is that the second class of measures, land use changes which affect both nitrogen and phosphorous reductions, are relatively inexpensive in the drainage regions of these basins (see Table C2, Appendix C).

5. Sensitivity analysis

Needless to say, calculations are uncertain due to the several assumptions with respect to biological, technological and economic parameters. The biological parameters include leaching and retention of nutrient from emission sources, which affect total load estimates and abatement impact of land use measures. Technological parameters refer to abatement capacity of emission oriented measures such as sewage treatment plants and selective catalytic reductions, and economic parameters are cost of measures at sources such as losses in profits from converting land to grass land or wetland.

The minimum cost solutions presented in Chapter 4 are affected by changes in biological parameters in two ways. Alterations in leaching and retention parameters imply changes in calculated total load of nutrients to the Baltic Sea, which, in turn, means that the same percentage reduction targets affect decreases as measured in tons. Furthermore, costs of all upstream located measures are affected. They are reduced when leaching increases and retention decreases and vice versa. Since these changes also generate higher or lower calculated loads, the net effect on minimum costs for a given target in per cent reduction is indeterminate. Total cost is reduced when the decrease in costs of measures is relatively larger than the required nutrient reductions. Impacts on minimum cost solutions for reductions in overall nutrient loads to the Baltic Sea from increases in leaching and retention by 10 per cent are presented in Figure 12.

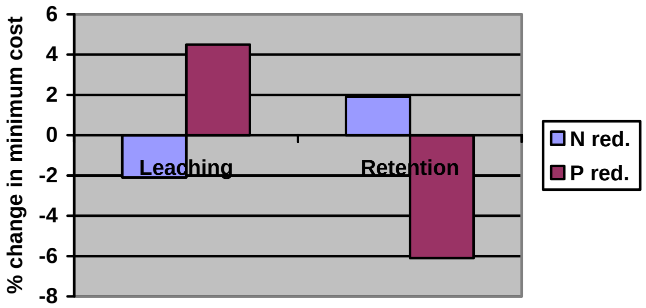


Figure 12: Changes in minimum costs for N and P reductions of 20 per cent from increases in nutrient leaching and retention by 10 % respectively (Table D5, Appendix D).

It can be seen from Figure 12 that increases in retention and leaching have opposite impacts on costs of nitrogen and phosphorous reductions. While the net effect of increased load and cost reductions of land use measures implies reductions in total costs of nitrogen reductions, the increased reduction requirement implies a net cost increase for phosphorous reductions. For the same reasons, the cost of nitrogen reduction increases when retention is raised since marginal cost of upstream measures then increase, and the decrease in reduction requirement as measured in tonnes of P outweighs the cost increase for upstream located measures reducing phosphorous loads. The impacts on costs are similar for higher reduction requirements and for decreases in leaching and retention (see Table D5 in Appendix D).

Sensitivity analyses are also carried out for changes in costs of nutrient cleaning at sewage treatment and a raise in land price, which affect land use measures. Furthermore, calculations of impacts on costs are made for changes in abatement capacity by wetlands. In Figure 13, cost impacts are presented for separate nitrogen and phosphorous reductions by 20 per cent.

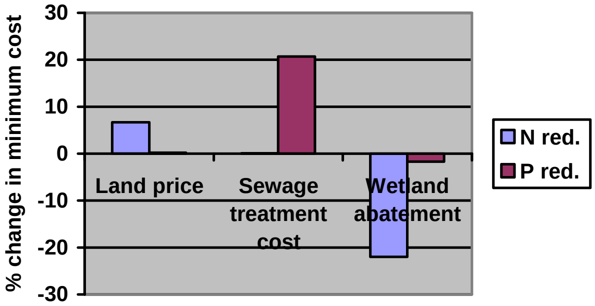


Figure 13: Changes in minimum costs for N and P reductions of 20 per cent from increases in by 25 % of land prices, sewage treatment costs, and wetland abatement capacity (Tables D6 and D7, Appendix D).

As expected, the sensitivity of minimum costs to changes in costs and abatement capacity of measures differ for nitrogen and phosphorus reductions. Estimated minimum costs of nitrogen reductions are more sensitive to parameter changes affecting land use measures and calculated minimum costs of phosphorous reductions are relatively sensitive to changes in costs of sewage treatment. This result holds also for large reduction requirement and for decreases in costs of measures and abatement capacity of wetlands (Tables D6 and D7,

Appendix D). Minimum costs of nitrogen reductions are particularly sensitive for changes in wetland abatement capacity. Since SCR turned out to be a low cost measure for nitrogen reductions and P free detergents for phosphorous reductions, impacts on costs for respective nutrient reduction have also been calculated for changes in abatement capacities of these measures, which are reported in Table D7 in Appendix D.

6. Brief summary and conclusions

The main purpose of this paper has been to estimate costs of measures reducing nitrogen and/or phosphorous loads to the Baltic Sea. In total, 14 measures have been included for nitrogen reductions and 12 for phosphorous reduction, out of which six measures affect both nutrients. These measures were classified into two main categories; emission oriented measures reducing nutrient discharges at the sources, and leaching and retention oriented measures. Examples of the former are decreases in airborne emissions from installation of selective catalytic reduction and increased cleaning at sewage treatment plants, and land use changes, such as catch crop cultivation and wetland creation provide examples of the latter. The reason why it is important to distinguish between these classes of measures is their interdependence. The cleaning capacity, and hence costs of reducing loads to the Baltic Sea, of measures affecting leaching and retention are dependent of the load of nutrient from air and soil, which are affected by the emission oriented measures. Unless this interdependency is accounted for, costs of emission oriented measures for reductions in nutrients to the Baltic Sea are underestimated, which, in turn, implies deviations from cost effective solutions.

Calculations of costs of different measures reveals that the low cost measures for nitrogen reductions are the second class of measures in the 'chain of impacts', i.e. land use changes, and for phosphorous the first class of measures. Estimated marginal costs vary considerably among measures and drainage basins for both nitrogen and phosphorus reductions. Relatively small reductions in fertilizer provide low cost options, while reductions at high levels constitute the most costly measures for reductions in both nutrients. Other low cost options for nitrogen reductions are wetland creation, catch crop cultivation and installation of catalytic reduction of nitrogen oxides on ships. Removal of phosphorus in detergents and increased cleaning at sewage treatment plants are among the least expensive measures for phosphorous reductions. Low cost location of measures in drainage basins is determined by target setting for nutrient reductions, and leaching and retention in the drainage basins.

Calculated total minimum costs for nutrient indicated large variation in total costs for the same percentage nutrient reduction depending on target formulation. Two types of targets were chosen: overall reductions of nutrient to the Baltic Sea and reductions to specific basins. Three different assumptions on adjustments among basins to exogenous load changes were made for basin specific targets; no adjustment, partial first-order adjustment, and total steady state adjustment. For a given nutrient reduction in percent, both estimated total cost and cost effective allocation of reduction in loads to different basins vary considerably depending on target setting. For example, at the 20 percent reduction of annual nitrogen minimum cost vary between 295 and 2245 millions of SEK depending on target specification with respect to overall reductions or decreases in load to specific basins. The corresponding range in costs of phosphorous reductions is larger, between 181 and 2727 millions of SEK. Furthermore, for all target specifications except when no adjustments among basins are assumed, cost effective solutions imply reductions in nutrient load from most of the drainage basins of the Sea.

However, costs of different measures, and thereby estimated minimum cost solutions are sensitive to parameter values on leaching, retention, and abatement cost and capacity. Sensitivity analyses were therefore carried out which showed that minimum costs of nitrogen reductions are mainly affected by changes in assumed abatement capacity of land use measures, and costs of phosphorus reductions of cleaning cost at sewage treatment costs. However, common to costs of measures for both nutrient reductions is the neglect of side benefits from measures such as provision of biodiversity of wetlands, which implies an overestimation of total costs, and exclusion of economy wide dispersion impacts of measures which can imply either an over- or underestimation of costs depending on the economies’ adjustment options.

Appendix A: Input data

Definition of drainage basins

Abbreviation	*Drainage basin*
Denka	Denmark, Kategat
Denso	Denmark, the Sound
Fibb	Finland, Bothnian Bay
Fibs	Finland, Bothnian Sea
Fifv	Finland, Gulf of Finland
Gerso	Germany, the Sound
Gerbp	Germany Baltic Proper
Vist	Poland, Vistula
Oder	Poland, Oder
Polcos	Poland, Polish coast
Sebb	Sweden, Bothnian Bay
Sebs	Sweden, Bothnian Sea
Sebap	Sweden, Baltic Proper south
Sebano	Sweden, Baltic Proper north
Seso	Sweden, the Sound
Seka	Sweden, Kattegat
Estob	Estonia, Baltic Proper
Estog	Estonia, Gulf of Riga
Estof	Estonia, Gulf of Finland
Latvib	Latvia, Baltic Proper
Latvig	Latvia, Gulf of Riga
Lithua	Lithuania
Sukal	Russia, Kaliningrad
Supet	Russia, S:t Petersburg

Table A1: Area of land use, leaching and retention

Region	*Total area*[1] *thous. Km*^{2}	*Arable land*[1] *thous. Km*^{2}	*Leach, N*[2]	*Leach, P*[2]	*Retention, N*[3]	*Retention. P*[3]
Denka	9.60	8.03	0.095	0.01	0.1	0.02
Denso	16.16	12.93	0.095	0.01	0.1	0.02
Fibb	134.3	9.08	0.162	0.028	0.29	0.26
Fibs	46.66	5.37	0.162	0.028	0.29	0.26
Fifv	52.56	3.57	0.162	0.028	0.29	0.26
Gerso	9.77	7.26	0.16	0.014	0.34	0.6
Gerbp	11.95	8.49	0.16	0.014	0.34	0.6
Vist	192.90	124.10	0.229	0.067	0.44	0.38
Oder	117.59	75.51	0.229	0.067	0.44	0.38
Polcos	25.58	15.38	0.229	0.067	0.44	0.38
Sebb	128.86	1.55	0.051	0.019	0.23	0.4
Sebs	180.19	5.67	0.085	0.025	0.27	0.4
Sebap	30.65	7.86	0.164	0.013	0.6	0.47
Sebano	50.63	9.48	0.164	0.013	0.6	0.47
Seso	2.90	2.47	0.276	0.016	0.3	0
Seka	71.65	10.60	0.207	0.016	0.2	0.4
Estob	6.07	2.15	0.315	0.066	0.23	0.36
Estog	11.34	4.69	0.315	0.066	0.23	0.36
Estof	65.49	32.84	0.315	0.066	0.23	0.36
Latvib	96.69	10.00	0.358	0.093	0.45	0.4
Latvig	122.45	62.25	0.358	0.093	0.45	0.4
Lithua	96.69	59.01	0.442	0.114	0.35	0.3
Sukal	20.00	15.08	0.617	0.067	0.6	0.6
Supet	310.10	49.04	0.55	0.036	0.6	0.5

1) Shou et al. (2006) table A3.5, page 63, for Sweden from Swedish Statistics (2005) ; 2) Elofsson (2000) page 50; 3) Shou et al. (2006), table A2.4, page 53

Table A2: Fertilizer use, nutrient content in and holdings of livestock

Region	*Fertiliser [1], Kg N/ha*	*Fertiliser ,[2] Kg P/ha*	*Nutrient content of livestock N/P unit*			*Holdings of animals, million units*		
			Cattle[3]	*Pigs[3]*	*Chicken[4]*	*Cattle[5]*	*Pigs[5]*	*Poultry[6]*
Denka	90	9	84/14	18/5.3	1.2/0.32	0.68	4.31	5.73
Denso	90	9	84/14	18/5.3	1.2/0.32	1.17	7.71	9.32
Fibb	75	12	83/14	18/5.3	1.2/0.32	0.53	0.65	2.28
Fibs	75	12	83/14	18/5.3	1.2/0.32	0.27	0.21	1.35
Fifv	75	12	83/14	18/5.3	1.2/0.32	0.18	0.21	0.90
Gerso	133	11	75/13	17/4.9	1.1/0.29	0.87	1.60	6.75
Gerbp	133	11	75/13	17/4.9	1.1/0.29	1.02	1.86	7.90
Vist	62	3	58/11	15/4.1	1/0.27	4.96	17.37	49.43
Oder	62	3	58/11	15/4.1	1/0.27	3.02	10.57	30.13
Polcos	62	3	58/11	15/4.1	1/0.27	2.15	6.15	6.14
Sebb	86	15	89/15	20/5.6	1.3/0.34	0.10	0.12	0.38
Sebs	88	12	89/15	20/5.6	1.3/0.34	0.39	0.45	1.41
Sebap	104	15	89/15	20/5.6	1.3/0.34	0.55	0.66	1.95
Sebano	90	15	89/15	20/5.6	1.3/0.34	0.57	0.41	2.54
Seso	133	22	89/15	20/5.6	1.3/0.34	0.15	0.17	0.66
Seka	108	19	89/15	20/5.6	1.3/0.34	0.64	0.74	2.63
Estob	42	5	67/12	17/4.6	1.1/0.30	0.09	0.11	0.76
Estog	42	5	67/12	17/4.6	1.1/0.30	0.19	0.24	1.66
Estof	42	5	67/12	17/4.6	1.1/0.30	1.31	1.64	11.63
Latvib	20	4	58/11	15/4.1	1/0.27	0.2	0.2	1.88
Latvig	20	4	58/11	15/4.1	1/0.27	1.3	1.3	11.70
Lithua	34	2	57/11	15/4.1	1/0.27	1.77	2.24	16.46
Sukal	9	4	45/9	12/3.3	0.8//0.22	3.17	1.96	4.04
Supet	9	4	45/9	12/3.3	0.8/0.22	10.3	6.38	12.16

1)Based on calculations from Shou et al. (2006) table 8 page 34 and area of arable land in Table A1 for N, Elofsson (2000) Table A2 page 42 for P, for Sweden Swedish Statistics (2005); 2.Elofsson (2000) table A2 page 42, for Sweden Swedish Statistics (2005); 3). Shou (2006) table A1.2 page 51; 4) Proportional to N/P in cattle as reported in Elofsson (2000) table A6, page 44; 5) Shou et al. (2006) table A3.5, page 63; 6) FAO (2008), for year 2004.

Table A3; Population, direct sewage discharges, and calculated upstream discharges at the source.

	Population[1] in thousand	*Direct discharges[2] in tonnes*		*Upstreams discharges[3]*	
		N	*P*	*N*	*P*
Denka	1500	789	90	555	103
Denso	3100	2390	310	1181	219
Fibb	1010	2030	72	608	114
Fibs	1388	3134	139	771	144
Fifv	2536	2674	100	2391	448
Gerso	1560	1978	24	1559	228
Gerbp	1740	20	1	1394	204
Vist	20520	248	37	33075	9805
Oder	12920	106	16	20824	6173
Polcos	4560			7141	2117
Sebb	390	1177	53	169	28
Sebs	1123	2947	177	621	104
Sebap	820	1097	35	299	50
Sebano	3280	2936	89	1199	201
Seso	625	976	33	186	31
Seka	2136	1877	100	893	150
Estob	80	0	0	52	15
Estog	295	73	11	361	104
Estof	1265	1528	77	915	264
Latvib	276	239	31	509	153
Latvig	1978	1312	182	3648	1096
Lithua	3404	293	39	4854	1541
Sukal	878	2033	150	1050	321
Supet	8000	9008	1090	7698	2486

1).Total population calculated from data non-connected population in Shou et al (2006) table A3.10 page 61 and COWI (2007) table 5-1, page 38 on % share of unconnected of total population. It is assumed that this share is the same in all drainage basins within each country ; 2) Helcom (2007) tables 6 page 18 and 10 page 20; 3) calculations based on shares of population connected to different treatment and nutrient removals (COWI table 5-1, page 38 and Table 5-2 page 40), on annual production of 4.38 kg N/PE and 1.095 kg P/PE (Shou et al (2006) page 38, of P in detergents per capita in COWI (2007) table 5-8, page 45, and on the assumption that 90 % of the rural and 15 % of the urban population lives beyond 10 km from the Baltic Sea shores (Grid-Arendal (2007).

Table A4: Nitrogen dioxide, ammonia emissions, shares of direct airborne deposition on the Baltic Sea, and share of total Baltic Sea nitrogen deposition on drainage basins.

Region	*Nitrogen dioxides, thousand tonnes*[1]	*Ammonia, thousand tonnes*[2]	*Share of direct NO_x on the Baltic Sea*[3]	*Share of ammonia on the Baltic Sea*[4]	*Share of Baltic Sea emission on drainage basins*[5]
Denka	16	25	0.105	0.140	0.004
Denso	41	51	0.007	0.140	0.007
Fibb	11	12	0.083	0.198	0.038
Fibs	15	10	0.083	0.198	0.013
Fifv	28	8	0.083	0.198	0.015
Gerso	26	32	0.040	0.038	0.025
Gerbp	30	28	0.040	0.038	0.027
Vist	133	156	0.047	0.048	0.032
Oder	84	94	0.047	0.048	0.019
Polcos	30	19	0.047	0.048	0.004
Sebb	2.8	3.9	0.098	0.162	0.038
Sebs	8.2	12	0.098	0.162	0.053
Sebap	6	3.2	0.098	0.162	0.010
Sebano	23.9	13	0.098	0.162	0.015
Seso	4.6	3.5	0.098	0.162	0.019
Seka	15.6	6.9	0.098	0.162	0.001
Estob	0.5	1.5	0.099	0.184	0.002
Estog	1.8	2.5	0.099	0.184	0.012
Estof	7.7	3.5	0.099	0.184	0.001
Latvib	1.5	7.3	0.10	0.165	0.007
Latvig	11	4.8	0.10	0.165	0.011
Lithua	18	33	0.062	0.111	0.014
Sukal	7	25	0.062	0.111	0.002
Supet	58	87	0.042	0.099	0.027

1) EMEP (2007) Table B.2, page 124, division among drainage basins according to population in Table A3; 2) EMEP (2007) table B.3, page 126, division among drainage basins in a country according to area of arable land in Table A1; 3) EMEP (2007) table B.2; 4) EMEP (2007) table B.3; 5) EMEP (2007) table B.2, division among drainage basins in a country according to total area; 6) Calculated deposition from riparian countries divided by total deposition from EMEP (2007) table B.2

Table A5: Shares of total nitrogen oxides emission from column drainage basins to row drainage basins

	Denka	Denso	Fibb	Fibs	Fifv	Gerso	Gerbp	Vist	Oder	Polcos	Sebb	Sebs
Denka	0.0026	0.0027	0.0004	0.0004	0.0004	0.0016	0.0016	0.0008	0.0008	0.0008	0.0012	0.0012
Denso	0.0043	0.0043	0.0008	0.0008	0.0008	0.0026	0.0026	0.0013	0.0013	0.0013	0.0020	0.0020
Fibb	0.0265	0.0265	0.100	0.100	0.100	0.0085	0.0085	0.0146	0.0146	0.0146	0.0465	0.0465
Fibs	0.0088	0.0088	0.034	0.034	0.034	0.0029	0.0029	0.005	0.005	0.005	0.016	0.016
Fifv	0.0097	0.0097	0.0378	0.0378	0.0378	0.0032	0.0032	0.0055	0.0055	0.0055	0.0176	0.0176
Gerso	0.0010	0.0010	0.0002	0.0002	0.0002	0.0399	0.0399	0.0011	0.0011	0.0011	0.0004	0.0004
Gerbp	0.0013	0.0013	0.0002	0.0002	0.0002	0.0475	0.0475	0.0013	0.0013	0.0013	0.0005	0.0005
Vist	0.0297	0.0297	0.0085	0.0085	0.0085	0.0325	0.0325	0.0905	0.0905	0.0905	0.0167	0.0167
Oder	0.0179	0.0179	0.0051	0.0051	0.0051	0.0196	0.0196	0.0545	0.0545	0.0545	0.0101	0.0101
Polcos	0.0036	0.0036	0.001	0.001	0.001	0.0039	0.0039	0.0109	0.0109	0.0109	0.0020	0.0020
Sebb	0.0362	0.0362	0.0261	0.0261	0.0261	0.0103	0.0103	0.0087	0.0087	0.0087	0.0544	0.0544
Sebs	0.0455	0.0455	0.0364	0.0364	0.0364	0.0142	0.0142	0.0121	0.0121	0.0121	0.0758	0.0758
Sebap	0.0082	0.0082	0.0065	0.0065	0.0065	0.0026	0.0026	0.0022	0.0022	0.0022	0.0136	0.0136
Sebano	0.0128	0.0128	0.0103	0.0103	0.0103	0.0040	0.0040	0.0034	0.0034	0.0034	0.0213	0.0213
Seso	0.0012	0.0012	0.0131	0.0131	0.0131	0.0004	0.0004	0.0003	0.0003	0.0003	0.0019	0.0019
Seka	0.0163	0.0163	0.0009	0.0009	0.0009	0.0051	0.0051	0.0044	0.0044	0.0044	0.0272	0.0272
Estob	0.0007	0.0007	0.0010	0.0010	0.0010	0.0003	0.0003	0.0051	0.0051	0.0051	0.0013	0.0013
Estog	0.0011	0.0011	0.0017	0.0017	0.0017	0.0004	0.0004	0.0079	0.0079	0.0079	0.0025	0.0025
Estof	0.007	0.0070	0.0103	0.0103	0.0103	0.0026	0.0026	0.0486	0.0486	0.0486	0.0154	0.0154
Latvib	0.0047	0.0047	0.0042	0.0042	0.0042	0.0021	0.0021	0.0038	0.0038	0.0038	0.0043	0.0043
Latvig	0.0077	0.0077	0.0069	0.0069	0.0069	0.0034	0.0034	0.0063	0.0063	0.0063	0.0070	0.0070
Lithua	0.0124	0.0124	0.0074	0.0074	0.0074	0.0074	0.0074	0.0153	0.0153	0.0153	0.0080	0.0080
Sukal	0.0016	0.0016	0.0074	0.0074	0.0074	0.0007	0.0007	0.0012	0.0012	0.0012	0.0021	0.0021
Supet	0.0254	0.0254	0.0057	0.0057	0.0057	0.0103	0.0103	0.0194	0.0194	0.0194	0.0326	0.0326

Source: EMEP (2007) table B.2, page 124, deposition on drainage basins within a country is assumed to be proportional to the total territory area in Table A1

Table A5: Continues

	Sebap	Sebano	Seso	Seka	Estob	Estog	Estof	Latvib	Latvig	Lithua	Sukal[1]	Supet
Denka	0.0012	0.0012	0.0012	0.0012	0	0	0	0	0	0	0.0001	0.0001
Denso	0.0020	0.0020	0.0020	0.0020	0	0	0	0	0	0	0.0002	0.0002
Fibb	0.0465	0.0465	0.0465	0.0465	0.0651	0.0651	0.0651	0.0371	0.0371	0.023	0.0078	0.0079
Fibs	0.016	0.016	0.016	0.016	0.0224	0.0224	0.0224	0.0128	0.0128	0.0103	0.0027	0.0027
Fifv	0.0176	0.0176	0.0176	0.0176	0.0247	0.0247	0.0247	0.0141	0.0141	0.0113	0.0029	0.0030
Gerso	0.0004	0.0004	0.0004	0.0004	0.0023	0.0023	0.0023	0.003	0.003	0.0060	0.0060	0.0002
Gerbp	0.0005	0.0005	0.0005	0.0005	0.0029	0.0029	0.0029	0.005	0.005	0.0074	0.0074	0.0002
Vist	0.0167	0.0167	0.0167	0.0167	0.0118	0.0118	0.0118	0.0186	0.0186	0.0365	0.0365	0.0085
Oder	0.0101	0.0101	0.0101	0.0101	0.0071	0.0071	0.0071	0.0112	0.0112	0.0221	0.0221	0.0051
Polcos	0.0020	0.0020	0.0020	0.0020	0.0014	0.0014	0.0014	0.0022	0.0022	0.0044	0.0022	0.001
Sebb	0.0544	0.0544	0.0544	0.0544	0.0137	0.0137	0.0137	0.013	0.013	0.0096	0.0096	0.0261
Sebs	0.0758	0.0758	0.0758	0.0758	0.0191	0.0191	0.0191	0.019	0.019	0.0134	0.0134	0.0364
Sebap	0.0136	0.0136	0.0136	0.0136	0.0034	0.0034	0.0034	0.003	0.003	0.0002	0.0002	0.0065
Sebano	0.0213	0.0213	0.0213	0.0213	0.0054	0.0054	0.0054	0.0053	0.0053	0.0038	0.0038	0.0103
Seso	0.0019	0.0019	0.0019	0.0019	0.0005	0.0005	0.0005	0.0005	0.0005	0.0003	0.0003	0.0009
Seka	0.0272	0.0272	0.0272	0.0272	0.0068	0.0068	0.0068	0.0067	0.0067	0.0048	0.0048	0.0131
Estob	0.0013	0.0013	0.0013	0.0013	0.0029	0.0029	0.0029	0.0016	0.0016	0.0012	0.0012	0.0010
Estog	0.0025	0.0025	0.0025	0.0025	0.0053	0.0053	0.0053	0.0031	0.0031	0.0022	0.0022	0.0017
Estof	0.0154	0.0154	0.0154	0.0154	0.0326	0.0326	0.0326	0.0192	0.0192	0.0137	0.0137	0.0103
Latvib	0.0043	0.0043	0.0043	0.0043	0.0077	0.0077	0.0077	0.0182	0.0182	0.0152	0.0152	0.0042
Latvig	0.0070	0.0070	0.0070	0.0070	0.0126	0.0126	0.0126	0.0298	0.0298	0.0348	0.0348	0.0069
Lithua	0.0080	0.0080	0.0080	0.0080	0.0102	0.0102	0.0102	0.032	0.032	0.0571	0.0027	0.0027
Sukal	0.0021	0.0021	0.0021	0.0021	0.0028	0.0028	0.0028	0.0032	0.0032	0.0032	0.0571	0.0032
Supet	0.0326	0.0326	0.0326	0.0326	0.0447	0.0447	0.0447	0.0498	0.0498	0.0498	0.0498	0.1243

1) Coefficients assumed to be the same as for Lithuania

Table A6: Shares of total ammonia emissions from column drainage basins to row drainage basins

	Denka	Denso	Fibb	Fibs	Fifv	Gerso	Gerbp	Vist	Oder	Polcos	Sebb	Sebs
Denka	0.0421	0.0421	0	0	0	0.0025	0.0025	0.0006	0.0006	0.0006	0.0041	0.0041
Denso	0.0688	0.0688	0	0	0	0.0041	0.0041	0.0009	0.0009	0.0009	0.0067	0.0067
Fibb	0.0114	0.0114	0.2004	0.2004	0.2004	0.0051	0.0051	0.0106	0.0106	0.0106	0.0283	0.0283
Fibs	0.0040	0.0040	0.0691	0.0691	0.0691	0.0017	0.0017	0.0036	0.0036	0.0036	0.0097	0.0097
Fifv	0.0043	0.0043	0.0760	0.0760	0.0760	0.0019	0.0019	0.0040	0.0040	0.0040	0.0107	0.0107
Gerso	0.0024	0.0024	0.0002	0.0002	0.0002	0.2010	0.2010	0.0024	0.0024	0.0024	0.0007	0.0007
Gerbp	0.0029	0.0029	0.0002	0.0002	0.0002	0.2460	0.2460	0.0029	0.0029	0.0029	0.0009	0.0009
Vist	0.0167	0.0167	0.0039	0.0039	0.0039	0.0214	0.0214	0.2486	0.2486	0.2486	0.0135	0.0135
Oder	0.0101	0.0101	0.0023	0.0023	0.0023	0.0129	0.0129	0.1501	0.1501	0.1501	0.0081	0.0081
Polcos	0.0020	0.0020	0.0005	0.0005	0.0005	0.0026	0.0026	0.0300	0.0300	0.0300	0.0002	0.0002
Sebb	0.0238	0.0238	0.0304	0.0304	0.0304	0.0072	0.0072	0.0068	0.0068	0.0068	0.0199	0.0199
Sebs	0.0331	0.0331	0.0423	0.0423	0.0423	0.0101	0.0101	0.0096	0.0096	0.0096	0.0712	0.0712
Sebap	0.0060	0.0060	0.0076	0.0076	0.0076	0.0027	0.0027	0.0017	0.0017	0.0017	0.0997	0.0997
Sebano	0.0094	0.0094	0.0119	0.0119	0.0119	0.0042	0.0042	0.0027	0.0027	0.0027	0.1188	0.1188
Seso	0.0009	0.0009	0.0011	0.0011	0.0011	0.0003	0.0003	0.0002	0.0002	0.0002	0.0318	0.0318
Seka	0.0119	0.0119	0.0152	0.0152	0.0152	0.0053	0.0053	0.0034	0.0034	0.0034	0.1355	0.1355
Estob	0.0003	0.0003	0.0005	0.0005	0.0005	0.0002	0.0002	0.0003	0.0003	0.0003	0.0005	0.0005
Estog	0.0005	0.0005	0.0009	0.0009	0.0009	0.0003	0.0003	0.0006	0.0006	0.0006	0.0009	0.0009
Estof	0.0031	0.0031	0.0054	0.0054	0.0054	0.0019	0.0019	0.0036	0.0036	0.0036	0.0056	0.0056
Latvib	0.0025	0.0025	0.0026	0.0026	0.0026	0.0013	0.0013	0.0034	0.0034	0.0034	0.0035	0.0035
Latvig	0.0041	0.0041	0.0042	0.0042	0.0042	0.0022	0.0022	0.0055	0.0055	0.0055	0.0058	0.0058
Lithua	0.0053	0.0053	0.0034	0.0034	0.0034	0.0037	0.0037	0.0160	0.0160	0.0160	0.0070	0.0070
Sukal	0.0017	0.0017	0.0034	0.0034	0.0034	0.0006	0.0006	0.0018	0.0018	0.0018	0.0070	0.0070
Supet	0.0258	0.0258	0.0322	0.0322	0.0322	0.0096	0.0096	0.0285	0.0285	0.0285	0.0226	0.0226

Source: EMEP (2007) table B.3, page 126, deposition on drainage basins within a country is assumed to be proportional to the total territory area in Table A1.

Table A6: Continues

	Sebap	Sebano	Seso	Seka	Estob	Estog	Estof	Latvib	Latvig	Lithua	Sukal[1]	Supet
Denka	0.0041	0.0041	0.0041	0.0041	0	0	0	0	0	0.0008	0.0008	0
Denso	0.0067	0.0067	0.0067	0.0067	0	0	0	0	0	0.0013	0.0013	0
Fibb	0.0283	0.0283	0.0283	0.0283	0.0534	0.0534	0.0534	0.0252	0.0252	0.0178	0.0178	0.0048
Fibs	0.0097	0.0097	0.0097	0.0097	0.0184	0.0184	0.0184	0.0087	0.0087	0.0062	0.0062	0.0016
Fifv	0.0107	0.0107	0.0107	0.0107	0.0203	0.0203	0.0203	0.0096	0.0096	0.0068	0.0068	0.0018
Gerso	0.0007	0.0007	0.0007	0.0007	0.0006	0.0006	0.0006	0.0004	0.0004	0.0007	0.0007	0.0002
Gerbp	0.0009	0.0009	0.0009	0.0009	0.0007	0.0007	0.0007	0.0005	0.0005	0.0009	0.0009	0.0002
Vist	0.0135	0.0135	0.0135	0.0135	0.0076	0.0076	0.0076	0.0151	0.0151	0.0428	0.0428	0.0039
Oder	0.0081	0.0081	0.0081	0.0081	0.0046	0.0046	0.0046	0.0091	0.0091	0.0258	0.0258	0.0023
Polcos	0.0002	0.0002	0.0002	0.0002	0.0009	0.0009	0.0009	0.0002	0.0002	0.0052	0.0052	0.0005
Sebb	0.0199	0.0199	0.0199	0.0199	0.0088	0.0088	0.0088	0.0088	0.0088	0.0072	0.0072	0.0304
Sebs	0.0712	0.0712	0.0712	0.0712	0.0123	0.0123	0.0123	0.0122	0.0122	0.0101	0.0101	0.0423
Sebap	0.0997	0.0997	0.0997	0.0997	0.0022	0.0022	0.0022	0.0022	0.0022	0.0018	0.0018	0.0076
Sebano	0.1188	0.1188	0.1188	0.1188	0.0035	0.0035	0.0035	0.0034	0.0034	0.0028	0.0028	0.0119
Seso	0.0318	0.0318	0.0318	0.0318	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0011
Seka	0.1355	0.1355	0.1355	0.1355	0.0044	0.0044	0.0044	0.0044	0.0044	0.0036	0.0036	0.0152
Estob	0.0005	0.0005	0.0005	0.0005	0.0157	0.0157	0.0157	0.0030	0.0030	0.0009	0.0009	0.0005
Estog	0.0009	0.0009	0.0009	0.0009	0.0291	0.0291	0.0291	0.0056	0.0056	0.0016	0.0016	0.0009
Estof	0.0056	0.0056	0.0056	0.0056	0.1789	0.1789	0.1789	0.0347	0.0347	0.0098	0.0098	0.0054
Latvib	0.0035	0.0035	0.0035	0.0035	0.0149	0.0149	0.0149	0.0925	0.0925	0.0304	0.0304	0.0026
Latvig	0.0058	0.0058	0.0058	0.0058	0.0245	0.0245	0.0245	0.1509	0.1509	0.0496	0.0496	0.0042
Lithua	0.0070	0.0070	0.0070	0.0070	0.0131	0.0131	0.0131	0.0696	0.0696	0.2615	0.0055	0.0034
Sukal	0.0070	0.0070	0.0070	0.0070	0.0039	0.0039	0.0039	0.0039	0.0039	0.0055	0.2615	0.0025
Supet	0.0226	0.0226	0.0226	0.0226	0.0612	0.0612	0.0612	0.0612	0.0612	0.0867	0.0867	0.3049

1) Coefficients assumed to be the same as for Lithuania

Table A7: Shares of airborne deposition from drainage basins to marine basins

Region	*BoB*	*BoS*	*GoF*	*GoR*	*BaP*	*Sound*	*Kattegat*
Denka	0.013	0.047	0.021	0.019	0.388	0.242	0.269
Denso	0.013	0.047	0.021	0.019	0.388	0.242	0.269
Fibb	0.325	0.281	0.151	0.034	0.187	0.008	0.014
Fibs	0.325	0.281	0.151	0.034	0.187	0.008	0.014
Fifv	0.325	0.281	0.151	0.034	0.187	0.008	0.014
Gerso	0.018	0.087	0.037	0.031	0.550	0.176	0.101
Gerbp	0.018	0.087	0.037	0.031	0.550	0.176	0.101
Vist	0.031	0.117	0.038	0.038	0.728	0.022	0.026
Oder	0.031	0.117	0.038	0.038	0.728	0.022	0.026
Polcos	0.031	0.117	0.038	0.038	0.728	0.022	0.026
Sebb	0.069	0.222	0.047	0.034	0.544	0.019	0.065
Sebs	0.069	0.222	0.047	0.034	0.544	0.019	0.065
Sebap	0.069	0.222	0.047	0.034	0.544	0.019	0.065
Sebano	0.069	0.222	0.047	0.034	0.544	0.019	0.065
Seso	0.069	0.222	0.047	0.034	0.544	0.019	0.065
Seka	0.069	0.222	0.047	0.034	0.544	0.019	0.065
Estob	0.063	0.176	0.443	0.098	0.209	0.005	0.006
Estog	0.063	0.176	0.443	0.098	0.209	0.005	0.006
Estof	0.063	0.176	0.443	0.098	0.209	0.005	0.006
Latvib	0.005	0.018	0.117	0.391	0.467	0.001	0.001
Latvig	0.005	0.018	0.117	0.391	0.467	0.001	0.001
Lithua	0.045	0.179	0.087	0.112	0.564	0.010	0.003
Sukal	0.105	0.213	0.212	0.055	0.397	0.009	0.009
Supet	0.105	0.213	0.212	0.055	0.397	0.009	0.009

Source: Helcom (2005) table 2, page 20. It is assumed that the country shares are the same for all drainage basins within the country

Table A8: Market prices and annualized values of arable land/ha

Region	*SEK/ha*	*Year*	*In 2005 year prices*	*Annual cost 5 % and 50 year*	*Annual cost for 3 % and 50 year*
Deka[1]	148304	2004	151270	8286	5879
Deso[1]	148304	2004	151270	8286	5879
Fibb[1]	48171	2004	49134	2691	1910
Fibs[1]	48171	2004	49134	2691	1910
Figf[1]	48171	2004	49134	2691	1910
Gerso[1]	87277	2001	92515	5068	3600
Gerbp[1]	87277	2001	92515	5068	3600
Polvist[1]	13561	2004	13832	758	538
Poloder[1]	13561	2004	13832	758	538
Polcost[1]	13561	2004	13832	758	538
Sebb[2]	6900	2005	6900	378	268
Sebs[2]	9950	2005	9950	545	387
Sebap[2]	26700	2005	26700	1463	1038
Seka[2]	29900	2005	29900	1638	1162
Seso[2]	58400	2005	58400	3199	2270
Estorg[3]			13832	758	538
Estogf[3]			13832	758	538
Estobp[3]			13832	758	538
Latbp[1]	9677	2004	9870	541	384
Latrg[1]	9677	2004	9870	541	384
Lith[1]	3763	2004	3838	210	149
Ruskal[4]			3838	210	149
Ruspet[4]			3838	210	149

1) Agriculture in the European union, - and Statistical economic information 2005- published by DG AGRI, ISSN 1683-6480; ISBN 92-79-01625-3. See tables 3.3.8 and 3.3.9 (http://ec.europa.eu/agriculture/agrista/2005/table_en/index.htm); 2) Statistics Sweden (2005), Table XX Agricultural land prices; 3) official statistics not available assuming that the price is the same as in Poland; 4) official statistics not available assuming that the price is the same as in Lithuania

Table A9: Fertiliser prices , demand elasticities and costs of livestock reductions.

Region	*N, SEK/100 kg*	*Elasticity of N demand*[5]	*P, SEK/100 kg*	*Elasticity of P demand*[5]	*Costs of livestock reductions, SEK/unit* *Cattle*[7]	*Pig*[7]	*Poultry*[8]
Deka[1]	819	-0.45[6]	2129	-0.27	3100	618	39
Deso[1]	819	-0.45[6]	2129	-0.27	3100	618	39
Fibb[1]	695	-0.57	1295	-0.22	2235	575	57
Fibs[1]	695	-0.39	1295[4]	-0.23	2217	534	54
Figf[1]	695	-0.39	1295[4]	-0.20	2018	525	42
Gerso[1]	575	-0.30	1083[4]	-0.30	2053	555	39
Gerbp[1]	575	-0.30	1083[4]	-0.30	2053	555	39
Polvist[1]	186	-0.30	460	-0.30	1162	398	31
Poloder[1]	186	-0.30	460	-0.30	1162	398	31
Polcost[1]	186	-0.30	460	-0.30	1162	398	31
Sebb[2]	814	-0.74	1295	-0.99	2235	575	57
Sebs[2]	814	-0.64	1295	-0.47	2217	534	54
Sebap[2]	814	-0.71	1295	-0.24	2018	525	42
Sebano	814	-0.71	1295	-0.24	1899	486	50
Seka[2]	814	-0.71	1295	-0.24	1788	525	42
Seso[2]	814	-0.71	1295	-0.24	2074	501	39
Estorg[3]	307	-0.30	398	-0.30	1843	712	55
Estogf[3]	307	-0.30	398	-0.30	1843	712	55
Estobp[3]	307	-0.30	398	-0.30	1843	712	55
Latbp[1]	180	-0.30	397	-0.30	1361	597	46
Latrg[1]	180	-0.30	397	-0.30	1361	597	46
Lith[1]	640	-0.30	1284	-0.30	492	230	18
Ruskal[3]	181	-0.30	397[3]	-0.30	1162	398	31
Ruspet[3]	181	-0.30	397[3]	-0.30	1162	398	31

Maximum reductions of livestock are assumed to be 50 % (Elofsson, 2000); Maximum fertilizer reductions are assumed to be related to use per ha according to: 50 % in Sweden, Germany, Denmark, Finland, 40 % in Poland, 30 % in Estonia, Latvia and Lithuania, and 10 % in Russia

1) Eurostat; Agricultural prices and price indices; 2) For N Eurostat, Agriculttural prices and price indices, for P Statistics Sweden; The yearbook of Agricultural Statistics 2006, Table XX; 3) Elofsson (2000), table A11, page 47, expressed in 2006 year prices by applying Swedish KPI; 4) Assumption of the same proportions of Swedish P prices as in Elofsson (2000); 5) Gren et al. 1995; 6) Hansen, (2004); 7) Shou et al. (2006). table 6, page 29, for Sweden and Finland the costs are proportional to the costs in Elofsson (2000) table A5, page 44; 8) Elofsson (2000) table A5, page 44. For Poland, Estonia, Latvia, Lithuania, and Russia the poultry reduction costs are assumed to be proportional to the pig reduction costs in Seka (Elofsson, 2000, page 44)

Table A10: Land use measures, cost/ha, area restriction, and leaching impacts

Land use measure	*Cost/ha*	*Maximum area*	*% leaching reduction,*	
			N	*P*
Catch crops	10 % of AMPL [1,2] labour and seeding[3]	33 % of arable land in rotation[4]	30[3]	5[3]
Grassland	AMPL	50 % of arable land[5]	65[3]	10[3]
Energy forests	Net cost[6]	10 % of arable land[7]	50[3]	5[3]
Buffer strips	AMPL	0.5 % of arable land[5]	0[3]	62[11]
Wetlands	AMPL + construction cost[8]	2 % of arable land[9]	62[10] 10 in BB 50 in BS	17[12]

1) AMPL: Annualised Market Price of Land see Table A8; 2) 10 % from Shou et al. (2006) page 33; 3) Elofsson (2000) table A3, page 43; 4) Shou et al page 22 and Elofsson (2000) page 19; 5) Elofsson (2000) page 19; 6) Elofsson (2000) table A7, page 45; 7) Elofsson (2000) page 60; 9) Shou et al. (2006) page 19 state 5 % which is regarded as too much when considering strategic location at coastal shorelines; 10) Treper and Palmeri (2002), page 135. 11) Uusi-Kämppä et al. (2000) show that leaching reduction varies between 0.27 and 0.97, an average is assumed; 12) Uusi-Kämppä et al. (2000).

Table A11: Costs of nitrogen reductions at sources SEK/kg N reduction

Country	*Sew. tertiary, rural*[1]	*Sew. tertiary, urban*[1]	*Priv. sewers*[2]	*SCR on ships*[3]	*SCR in heavy vehicle*[3]	*SCR in power plants*[3]	*Changed manure spread*[4]
Denmark	301	141	509	5	34	54	9
Finland	301	141	509	5	33	53	9
Germany	301	141	509	5	30	51	14
Poland	254	113	429	5	31	52	9
Sweden	301	141	509	5	31	53	9
Estonia	254	113	429	5	32	52	15
Latvia	254	113	429	5	31	52	15
Lithuania	254	113	429	5	31	51	15
Russia	254	113	429	5	31	52	14
Capacity constraints: tertiary treatment calculations based on table 5-1 and 5-2 in COWI (2007); SCR on ships from COWI (2007) table 5-38, on heavy vehicles from COWI (2007) table 5-36, SCR on power plants from COWI (2007) table 5-34.							

1) COWI table 5-7, page 44; 2) Average annual investment cost per household in SEPA (2007) from tables 12 and 13 and assumption of 4 PE/household,and assuming that the costs for Poland, Estonia, Latvia, Lithuani, and Russia have the same proportions as costs of sewage treatment in rural areas; 3) COWI Table 5-38 page 75 for ships, Table 5-33 for power plants, calculations based on costs per car in table 5-35 and data on emission per car on page 72, ; 4) COWI (2007) Table 5-31, page 67;

Table A12: Costs of phosphorous reductions SEK/kg P reduction

	Sew. tertiary, rural[1]	Sew. tertiary, urban[1]	Priv. sewers[2]	P free deterg.[3]
Denmark	1260	573	2397	103.4
Finland	1260	573	2397	103.4
Germany	1260	573	2397	103.4
Poland	837	385	2013	103.4
Sweden	1260	573	2397	103.4
Estonia	837	385	2013	103.4
Latvia	837	385	2013	103.4
Lithuania	837	385	2013	103.4
Russia	837	385	2013	103.4
Capacity constraints: Tertiary treatment from COWI, table 5-1; 90 % cleaning capacity of private sewers in rural areas; 80 % reduction of P detergents discharges into waters calculated from COWI, 2007, tables 5-8 and 5-1.				

1) COWI table 5-7, page 44; 2) SEPA (2007) for Swedish estimates, and assuming that the costs for Poland, Estonia, Latvia, Lithuani, and Russia have the same proportions as costs of sewage treatment in rural areas ; 3) COWI table 5-7, page 44

Table A13: Coefficient matrix showing share of total N transports in columns to different basins in rows.

	BB	BS	BP	GF	GR	DS	KT
BB	0.05	0.11					
BS	0.95	0.14	0.26				
BP		0.75	0.26	0.75	0.66	0.40	
GF			0.11	0.25			
GR			0.03		0.34		
DS			0.34			0.03	0.40
KT						0.57	0.60
Coastal retention		0.4	0.10	0.22		0.16	0.18

Source: Gren and Wulff (2004), Savchuk (2005)

Table A14: Coefficient matrix showing share of total P transports in columns to different basins in rows.

	BB	BS	BP	GF	GR	DS	KT
BB	0.62	0.11					
BS	0.38	0.24	0.26				
BP		0.65		0.81	0.90	0.41	
GF			0.28	0.19			
GR			0.04		0.20		
DS			0.42			0.04	0.33
KT						0.55	0.67
Coastal retention		0.07	0.13	0.45			

Source: Gren and Wulff (2004), Savchuk (2005)

Appendix B: Calculated nutrient loads

Table B1: Allocation of N discharges into Baltic Sea on drainage basins and sectors, thousand tons of N

	Air borne emissions:			*Sewage*	*Agriculture*	*Total*
	Dir	*Indirekt*	*Total*			
Denka	5	1	6	1	7	15
Denso	11	2	13	2	13	28
Fibb	4	3	7	3	10	20
Fibs	4	3	6	2	7	15
Fifv	3	2	5	4	5	14
Gerso	2	3	6	2	15	23
Gerbp	2	3	5	2	17	24
Vist	15	30	45	23	117	185
Oder	9	13	22	14	73	109
Polcoast	2	3	5	4	15	24
Sebb	1	0	1	1	0	3
Sebs	4	2	5	3	2	11
Sebap	1	1	2	2	5	9
Sebano	4	2	5	3	6	15
Seso	1	3	4	2	6	11
Seka	2	3	5	3	17	25
Estob	0	1	1	0	3	5
Estog	1	1	2	1	6	10
Estof	1	2	3	2	36	41
Latvib	2	3	5	1	5	11
Latvig	1	3	4	3	26	33
Lith	5	12	17	4	71	93
Sukal	3	5	8	2	6	17
Supet	10	28	39	12	16	66
Bal	18		18			18
Total	112	127	239	98	487	824

1) The number refers to emission sources in the sea and emissions and leaching from the drainage basin. Outside emission sources add further 113 thousand tonnes of N

Table B2: Allocation of P discharges into Baltic Sea from different drainage basins and sectors

	Sewage	*Agriculture*	*Total*
Denka	0.196	0.199	0.395
Denso	0.371	0.378	0.749
Fibb	0.163	0.381	0.544
Fibs	0.154	0.283	0.438
Fifv	0.443	0.222	0.665
Gerso	0.104	0.135	0.239
Gerbp	0.096	0.133	0.229
Vist	6.657	5.773	11.291
Oder	4.059	3.641	8.666
Polcoast	1.302	0.731	1.928
Sebb	0.071	0.041	0.113
Sebs	0.318	0.150	0.468
Sebap	0.154	0.094	0.248
Sebano	0.192	0.137	0.328
Seso	0.066	0.074	0.140
Seka	0.196	0.148	0.345
Estob	0.026	0.105	0.131
Estog	0.090	0.201	0.291
Estof	0.266	0.956	1.222
Latvib	0.139	0.470	0.609
Latvig	0.813	1.569	2.382
Lith	1.097	2.350	3.447
Sukal	0.281	0.472	0.753
Supet	0.274	0.819	3.193
Total	*19.628*	*19.282*	*38.910*

Table B3: Country shares of nitrogen loads and phosphorous loads from different calculation sources, % of total estimated loads.

Country	*Nitrogen loads;*			*Phosphorous;*		
	Own	*BSAP*[1]	*Helcom*[2]	*Own*	*BSAP*[1]	*Helcom*[3]
Denmark	5.0	10.5	7.6	2.9	0.2	3.6
Finland	5.9	3.8	17.8	4.2	2.1	16.5
Germany	5.6	2.9	3.8	1.2	0.6	2.9
Poland	37.9	39.2	28.0	56.5	49.1	45.5
Sweden	9.0	13.2	21.4	4.2	3.1	16.6
Estonia	6.3	3.5	4.0	4.2	4.5	3.3
Latvia	5.4	1.9	6.6	7.7	7.4	3.6
Lithuania	11.2	8.9	4.3	8.9	8.4	1.9
Russia	10.4	16.3	6.5	10.1	23.9	6.2
Total	97.8[4]	100	100	100	100	100
Total load, thousand tonnes of N and P	823.9	550.1	822.2	38.9	27.9	41.2

1) Helcom (2007) table 2 page 3; 2) Helcom (2004) table 5.31, page 163; 3) Helcom (2004) table 5.32, page 164; 4) Own estimates of country shares do not sum to 100 due to the loads of emission sources operating on the Baltic Sea.

Table B4: Baltic Sea basin shares of nitrogen loads and phosphorous loads from different calculation sources, % of total estimated loads.

Basin	*Nitrogen;*			*Phosphorous;*		
	Own	*BSAP*[1]	*Helcom*[2]	*Own*	*BSAP*[1]	*Helcom*[2]
Bothnian Bay	3.1	7.0	6.7	1.7	7.2	8.9
Bothnian Sea	4.4	7.7	12.4	2.4	6.8	9.1
Baltic Proper	61.2	44.4	41.1	71.0	52.5	55.5
Gulf of Finland	14.2	15.3	15.4	13.2	19.1	13.5
Gulf of Riga	5.6	10.6	7.1	7.0	6.1	4.4
The Sound	6.6	6.2	6.1	2.9	3.9	3.1
Kattegat	5.0	8.7	11.1	1.9	4.4	5.6
Total	100	100	100	100	100	100

1) Helcom (2007) table 1, page 2; 2) Helcom (2004) table 5.31, page 163; 3) Helcom (2004) table 5.32, page 164

Appendix C: Calculated marginal costs for nutrient reductions to the Baltic Sea

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Table C1: Minimum marginal costs of reductions in airborne emissions and livestock, SEK/N reduction to the Baltic Sea.

	SCR car	*Fertilizer reduction*	*SCR on power plants*	*Livestock reductions;*			*Spring man. spread*
				cattle	*pigs*	*poultry*	
Denka	243	0 – 1451	387	613	570	540	75
Denso	243	0 – 1451	387	613	570	540	75
Fibb	246	0 – 473	396	313	371	552	52
Fibs	246	0 – 394	396	310	344	523	52
Fifv	246	0 – 381	396	282	339	407	52
Gerso	444	0 – 410	755	532	634	689	136
Gerbp	444	0 – 410	755	532	634	689	136
Vist	314	0 – 108	528	314	416	486	71
Oder	314	0 – 108	528	314	416	486	71
Polcoast	314	0 – 108	528	314	416	486	71
Sebb	218	0 – 472	373	431	493	753	77
Sebs	218	0 – 395	373	384	412	641	69
Sebap	218	0 – 406	373	356	412	508	71
Sebano	218	0 – 390	373	335	382	605	71
Seso	218	0 – 87	373	228	245	294	44
Seka	218	0 – 369	373	214	280	345	48
Estob	224	0 – 65	374	213	325	388	58
Estog	224	0 – 65	374	213	325	388	58
Estof	224	0 – 65	374	213	325	388	58
Latvib	228	0 – 156	351	208	352	407	66
Latvig	228	0 – 156	351	208	352	407	66
Lith	254	0 – 24	418	64	114	134	55
Sukal	267	0 – 369	440	208	267	312	56
Supet	360	0 – 414	604	256	329	384	69
Minimum cost per unit N reduction by SCR in ships including direct impact on the Baltic Sea and indirect on deposition on land in all drainage basins is SEK 19/kg N reduction.							

Table C2: Minimum marginal costs of catch crops, grassland, increased sewage cleaning, and private sewers, SEK/N reduction to the Baltic Sea.

	Catch crops	*Grass land*	*Energy forest*	*Wetlands*	*Sewage, urban*	*Sewage, rural*	*Private sewers*
Denka	299	1007	1071	66	175	331	565
Denso	290	974	1036	60	175	331	565
Fibb	147	317	822	139	222	419	717
Fibs	147	316	831	52	222	419	717
Fifv	146	313	1022	11	222	419	717
Gerso	113	324	583	23	239	451	771
Gerbp	114	327	588	25	239	451	771
Vist	91	82	118	10	232	448	766
Oder	97	88	127	11	232	448	766
Polcoast	106	96	139	10	232	448	766
Sebb	376	188	3487	2764	205	387	661
Sebs	287	198	2571	1191	216	408	697
Sebap	204	302	1814	353	395	745	1272
Sebano	193	286	1661	296	395	745	1272
Seso	46	75	544	75	225	425	727
Seka	111	261	773	131	197	372	636
Estob	80	58	109	48	168	325	557
Estog	78	57	107	50	168	325	557
Estof	79	57	108	67	168	325	557
Latvib	204	140	283	64	236	456	780
Latvig	202	139	280	93	236	456	780
Lith	71	20	107	20	200	386	660
Sukal	178	156	235	143	325	627	1072
Supet	193	169	255	94	325	627	1072

Table C3: Minimum marginal costs of reductions in sewage and P free detergents for P reductions to the Baltic Sea, SEK/P reduction.

	Sewage treatment, upstream urban areas	*Sewage treatment, upstream rural areas*	*Private sewers, upstream*	*P free det. Upstream connected*	*P free det. upstream unconnected*	*P free det. direct connected*	*Fertiliser reduction*
Denka	665	1271	2445	434	104	425	0 – 102646
Denso	665	1271	2445	434	104	425	0 – 102649
Fibb	881	1683	3239	493	138	365	0 – 11061
Fibs	881	1683	3239	493	138	365	0 – 11215
Fifv	881	1683	3239	493	138	365	0 – 10754
Gerso	1630	3115	5992	1256	255	502	0 – 93506
Gerbp	1630	3115	5992	1256	255	502	0 – 93506
Vist	686	1335	3246	270	165	167	0 – 5180
Oder	686	1335	3246	270	165	167	0 – 5180
Polcoast	686	1335	3246	270	165	167	0 – 5180
Sebb	1087	2076	3995	831	170	499	0 – 7784
Sebs	1087	2076	3995	831	170	499	0 – 8342
Sebap	1230	2350	4522	941	193	499	0 – 18580
Sebano	1230	2350	4522	941	193	499	0 – 9771
Seso	652	1246	2397	499	102	499	0 – 38884
Seka	1086	2076	3995	831	170	499	0 – 2613
Estob	664	1293	3145	279	159	178	0 – 2613
Estog	664	1293	3145	279	159	178	0 – 2613
Estof	664	1293	3145	279	159	178	0 – 2752
Latvib	708	1380	3355	340	170	204	0 – 2752
Latvig	708	1380	3355	340	170	204	0 – 2752
Lith	607	1182	2875	190	146	133	0 – 1503
Sukal	1062	2070	5032	426	255	170	0 – 10208
Supet	1062	2070	5032	310	255	124	0 – 19000

Table C4: Minimum marginal costs of livestock reductions, buffer strips, grasslands, and wetlands SEK/kg P reduction to the Baltic Sea.

	Livestock reductions;			*Buffer strips*	*Catch crop*	*Wetlands*
	Cattle	*pigs*	*poultry*			
Denka	45189	23796	24872	37713	9899	8677
Denso	45189	23796	24872	31067	7455	6992
Fibb	15409	10472	17193	8060	6154	2363
Fibs	15285	9725	16288	7514	5095	1666
Fifv	13913	9561	12668	7419	4933	751
Gerso	56401	40451	48029	6716	1444	2999
Gerbp	56401	40451	48029	8529	1873	3870
Vist	5086	4673	5527	2532	3102	679
Oder	5086	4673	5527	2462	2941	663
Polcoast	5086	4673	5527	2588	3239	459
Sebb	26140	18013	29411	2548	7366	30797
Sebs	19706	12714	21176	3754	6784	32328
Sebap	39051	27213	35857	18119	66649	63801
Sebano	36748	25191	42687	15556	25963	40837
Seso	17283	11183	14338	7444	8876	25805
Seka	24833	19531	25735	35118	50070	46778
Estob	7271	7328	8680	2377	19055	7031
Estog	7271	7328	8680	2408	21974	6158
Estof	7271	7328	8680	2574	88657	9127
Latvib	4344	5218	6106	2156	8074	4232
Latvig	4344	5218	6106	2675	62177	5119
Lith	1120	1405	1670	891	4206	2405
Sukal	9635	9000	10515	1786	1417	9010
Supet	17932	16750	19570	2624	1994	10020

Appendix D: Minimum cost solutions

Table D1: Total and shadow costs of different reduction requirements in total load of N and P to the Baltic Sea

Reduction in per cent	*N reductions*		*P reductions*	
	Total cost Mill SEK	*Shadow cost SEK/kg N*	*Total cost Mill SEK*	*Shadow cost SEK/kg P*
10	684	12	1020	425
20	2245	30	2710	652
30	5664	68	6023	1271
40	13008	113	11133	1433
50	25540	252	16460	1806
60			25334	3279

Table D2: Minimum costs of nitrogen reductions to marine basins for different adjustments between basins

Reduction targets in %	*Nitrogen reductions*				*Phosphorous reductions*		
	BP	*GF*	*DS*	*KT*	*BP*	*GF*	*GR*
Direct discharges							
10	408	149	92	126	681	163	54
20	1057	765	295	412	1892	388	181
30	2495	2074	678	973	4368	614	517
40	5061	3592	1416	1825	7929	1098	883
50	10504	6292	3201	3272	11576	2053	1544
					16619		
					25340		
First-order adjustm.							
10	787	556	459	196	201	768	531
20	2603	1721	1273	680	746	2193	1948
30	6473	4234	2990	1574	1478	4076	4090
40	12276	8544	6248	3026	2572	8860	8021
50	25019	16359	12948	6167	4642	12836	12789
					7268		
					12145		
Steady state							
10	581	371	660	753	682	766	324
20	1783	1942	1979	2183	2727	2611	1356
30	4339	4244	4842	5217	7483	6522	3647
40	10246	7749	11219	11313	14091	13525	7842
50	22680	19117	25222	25116	23884	21786	17238
60					39942		
67					68671		

Table D3: Marginal costs in different basins for obtaining 20 and 50 per cent reductions in N and P in Baltic Proper, and N in Kategatt, and P in Gulf of Riga, separate targets.

	N		*P*	
	BP	*Kat*	*BP*	*GR*
First-order				
20 %				
BB	0			
BS	73		618	
BP	26			491
GF	75		772	5
GR	65		856	1260
DS	39	73	388	
KT	0	77		
50 %				
BB	0			
BS	606		2420	
BP	210			1647
GF	605		3026	5
GR	533		3355	4223
DS	323	585	1520	
KT		616		
Steady state:				
20 %				
BB	16	14	124	39
BS	19	17	349	110
BP	26	23	756	238
GF	18	16	506	158
GR	14	12	580	1872
DS	11	74		
KT	2	120		
50 %				
BB	206	135	641	268
BS	241	158	1810	759
BP	325	214	3921	1647
GF	227	149	2625	1098
GR	180	118	3013	12940
DS	137	680		
KT	28	1109		

Table D4: Marginal costs for reduction targets of 20 and 50 per cent for N and P at all target basins

	20´		*50*	
	N	*P*	*N*	*P*
Direct discharges:				
BP	14	489	125	1647
GF	93	772	547	2523
GR		1260		3222
DS	84		543	
KT	53		592	
First-order adjustment:				
BB				
BS	50	351	510	1452
BP	17	488	176	1647
GF	50	772	511	2941
GR	44	486	449	2013
DS	47	220	679	912
KT	72		428	
Steady state:				
BB	5	188	115	464
BS	6	532	135	1308
BP	8	1154	183	2834
GF	72	772	412	3284
GR	4	1135	101	2178
DS	494		1319	
KT	103		332	

Table D5: Increase/decrease in leaching and retention by 10 % of nutrients for 20 and 50 per cent nutrient reduction targets.

Reduction targets	*N reductions*				*P reductions:*			
	Leaching		*Retention*		*Leaching*		*Retention*	
	-10 %	*10 %*	*- 10 %*	*10 %*	*-10 %*	*10 %*	*- 10 %*	*10 %.*
Change in estimated load, %	-7.4	7.4	5.8	- 5.8	-4.0	4.0	5.5	-5.5
20 %´:								
Total cost	2314	2198	2221	2283	2584	2831	2873	2545
Marginal cost	29	22	24	28	652	652	652	652
50 %:								
Total cost	26940	24440	24973	26224	15983	16996	16899	16061
Marginal cost	293	219	223	280	1684	1854	1800	1745

Table D6: Minimum cost solutions for increase/decrease in land price and sewage treatment costs by 25 % for 20 and 50 per cent nutrient reduction targets.

Reduction targets	*N reductions:*				*P reductions:*			
	Land price		*Sewage treatment*		*Land price*		*Sewage treatment*	
	-25 %	*25 %*	*- 25 %*	*25 %*	*-25 %*	*25 %*	*- 25 %*	*25 %.*
20 %´:								
Total cost	1993	2395	2246	2246	2696	2714	2099	3270
Marginal cost	23	29	26	26	652	652	489	726
50 %:								
Total cost	22396	28309	24482	26597	16626	16724	13534	19397
Marginal cost	220	278	250	251	1640	1810	1510	1873

Table D7: Minimum cost solutions for increase/decrease in abatement capacity by wetlands, SCR, and P removal in detergents for 25 % for 20 and 50 per cent nutrient reduction targets.

Reduction targets	*N reductions:*				*P reductions:*			
	Wetland		*SCR*		*Wetland*		*P free deterg*	
	-25 %	*25 %*	*- 25 %*	*25 %*	*-25 %*	*25 %*	*- 25 %*	*25 %.*
20 %´:								
Total cost	2894	1752	2268	2228	2726	2664	2900	2522
Marginal cost	36	20	26	24	652	577	652	599
50 %:								
Total cost	32397	21005	26349	24772	16785	16215	17215	15914
Marginal cost	393	154	264	237	1937	1570	2013	1457

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