PAN-BALTIC MANUAL

OF BEST PRACTICES ON CLEAN SHIPPING AND PORT OPERATIONS

BSR InnoShip

Baltic Sea Region Programme 2007-2013
Part-financed by the European Union (European Regional Development Fund and European Neighbourhood and Partnership Instrument)

PAN-BALTIC MANUAL OF BEST PRACTICES ON CLEAN SHIPPING AND PORT OPERATIONS

The Pan-Baltic Manual of Best Practices on Clean Shipping and Port Operations is a main output of the BSR InnoShip - Baltic Sea cooperation for reducing ship and port emissions through knowledge- & innovation-based competitiveness, led by Tapani Stipa at The Baltic Institute of Finland. BSR InnoShip is a flagship project of the Strategy for the Baltic Sea Region of the European Union, under the Priority Area SHIP.

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FOREWORD
AIM AND ADDRESSES OF THE MANUAL

AUTHOR: LEAD PARTNER TAPANI STIPA (BALTIC INSTITUTE OF FINLAND)

This manual provides a collection of best practices in addressing the tightening exhaust emission regulations for ships. The manual is intended to serve as a high-level guidance for local and national authorities, ship-owners and logistics managers to prepare for the future shipping market, in particular in European emission control areas.

The shipping market in the Baltic and North seas is expected to go through a disruptive change in the next few years, especially when the fuel prices increase considerably on January 1, 2015, as a result of the lowering of the fuel sulphur content limit from 1.0% to 0.1%. The freight rates for maritime transport are expected to increase by 20 – 40 % burdening the exporting and importing industries. Modal shifts from sea to road can be expected.

Action needs to be taken by authorities, shipowners ports, and freight owners, as well as by other components of the logistics chains.

Shipowners face a pressure to retrofit their existing vessels with exhaust cleaning equipment or purchase new vessels, a financial challenge in present economic conditions. The technical challenges in complying even in the most simple case are not be overlooked. In the selection of new technologies, facts about the capabilities of those technologies and challenges faced in their operations are an important element for the decision making.

The ports need to adjust to ever faster port operations, larger ships, and new types of sewage from exhaust cleaning equipment. A new fuel, liquefied natural gas LNG, will slowly become available at ports and needs its own safety procedures and logistic arrangements. Differential port dues may need to be considered.

Freight owners, in many cases, need to realize that their logistic chains are going to slow down, at least for the maritime part. This may imply a need for increased storage space. The increased costs for the warehousing and working capital need to be balanced against increasing freight rates (the cost of speed).

The authorities need to understand how to ensure a level playing field for the transport service industry in a situation, where the financial incentives for non-compliance with the regulations are high. Existing control regimes such as port state control and coastguard patrols may need to understand and implement new procedures. The interpretation and implementation of regulations by member states benefits from harmonization.

This manual provides a collection of best practices, based on existing good practices in the field as well as best available technologies, to help the stakeholders of maritime transportation to adapt to the expected disruption of the maritime transport links in the Baltic and North Seas. In chapter 1 the Manual gives a clear picture of Baltic maritime transport and its importance for Baltic Sea countries as well as of amount, structure and tendencies of ships' air emissions in the region. Chapter 2 describes the present regulations, as well as foreseen needs for their enforcement. Chapter 3 presents the state-of-the-art in compliance options for shipowners (and, at least for slow steaming, impacting freight owners as well). Chapter 4 describes the challenges on the port/city level. Chapter 5 describes the communication challenges and remedies.

As in every disruption, there will be winners and losers in the forthcoming change. This manual will help the stakeholders to make the right decisions in order to be well placed for the changes when their time comes.

The manual is a main output of the Baltic Sea Region Programme project "BSR InnoShip – Baltic Sea cooperation for reducing ship and port emissions through knowledge and innovation based competitiveness", which was implemented in 2011-2013. This project was carried out by 20 partners from all Baltic Sea countries including Norway and Russia. A major resource for the project was its often enthusiastic set of associate partners, who contributed with their knowledge and through their own actions in implementing clean shipping solutions. In partnership, the project partners developed information and solutions in the form of documented information (including patents), promising emission reduction equipment as well as best practices in major new infrastructure, such as LNG powered ships or scrubber installations.

CHAPTER 1:
CURRENT STATUS OF SHIP TRAFFIC AND SHIP EMISSIONS IN THE BALTIC SEA REGION

1.1 BALTIC MARITIME TRANSPORT, ITS STRUCTURE, COMPETITIVE SITUATION AND ECONOMIC WEIGHT

AUTHORS: PROF. DR. KARL-HEINZ BREITZMANN, MARKO MÖLLER AND DR. CHRISTIAN WENSKE
(BALTIC INSTITUTE ROSTOCK)

The Baltic Sea is very transport-intense. Its share in world sea-borne trade is in the range of 7 to 8 per cent (measured in tons of goods carried).

In the Baltic can be found all types of cargoes and transport technologies known in world shipping (see fig. 1), although in some sectors in a special expression reflecting the relative shorter sea distances and the limits for ship size, because of the maximal water depth of 17 m in the sea's entrance.

In 2010 total cargo handling in all Baltic Sea ports amounted to 810 million tons. In ports handling each 1 million tons and more (main ports) the total reached 759 million tons. Table 1 shows the commodity structure of Baltic Sea maritime transport in main ports.

Liquid goods present the highest transport volumes, their share is summing up to more than 40 per cent. That mainly is raw oil and oil products, but also chemicals. Nearly 60 per cent of the tanker transport is Russian export going through the Russian ports of Primorsk, St. Petersburg, Kaliningrad and Vysotsk, but also in transit through Tallinn, Ventspils and Klaipeda.

The second largest group of cargoes is dry bulk with about 25 per cent of all transports. Here coal, iron ore and grain as well as fertilizers and respective raw materials and building materials like cement, stone and gravel can be mentioned.

The remaining 3 cargo groups are much smaller with 12 to 10 per cent shares each. Higher value investment goods and consumer articles on the Baltic are handled by two technologies. In Baltic external trade container feeder services are dominating, but in Baltic internal transport this function is realized by ferries and ro-ro ships.

The final group, which Eurostat is calling "other cargo", includes break bulk and other general cargoes not included in the container and ro-ro segments. Here we find three sub-groups: Forestry products with about 50 per cent of the groups' volume, then iron and steel with 25 per cent and other general cargo also with nearly 25 per cent.

Traffic Relation	Transport technologies/ Operation modes		
	manufactured goods/ general cargo	**raw materials/ bulk goods**	**passengers**
Baltic external traffic	container feeder services (ro/ro-services)	medium size tankers medium size bulk carriers system carriers	cruise shipping
Baltic internal traffic	ferry lines ro/ro-services	handy and medium size tankers and bulk carriers system carriers	ferry lines cruise shipping

Figure 1: Structure of Baltic Sea transport according to traffic relation and transport technology
Source: Baltic Institute Rostock

Type of cargo	Year	Total		Baltic external transport		Baltic internal transport	
		(mill. tons)	share (%)	(mill. tons)	share (%)	(mill. tons)	share (%)
Liquids	2008	251	43,0	184	73,3	67	26,7
	2009	251	47,0	188	74,9	63	25,1
	2010	257	44,0	191	74,3	66	25,7
Dry bulk	2008	144	24,7	105	72,9	39	27,1
	2009	130	24,3	98	75,4	32	24,6
	2010	144	24,7	106	73,6	38	26,4
Ro-Ro	2008	71	12,2	13	18,3	58	81,7
	2009	59	11,1	10	16,9	49	83,1
	2010	65	11,1	10	15,4	55	84,6
Container	2008	59	10,1	54	91,5	5	8,5
	2009	48	9,0	43	89,6	5	10,4
	2010	58	9,9	52	89,7	6	10,3
Break bulk/ other general cargo	2008	59	10,1	44	74,6	15	25,4
	2009	46	8,6	35	76,1	11	23,9
	2010	60	10,3	46	76,7	14	23,3
Total	2008	584	100	400	68,5	184	31,5
	2009	534	100	374	70,0	160	30,0
	2010	584	100	405	69,3	179	30,7

Table 1: Structure of Baltic maritime transport according to type of cargo
Source: Baltic Institute Rostock, based on Eurostat data and Russian port statistics

Because of the recession transport in 2009 went down by 9 per cent to 534 million tons. The downfall was much higher in container (18 per cent), ro/ro (17,2 per cent), break bulk (16 per cent) and dry bulk (11,7 per cent) segments, whereas liquids were nearly constant (1,4 per cent).

The geographic pattern of Baltic maritime is characterized by a high share of Baltic external transport, i.e. either the port of origin or of destination is outside the Baltic Sea Region. More than 70 per cent of liquid and dry bulk goods handled are Baltic external shipments, in container transport this share amounts even to 90 per cent. In ro-ro traffic, on the other hand, Baltic internal transport is dominating, only a small number of ro-ro services operate between Baltic and North Sea ports.

Since the middle of the 1990s Baltic maritime transport increased considerably. The compound annual growth rate in cargo handling from 1995 to 2010 was 3,2 per cent and even 4,7 per cent in the period 2000 until 2007.

Container traffic shows the strongest growth followed by ro/ro cargoes and liquids, dry bulk increased only slightly and break bulk / other general cargo even diminished (see table 2).

Considerable structural changes occurred in the regional distribution of cargo flows and in the different countries´ importance as origin or destination of goods (see fig. 2).

The new market economies had a much stronger increase of maritime transport than the traditional market economies (see figure 2). Considering the period from 1995 to 2010, their compound annual growth rate in cargo handling was 7,2 per cent, compared to 0,9 per cent of the Nordic countries and Germany. The new market economies increased their share in Baltic cargo handling from 27 per cent in 1995 up to 48 per cent in 2010 (see

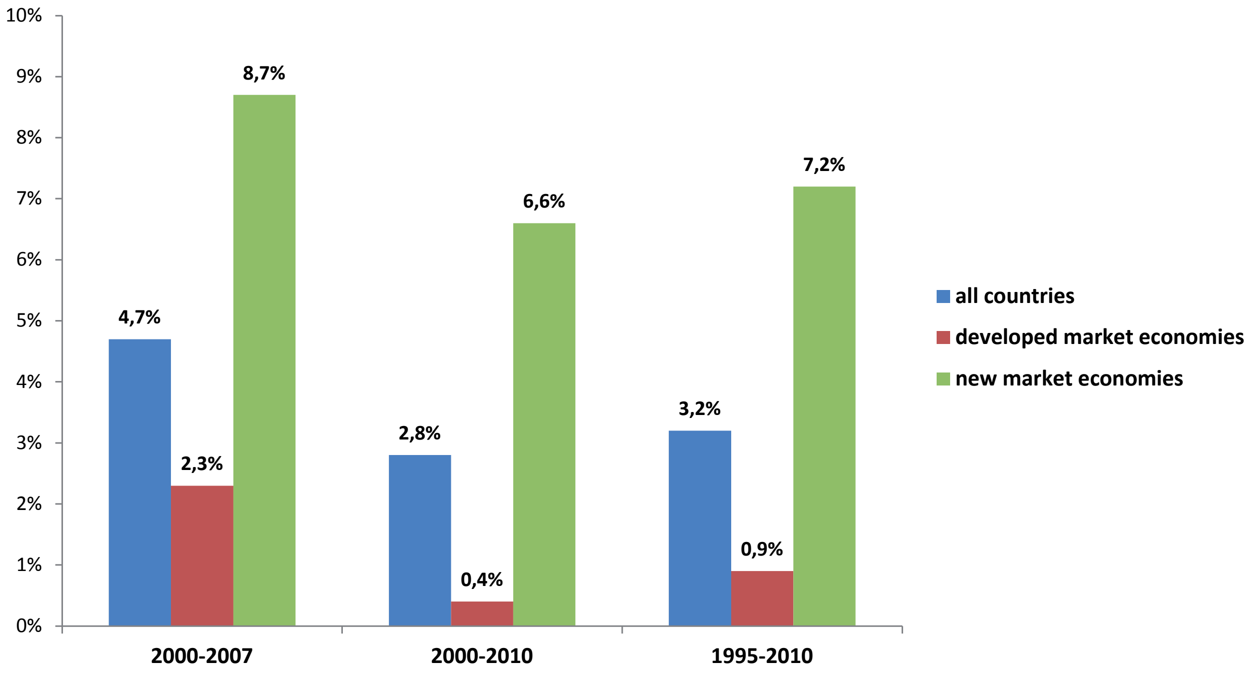

Figure 2: Annual growth rates of Baltic ports' cargo handling

figure 3). Since the year 2000 Russia has become the main driver for Baltic Sea transport growth.

MARITIME TRANSPORT IN COMPETITION WITH OTHER TRANSPORT MODES

Baltic Sea shipping is competing fiercely with other transport modes. For geographic reasons on routes between Western and Eastern Europe sea transport is particularly vulnerable. In 2010, e.g., transport of foreign trade goods between Western Europe (Germany, France, Netherlands, Belgium, Luxemburg, Spain, Portugal) and Eastern Europe (Russia, Kazakhstan) amounted to 10,4 million tons in west-east direction (exports from Western Europe) and to 197,3 million tons in the opposite direction (Western European imports). The modal split pattern of exports and imports is quite different (see table 2).

Western European exports are dominated by high-value goods (machinery, transport equipment, foodstuffs). They are mainly transported by truck, followed by sea ships. Road share increased to 56 per cent in 2010 from 42 per cent 1999, while the share of sea transport diminished from 48 per cent to 40 cent in this period.

Western European imports consist mainly of liquid and solid raw

Cargo group	period	CAGR* (%)	period	CAGR* (%)
Liquids	**2004-2007**	7,0	**2004-2010**	3,9
Dry bulk	**2004-2007**	1,7	**2004-2010**	1,7
Ro/ro	**2000-2007**	7,4	**2000-2010**	4,6
Break bulk / other general cargo	**2004-2007**	-3,1	**2004-2010**	-1,1
Container	**2000-2007**	13,8	**2000-2010**	9,2
Total	**2000-2007**	**4,7**	**2000-2010**	**2,8**

* compound annual growth rate

Source: Baltic Institute Rostock

Table 2: Dynamic of cargo handling in Baltic Sea ports according to type of cargo

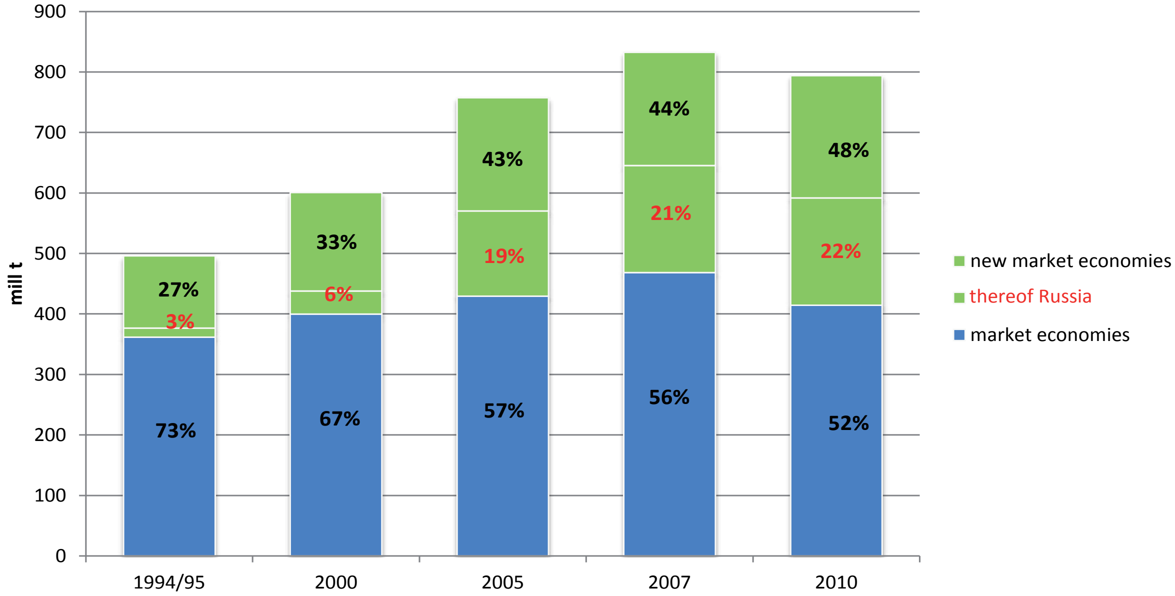

Figure 3: Dynamics of cargo handling in Baltic Sea ports according to groups of countries

materials and fuels (oil and oil products, natural gas, coal, ores) as well as of metals, fertilizers and chemicals. Here the share of road transport is insignificant. Sea transport´s share increased from 39 per cent in 1999 to 64 per cent in 2010, also on the expense of pipeline transport, which decreased even in absolute terms.

Particularly instructive is an analysis of transport patterns of high-value goods´ flows of different branch origin, summarized in the following as "general cargo". This cargo group in 2010 amounts to 8,3 million tons eastbound (exports) and 6,6 million tons westbound (imports).

In exports, dominated by machinery, vehicles and consumer goods, in 2010 the share of road transport reached 63 per cent against sea transport´s 33 per cent and railways´ 4 per cent (fig.4).

General cargo imported to Western Europe from Russia and Kazakhstan (break bulk cargoes) constitutes mainly of semi-finished rolled steel products and chemicals. In all break bulk cargoes the share of sea transport is 78% while 19% are carried by road. The share of railways is again negligible, as well as that of inland waterways shipping (fig. 5).

Road, and partially also rail transport, is a strong competitor to sea transport not only on routes along the southern Baltic coast, but on north-south routes, too. There exist competitive land based transport routes between Central Europe and Denmark, Norway, Sweden and Finland.

YEAR		SEA	ROAD	RAIL	PIPELINE	OTHERS/ UNKNOWN
1999	export	48	42	7	0	2
	import	39	12	0	55	5
2010	export	40	56	3	0	0
	import	64	1	0	26	9

Table 2: Modal split in Western European foreign trade with Eastern Europe (in per cent)
Source: Eurostat

Sea transport to Denmark across the Baltic is competing with rail and road routes via Jutland. Direct land transport routes to Sweden and Norway via Denmark can make use of the Great Belt and Öresund fixed links. For all these connection various combinations of land and sea links are available with quite different relations between land and distance.

Transport connections with Finland show a similar picture. Here direct sea transport is competing, i.g.,

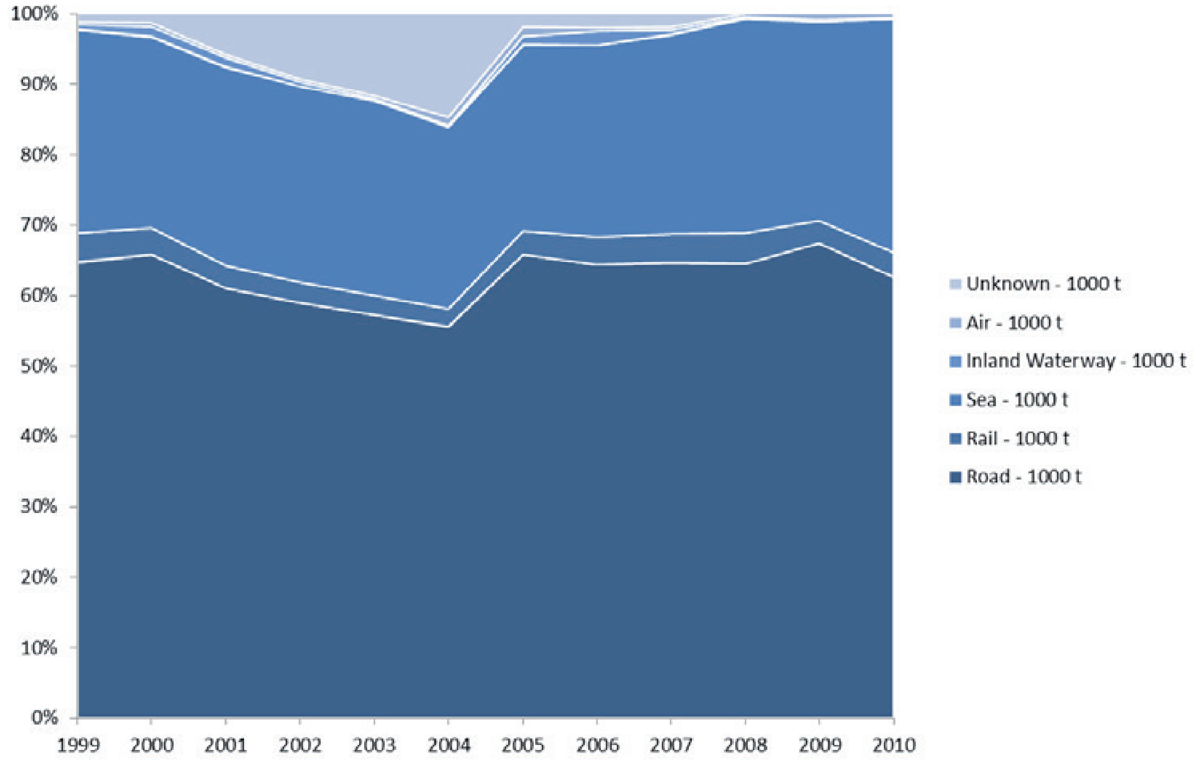

Figure 4: Development and modal split of general cargo exports

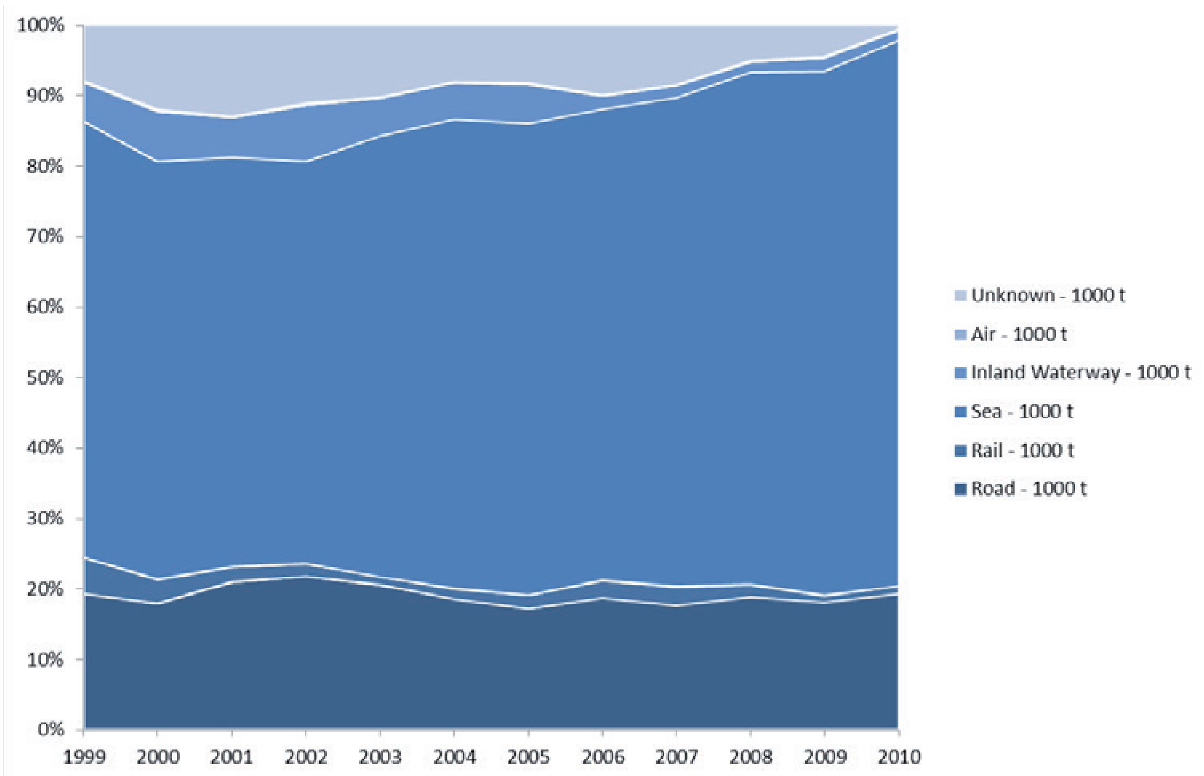

Figure 5: Development and modal split of general cargo imports

with long distance truck runs to Tallinn followed by short ferry crossing to Helsinki or land transport via Denmark and Sweden combined with a short sea leg from Sweden to Finland.

These considerations and the data cited allow for an important conclusion: Because of geographic factors in Baltic Sea transport, regulations and measures influencing transport costs and/or quality of a specific transport mode will change its position in intermodal competition. Rising shipping costs weaken the competitive position of sea transport, resulting in increasing shares of land transport and road transport in particular. Maritime transport can be replaced by road (and rail) transport entirely or good flows can switch from combinations of long sea leg / short land leg to ones composed of short sea leg / long land leg.

THE IMPORTANCE OF MARITIME TRANSPORT FOR BALTIC SEA COUNTRIES´ FOREIGN TRADE

Maritime transport is essential for all Baltic Sea countries, as substantial shares of their foreign trade are channeled through Baltic Sea ports. For each single country, however, the importance of Baltic Sea maritime transport has to be assessed individually, mainly because of their specific geographic situation. It can be measured by comparing the volumes of maritime transport with the respective volumes of foreign trade (see fig. 6).

Based on this ratio BSR countries can be grouped as follows:

Finland and Sweden

Finnish and Swedish foreign trade depend to a high degree on maritime transport. The ratio of 94 per cent in the case of Finland is a certain overstatement, as Russian transit traffic handled in Finnish ports is included (incoming containers, outgoing dry bulk goods), to some degree also the Swedish ratio is distorted by transit trade flows.
79 per cent of Finnish foreign trade is exchange with countries bordering with the European Sulphur Emission Control Area (SECA). Maritime transport through Finnish ports to ports in the SECA is even higher than respective Finnish foreign trade and totals 105% thereof. Quite similarly Swedish exports and imports to and from SECA countries make up to 74 per cent of total foreign trade while maritime transports amounts to 105 per cent of total trade volume.

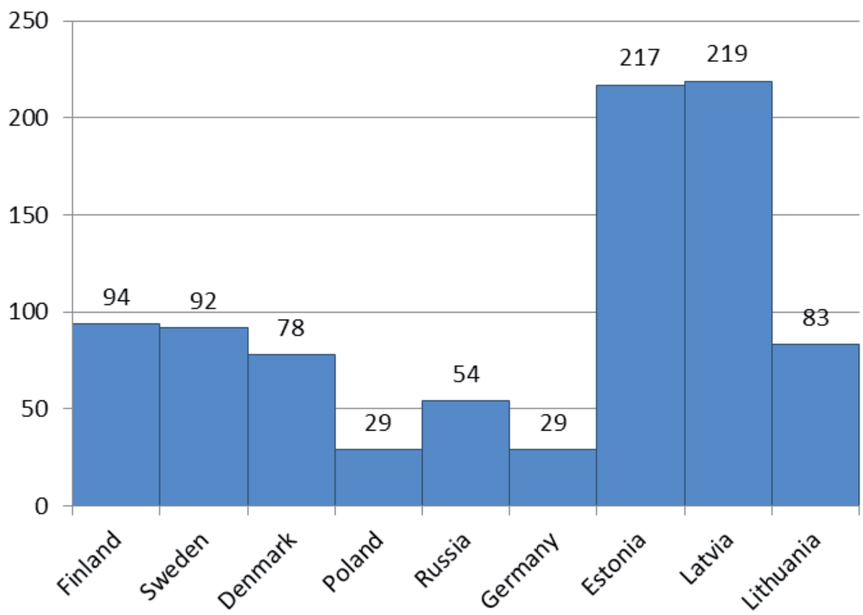

Figure 6: Sea transport volume as percentage of foreign trade tonnage 2010

Denmark and Poland

Both countries´ foreign trade is partly shipped by sea, partly by land transport. In the case of Denmark the real maritime share is smaller than the calculated 78 per cent as transit flows from Continental Europe to Sweden and Norway are channeled via Danish ports, too. Direct transports by truck and rail between Continental Europe and Denmark take the Jutland route. The SECA share in foreign trade is even 87 per cent. Here, too, sea transport share of 56 per cent is inflated by transit flows.

Polish foreign trade with Germany and other Western European countries uses mainly land transport routes as the geographically most logical solution, the sea transport share amounting to 29 per cent only. Foreign trade with SECA countries totals 57 per cent of foreign trade, 38 per cent being shipped by sea.

Estonia, Latvia, Lithuania

Sea transport to and from Estonian ports amounted to 217 per cent of the country´s foreign trade reflecting the substantial Russian transit traffic much alike as in the case of Latvia. Considerable shares of the three countries´ trade are carried by land transport, (e.g. trade with Russia and other CIS countries). In Estonia, e.g., in 2011 60 per cent of foreign trade were shipped by sea and 72 per cent of ports´ cargo handling consisted of transit goods.

The SECA share in Latvian foreign trade of 81 per cent is exceptionally high. Sea transport with European SECA ports reaches 168 per cent of respective foreign trade.

Figures for Latvia are similar. Due to mainly Russian transit maritime transport via Latvian ports is 218 per cent of the country´s foreign trade. Here SECA share in foreign trade is 82 per cent; sea transport with SECA ports nearly doubles foreign trade volume (194 per cent).

Although also Lithuania handles transit (e.g. from/to Ukraine, Belarus) total cargo handling in Klaipeda and Butinge is only 83 per cent of the volume of Lithuanian foreign trade. Foreign exchange goods with Eastern Europe are shipped by land transport, but 74 per cent of foreign trade (85 per cent exports, 65 per cent of imports) account for SECA countries and sea transport with these countries equals 74 per cent of total foreign trade.

Russia and Germany

Common feature of these countries is the availability of other than Baltic Sea ports – Russia has ports at the White, Black and Caspian Seas as well as at the Pacific Ocean and Germany mainly relies on North Sea ports.

Cargo handling in all Russian ports amounted in 2011 to 535 million tons, thereof Baltic Sea ports handled the biggest share - 172 million tons (32 per cent)

Most of Russian foreign trade with EU countries is carried by sea transport (53 per cent), Baltic

Sea ports handling the largest part thereof. Even slightly higher, 55 per cent, is the maritime share in trade with the European SECA countries. Adding Russian transit via the Baltic countries and Finland sea transport´s share exceeds 60 per cent.

German foreign trade totaled in 2010 950 million tons while cargo handling of national ports reached 272 million tons (20 per cent of foreign trade). However, large parts of German sea trade are channeled as transit cargo via Dutch and Belgian ports, enlarging the total share of sea transport to more than 50 per cent.

The share of Baltic Sea countries in German foreign trade amounts to 19 per cent, thereof 50 per cent are carried by sea.

From this overview it can be concluded, that maritime transport is of vital importance for BSR countries' foreign trade. In terms of tonnage it is even the decisive transport mode for Sweden and Finland and the most important for Denmark and Russia. Poland has, due to its geographic situation, a maritime share of less than 30 per cent. An exception among the BSR countries is Germany with a considerably lower importance of Baltic Sea shipping. For Estonia, Latvia and Lithuania the relevance of maritime transport consists not only in its role as means of transport for foreign trade goods, but also in the considerable income generated by handling transit cargoes for Russia and other CIS countries.

1.2 STATUS OF AIR EMISSIONS OF BALTIC SHIPPING

AUTHORS: JUKKA-PEKKA JALKANEN AND LASSE JOHANSSON (FINNISH METEOROLOGICAL INSTITUTE)

Fuel sulphur reduction has a significant impact on emitted Particulate Matter, which is commonly associated to detrimental human health effects. Most significant policy decisions affecting the ship emitted SOx and PM are the revision IMO MARPOL Annex VI SOx Emission Control Area requirements and the EU sulphur directive. The former restricts the marine fuel sulphur content in SECAs to 1.0% as of July 2010 whereas the latter requires ships to use 0.1%S fuel in harbor areas from 1.1.2010. SOx and Particulate Matter (PM) emissions from Baltic Sea shipping are in the decrease and during year 2011 about 79 000 tons of SOx and 23 000 tons of PM were emitted. It is noteworthy that there are some components of PM which are not affected by the fuel sulphur content, thus the decrease of PM is not as large as with SOx.

The policy changes alone are not responsible for the decrease of emitted pollutants, but also the decrease of overall economic activity and strong increase of the number of small vessels have had their impact on ship emissions. From 2006 to 2008, the total emissions of CO_2 and NOx were increasing, but decreased substantially in 2009, mainly caused by economic recession (Table 1). The recession started in 2008 and continued throughout 2009, during which the CO_2 emissions from commercial vessels decreased by 7 %. Regular passenger traffic was least affected by the recession, whereas there was a significant decrease in all of the emissions from container ships and vehicle carriers. Indeed, the results show a decrease of 16 % in predicted total cargo freight volume between 2006 and 2009.

During the time period 2006-2011, the number of small vessels with an AIS system installed has quadrupled, which increases the completeness of the vessel emission studies based on AIS. During this time, the traveled distance of commercial ship traffic has decreased by 14% from 2006 level, whereas the traveled distance of small vessels has doubled. In general, the emissions of all pollutants, except SOx and PM which were impacted by policy changes, have increased when compared to 2006 level (see Figure 1). It is expected that the upcoming requirement of 0.1%S fuel use in the Baltic Sea will further reduce sulphur and PM emissions from shipping, but also increase the fuel costs of shipping significantly.

The emissions of the Baltic Sea shipping were evaluated using an emission modeling program called Ship Traffic Emission Assessment Model, version 2 (STEAM2). The model allows for the influences of travel routes and ship speed, engine load, fuel sulfur content, multiengine setups and abatement

	NOx	SOx	PM	CO	CO_2
2006	336	144	29	52	15600
2007	369	132	28	58	15900
2008	377	132	26	64	16600
2009	360	124	23	64	15900
2010	345	90	23	63	17300
2011	356	75	22	36*	18700

Table 1 Emissions from Baltic Sea shipping, 2006-2011, in thousand tonnes.
* The calculation procedures of CO emissions were changed in 2011 data. The change of CO emissions cannot be thus attributed to change of ship activity.

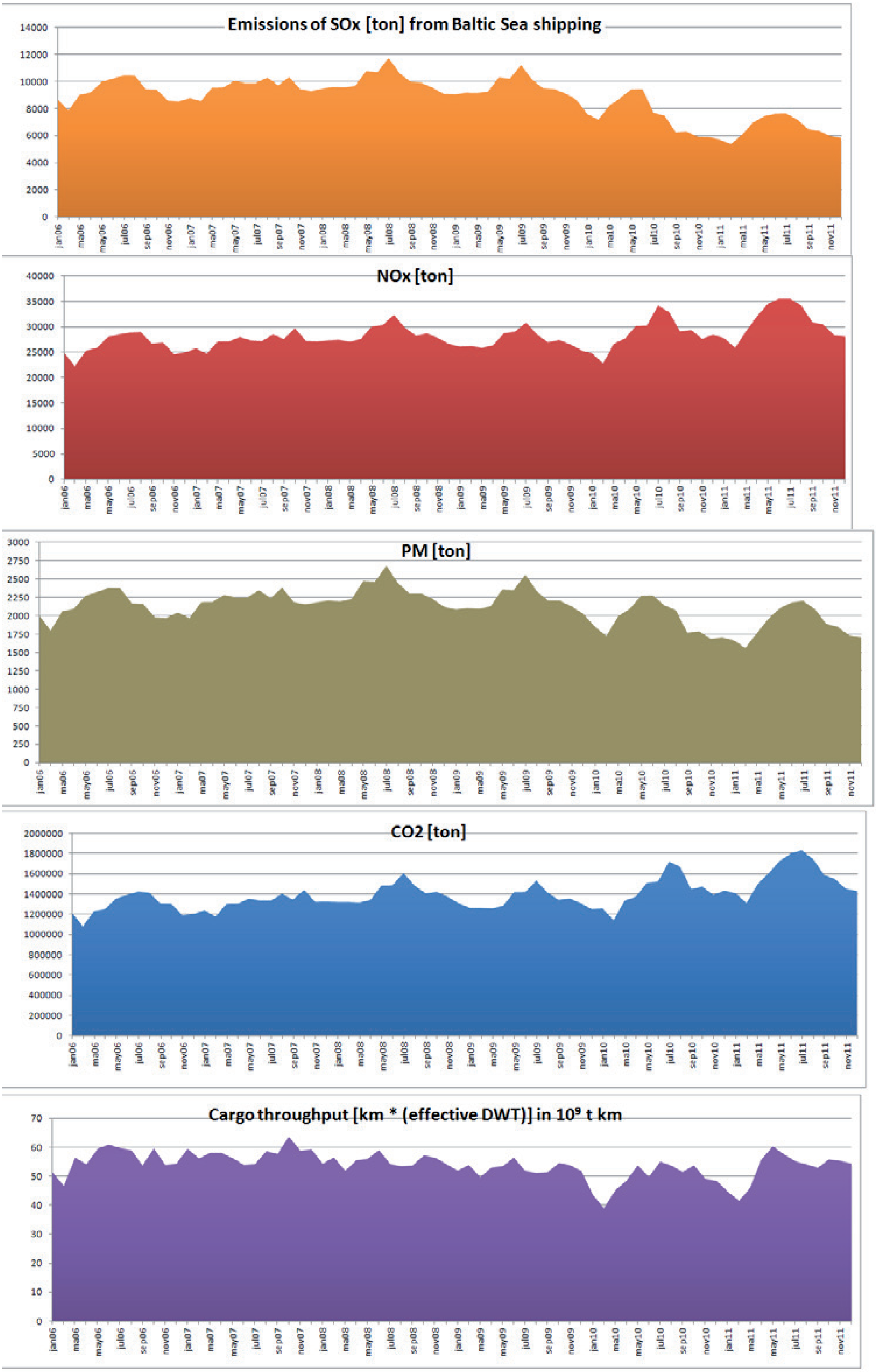

Figure 1 Emissions of NOx, SOx, CO, PM and CO_2 from the Baltic Sea shipping during 2006-2011. Cargo throughput (in ton km) is also illustrated.

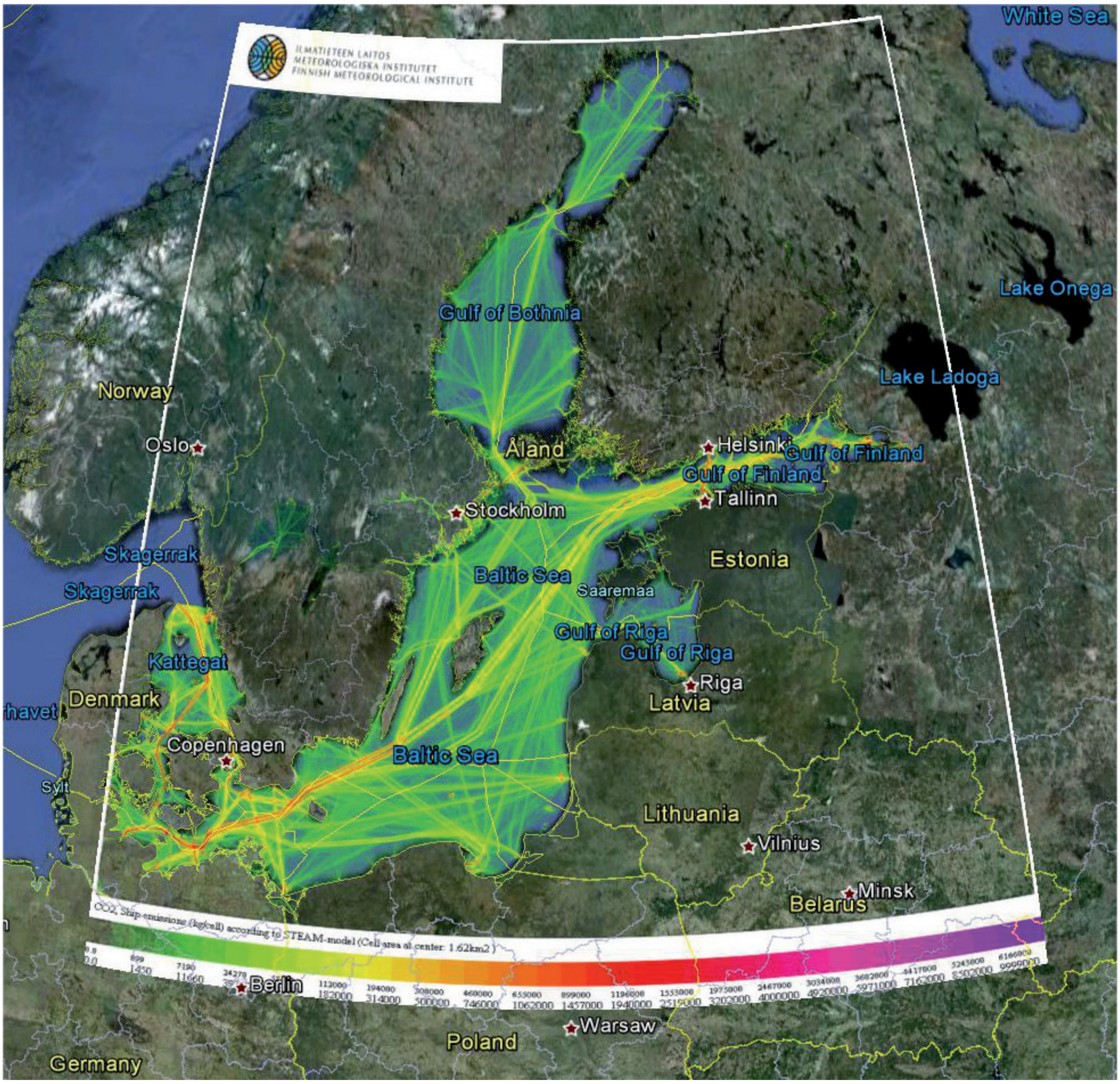

Figure 2 Geographical distribution of CO_2 emissions from Baltic Sea shipping during 2011

methods. This modeling approach uses the position reports generated by the Automatic Identification System(AIS); this system is onboard every vessel of over 300 gross tons in the Baltic Sea. The AIS system provides for automatic updates of the positions and instantaneous speeds of ships at intervals of a few seconds.

The geographical distribution of CO_2 emissions (fuel consumption) from ships is illustrated in Figure 2. As can be seen, most heavily trafficked areas are the Danish Straits, Kiel canal entry, Southern Baltic and the Gulf Finland, especially the Helsinki-Tallinn ferry route. The network of ship routes can be seen clearly from Figure 2. However, the network changes if difficult weather conditions block entry to direct routes; for example thick sea ice cover may alter ship routes and ice breaker assistance may be required. These features are automatically captured in ship emission patterns based on AIS data. The traffic patterns of different ship types can vary significantly. East-West cargo traffic is intersected by passenger traffic in many places, most notably between Åland-Stockholm and Helsinki-Tallinn, which are high risk areas for collisions between ships.

The emission, payload and vessel shares of different ship types are shown in Figure 3. Emissions from Tanker classes represent about 20 % of total SOx

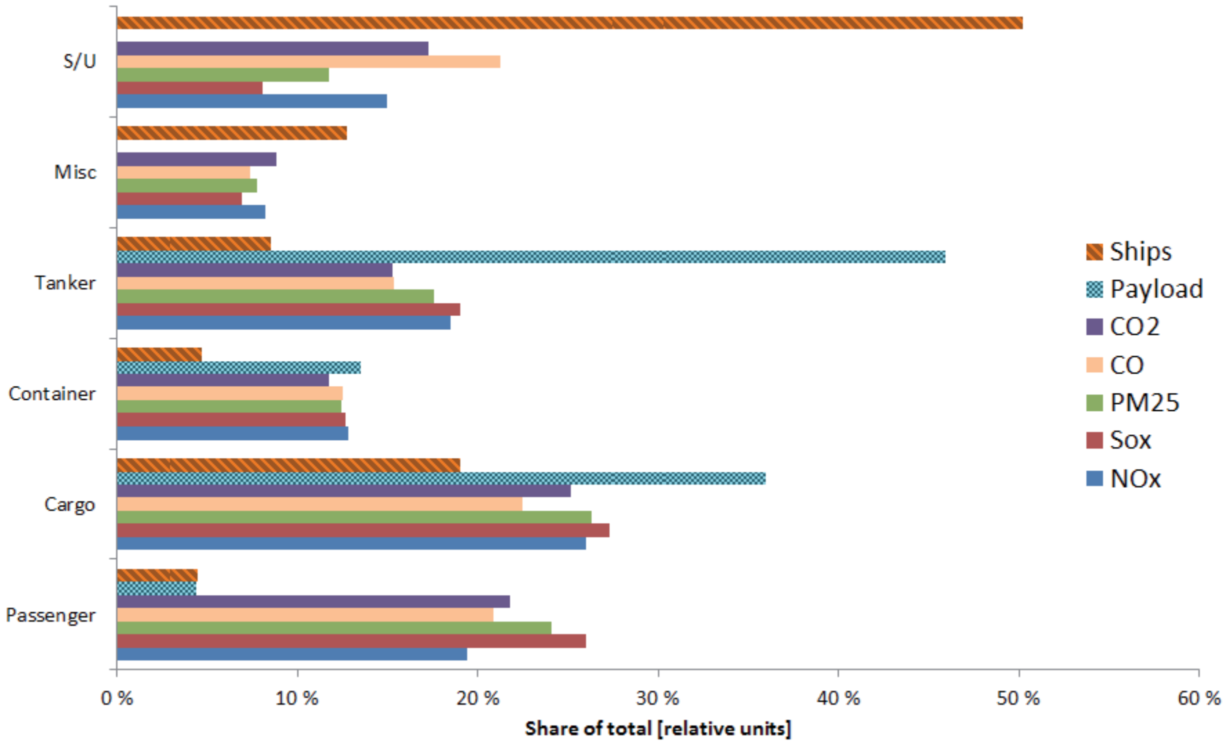

Figure 3 Emissions shares (%) of various ship types in the Baltic Sea region during 2011.

emissions, but also are responsible for almost half of the payload (cargo carried * distance traveled, in ton km). This information can be used to assess the energy efficiency of various ship types. This analysis reveals that there are order of magnitude differences between the environmental performance of various ship types ranging from bulk carriers and oil tankers to RoRo and RoPax vessels. The payload entry for small vessels could not be determined, because vessel data was insufficient in these cases.

The total ship emissions by pollutant for year 2011 in the Baltic Sea region are given in Table 1. In the same table, also the flag state distribution of emissions is illustrated. The Nordic fleets are on the top of this list, with large contributions from vessels sailing under flags of convenience. The flag state of each vessel was determined from the Maritime Mobile Service Identity (MMSI) entry and the Maritime Identification Digits (MID) contained within.

		NOx [t]	Sox [t]	PM2.5 [t]	CO [t]	CO2 [t]	Payload [10^6 kg*ton]	Ships	Messages	KM
All		356 311	75 498	21 794	36 274	18 698 232	638 452	27 684	426 641 793	137 241 490
	IMO	302 866	69 418	19 232	28 569	15 470 887	638 452	13 762	281 260 756	120 991 950
	S/U	53 445	6 080	2 562	7 705	3 227 345	0	13 922	145 381 037	16 249 541
Top flags	Sweden	53 114	11 748	3 527	6 138	3 219 926	23 344	2 569	63 996 456	17 372 005
	Denmark	29 614	5 277	1 738	4 262	1 745 903	22 442	1 654	84 881 550	11 461 364
	Finland	30 237	6 612	1 929	3 422	1 704 642	21 660	682	27 140 701	11 576 243
	Germany	23 457	4 976	1 445	2 765	1 260 947	20 899	2 613	39 466 478	9 145 888
	Netherlands	19 969	4 500	1 281	2 025	1 080 264	30 191	3 464	23 142 958	12 374 889
	Cyprus	16 213	3 520	985	1 490	804 045	38 805	423	10 291 011	6 729 587
	Malta	15 637	3 290	924	1 415	756 049	36 150	717	12 215 772	6 767 693
	Antigua_and_Barbuda	13 875	3 017	870	1 408	740 971	24 218	721	15 423 336	9 143 116
	United_Kingdom	14 550	3 284	888	1 285	686 668	37 861	1 811	9 484 776	4 657 193
	Liberia	16 694	3 523	928	1 215	672 740	82 397	809	5 168 522	3 332 692
	Bahamas	14 279	3 366	896	1 168	664 219	32 525	568	8 067 817	4 285 301
	Russia	9 831	1 367	504	1 095	542 965	10 664	784	16 465 951	5 065 321
	Norway	10 696	2 446	665	958	531 510	19 050	3 426	38 800 316	4 667 380
	Gibraltar	9 453	1 915	546	840	451 815	15 123	234	7 542 031	5 008 230
	Marshall_Islands	6 313	1 359	362	487	268 167	26 626	464	2 508 410	1 388 753
	Greece	7 553	1 639	410	492	267 575	56 145	170	1 548 915	1 118 054
	Italy	5 448	1 459	370	458	263 464	10 957	162	1 661 198	1 245 423
	Hong_Kong	4 226	905	240	295	175 299	21 412	297	1 289 945	853 109
	Saint_Vincent_and_the_Gre	2 067	346	114	193	112 914	3 060	157	5 235 898	2 221 157
	Panama	1 969	391	110	143	88 346	7 360	243	1 259 553	486 318
Ship types	Passenger	69 255	19 644	5 244	7 580	4 070 428	28 552	1 253	47 312 681	18 521 527
	Cargo	92 536	20 605	5 742	8 165	4 710 025	230 062	5 287	98 604 500	54 088 870
	Container	45 836	9 560	2 716	4 554	2 191 240	86 519	1 313	18 090 052	12 560 737
	Tanker	65 988	14 355	3 832	5 583	2 851 259	293 319	2 375	38 324 169	19 587 621
	Misc	29 251	5 256	1 698	2 687	1 647 935	0	3 534	78 929 354	16 233 194

Table 2 Emissions from Baltic Sea shipping during 2011

1.3 EMISSION TENDENCIES UNTIL 2030 ACCORDING TO SCENARIOS

AUTHOR: JUHA KALLI (CENTRE FOR MARITIME STUDIES, UNIVERSITY OF TURKU)

Emission projections are estimated for international shipping (13 ship types) in the European SECA until 2030. The first year in the projections is 2009 for which STEAM model has produced the emission and fuel consumption estimates. Emissions projections include assumptions for traffic growth, fleet renewal and efficiency increase separately for every ship type (Table 1).

Traffic growth assumptions are divided in to two time sequences: 1) until 2020 and 2) from 2020 to 2030. These forecast figures originate from the EU project Baltic Maritime Outlook. Parallel to traffic growth the projections also assume efficiency increase as presented in the Second IMO GHG study.

Emissions of sulphur oxides (SOx) and particulate matter (PM) have decreased drastically in 2010 when the 1.0% sulphur limit in marine fuels entered into force (Figure 1). Further decrease will occur in 2015 alongside the 0.1% sulphur limit. Figure 1 presents two scenarios: 1. 0.1%-S for all vessels after 1.1.2015 and 2. 0.1%-S for vessels built before 1.1.2015. We can see that the effect of scenario 2 would have only minor effect to the SOx and PM emissions.

	SHIP TYPE	AVERAGE LIFETIME [YEARS]	TRAFFIC GROWTH UNTIL 2020	TRAFFIC GROWTH FROM 2020 TO 2030	EFFICIENCY INCREASE	NUMBER OF SHIPS IN THE EUROPEAN SECA FLEET (2009)
11	Reefer ship	26	1.4%	1.4%	2.25%	472
2	General cargo ship	26	1.4%	1.4%	1.27%	3 350
3	Product tanker	26	1.0%	-1.7%	1.90%	530
4	Container ship	25	4.4%	4.4%	2.25%	1 466
5	Chemical tanker	26	1.0%	-1.7%	1.90%	1 715
6	Crude oil tanker	26	1.0%	-1.7%	1.90%	835
7	Liquid natural gas tanker	29	1.0%	-1.7%	1.90%	61
8	Bulk ship	26	1.8%	1.8%	1.90%	2 316
9	RO-RO ship	27	2.3%	2.3%	2.25%	273
10	ROPAX ship	27	2.3%	2.3%	2.25%	433
11	Vehicle carrier	27	1.4%	1.4%	2.25%	446
12	Liquid petroleum gas tanker	26	1.0%	-1.7%	1.90%	266
13	Cruise ship	27	6.0%	6.0%	2.25%	127
	SUM					12 290

Table 1 Assumptions in projections.

Figure 1 Projections for SOx and PM emissions from 2009 to 2030 and effect of the MARPOL Annex VI regulating sulphur in marine fuels (SECA SOx and PM emissions). A scenario when 5 year moratorium for ships built before 1.1.2015 is also presented.

Nitrogen oxides (NOx) projection (Figure 2) shows that the NOx emissions will stay nearly constant until 2030 if Baltic Sea and North Sea are not designated as Nitrogen oxide emission control areas (NECA). IMO's MEPC 65 meeting discussed to postpone the Tier III entry date until 2021 which will affect the emission scenario shown in Figure 3. This new decision could not be adapted into the scenarios while writing this report and therefore NECA designation scenario is drawn with old enforcement date of 1.1.2016. Nevertheless, we can conclude that establishing Baltic Sea and North Sea NECA would drastically decrease NOx emissions in the area (Figure 3).

Establishing NECA would mean investment to technology fulfilling the NOx limits of the Tier III standard. We estimated additional costs if the Tier III would be complied by selective catalytic reduction (SCR) technology. Investment cost of SCR was estimated for each vessel taking into account their number of engines (one SCR unit per engine) and engine power. Because the Tier III will only concern new ships (built after 2016), it was assumed that after average lifetime (as shown in the Table 1) a ship will be replaced with similar new ship which will utilize SCR. Interest rate for SCR investment is assumed to be 5%. Also the operation costs (mainly consumption of NaOH) are taken into account.

By calculating the difference in NOx emissions between NECA and no NECA scenarios (Figure 2 vs. Figure 3) together with SCR costs of the renewing fleet we were able to estimate the cost efficiency of the Baltic Sea and North Sea NECA. The results are shown in the Table 2. The unit cost (euros per abated ton of NOx) is different for each ship type. This is due to varying amount of traffic inside the NECA. It has been assumed that after

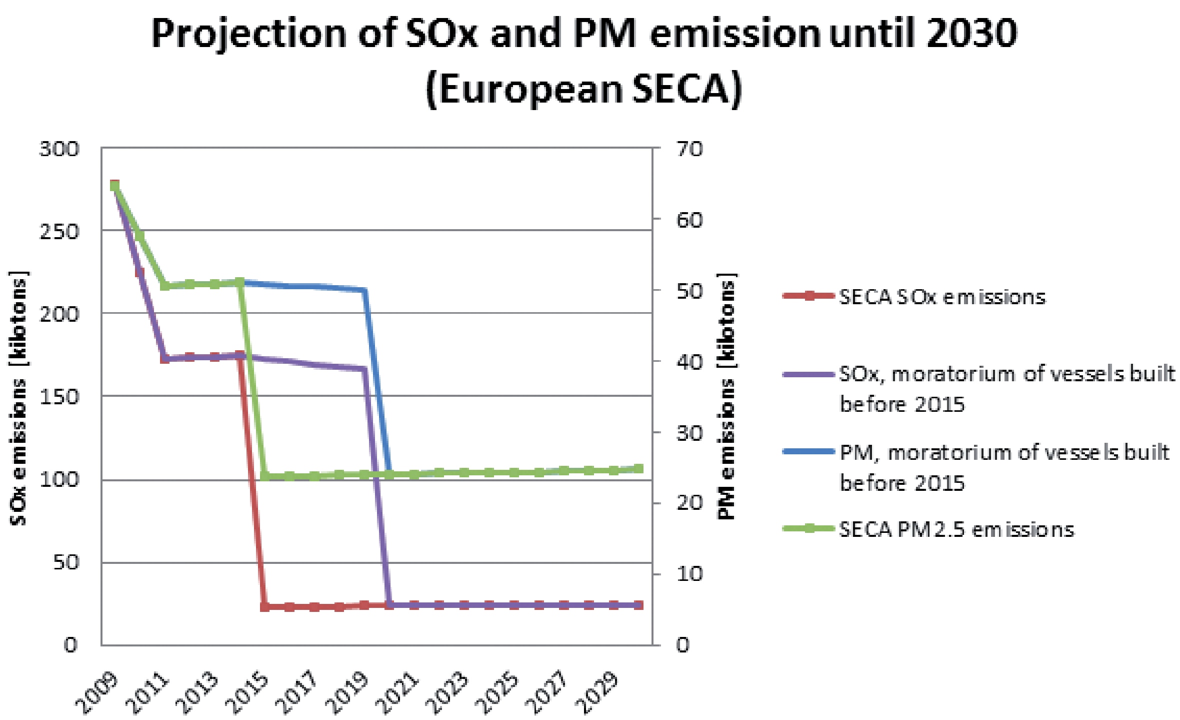

Figure 1 Projections for SOx and PM emissions from 2009 to 2030 and effect of the MARPOL Annex VI regulating sulphur in marine fuels (SECA SOx and PM emissions). A scenario when 5 year moratorium for ships built before 1.1.2015 is also presented.

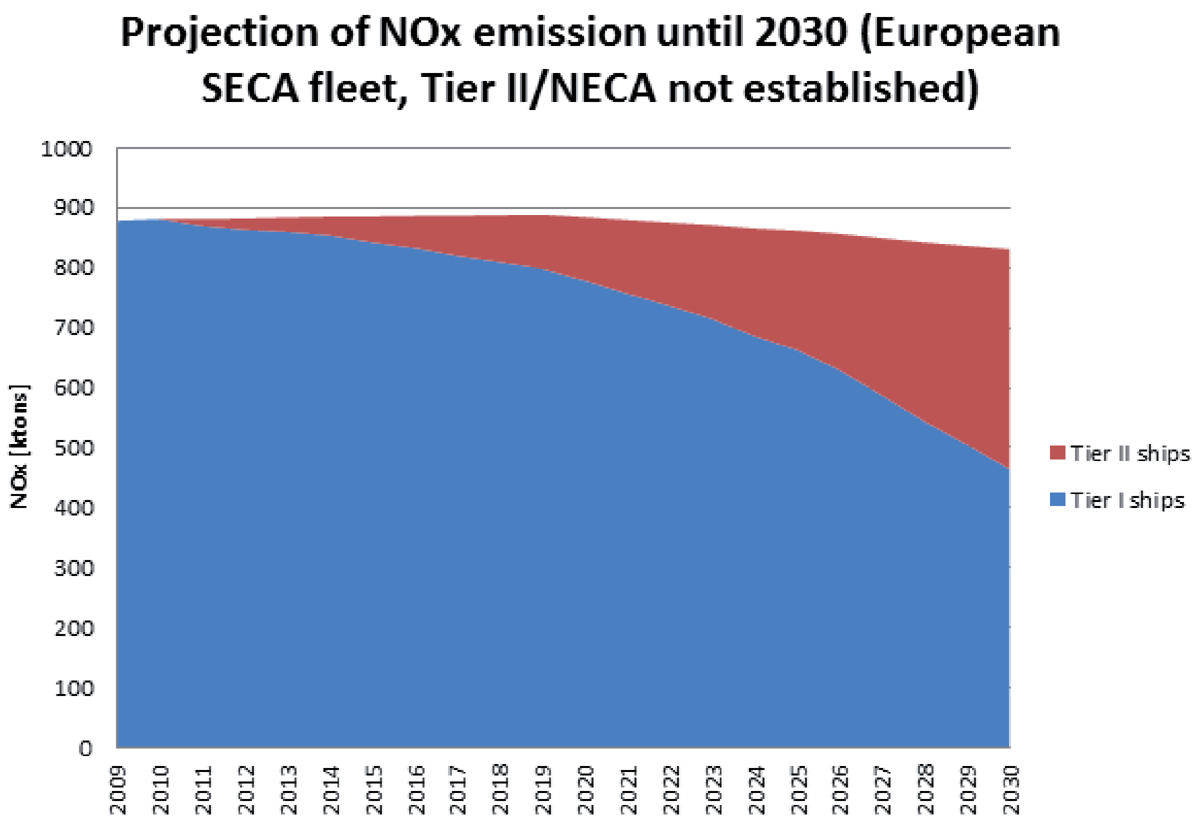

Figure 2 If NECA will not be established, there will still be only slight decrease in NOx emissions due to Tier II emission limits.

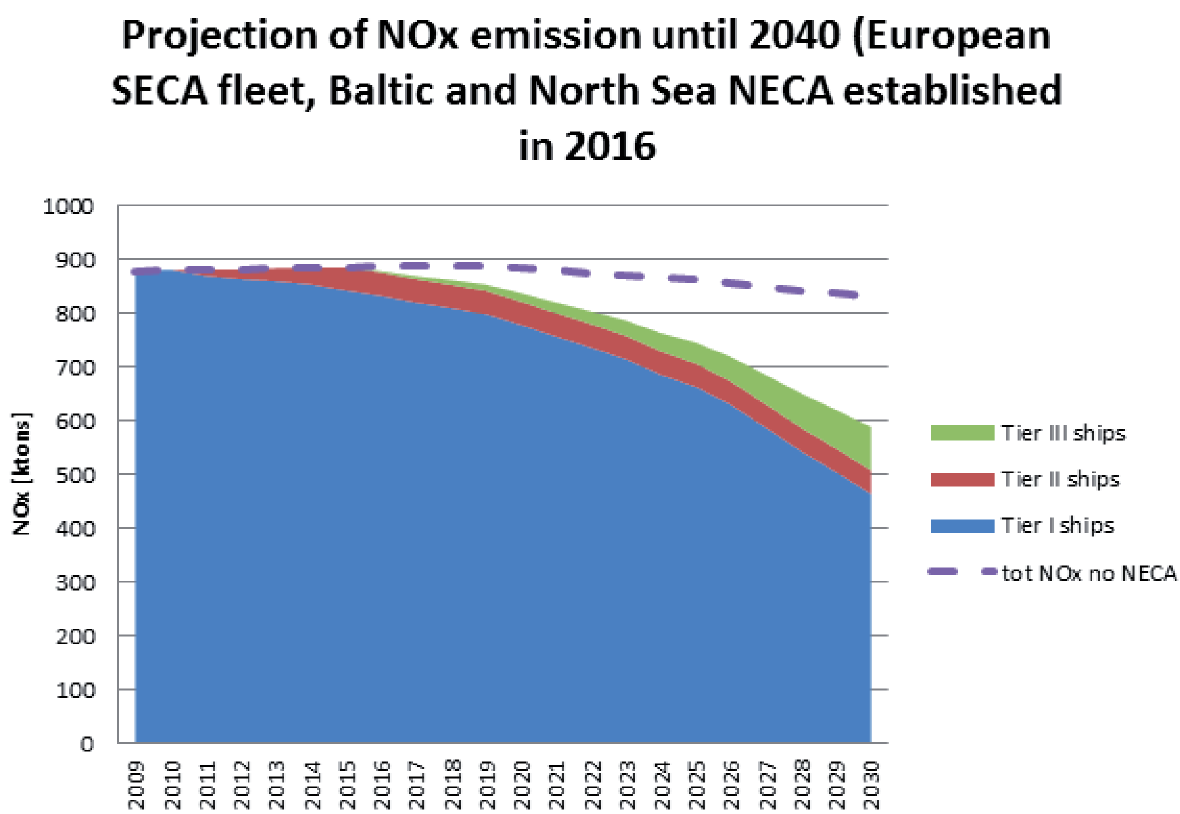

Figure 3 NOx emissions will drop dramatically if Baltic Sea and North Sea NECAs will be established.

€/ABATED TON OF NOX	2020	2025	2030
RO-RO	1 191	1 239	956
ROPAX	1 087	1 077	963
PRODUCT TANKER	2 694	3 010	3 464
CONTAINER	2 051	1 719	1 466
CHEMICAL TANKER	1 935	2 569	2 473
GENERAL CARGO	2 396	2 329	2 063
VEHICLE CARRIER	2 596	2 473	2 328
CRUDE OIL TANKER	2 886	3 151	3 087
BULK SHIP	4 445	4 446	4 111
LPG TANKER	2 299	2 176	2 200
CRUISE SHIP	2 626	1 904	1 187
REEFER	3 059	3 134	1 855

Table 2 Cost efficiency of Baltic Sea and North Sea NECA.

ship is leaving the area it will shut down the SCR. This assumption dramatically decreases the cost efficiency.

The unit cost is smallest for ro-ro and ro-pax ships which sails the most of the year inside the NECA. Bulk ships with occasional visits inside the area have much higher unit costs and therefore lower cost efficiency for SCR. The average unit cost for the NECA fleet is 1861 €/abated ton of NOx.

Table 2 Cost efficiency of Baltic Sea and North Sea NECA.

CONCLUSIONS

NOx emissions projection without NECA designation for the Baltic Sea and North Sea shows almost constant emission level. Effect of traffic growth to NOx emissions is negated by the efficiency increase and Tier II emission standard for new vessels. However, if NECA would be established the NOx emissions of the fleet would drastically decrease. Cost efficiency of the NECA is estimated in this study to be 1861 €/abated ton of NOx on average but varying between different ship types. Variation is mainly due to operation hours of SCR inside the NECA. Other methods to comply with the Tier III than SCR were not studied.

Emission projections show that the MARPOL Annex VI regulation on sulphur in marine fuels will effectively decrease the SOx and PM emissions. Assumed traffic growth and efficiency increase compensate each other's effects concerning the whole fleet. This can be seen in only slight gradual increase in emissions of SOx and PM. Projections of separate ship types show that emissions in some cases are facing considerable increase. For example traffic growth of containerships is more intense compared to efficiency increase leading to higher emissions than for other ship types.

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1.4 CALCULATED EFFECTS OF AIR EMISSIONS FROM BALTIC SHIPPING

AUTHORS: JAN EIOF JONSON AND MICHAEL GAUSS (NORWEGIAN METEOROLOGICAL INSTITUTE)

The effects of air pollutant emissions from Baltic shipping have been calculated by the EMEP chemistry transport model. This model has for many years been one of the key tools for air quality assessment in Europe, and is used in support of the Convention on Long-range Transboundary Air Pollution in Europe (CLRTAP, http://www.unece.org/env/lrtap/). The model is freely available from https://wiki.met.no/emep/page1/unimodopensource2011. The EMEP model is regularly evaluated against measurements in the EMEP annual reports, see http://emep.int/mscw/mscw_publications.html.

For the BSR Innoship project the model has been run for a full year covering a large part of Europe and the surrounding sea areas, including the Baltic Sea. The meteorological input data and the land based emissions are representative of year 2010. The ship emissions for the Baltic (and the North Sea) are representative for 2009 as described in section 1.2. The model calculates air concentrations and depositions of a number of pollutants. Health effects from air pollution can then be estimated based on the output from the model. Here we will concentrate on the effects of ship emissions on particle concentrations and on deposition of nitrogen. Particles in the atmosphere are associated with health effects, whereas depositions of nitrogen are associated with acidification and eutrophication. Particle concentrations are often shown as

particles with diameter below 10µm (PM10) or particles with diameter below 2.5µm (PM2.5). The smallest particles (PM2.5) are believed to have the largest health effects.

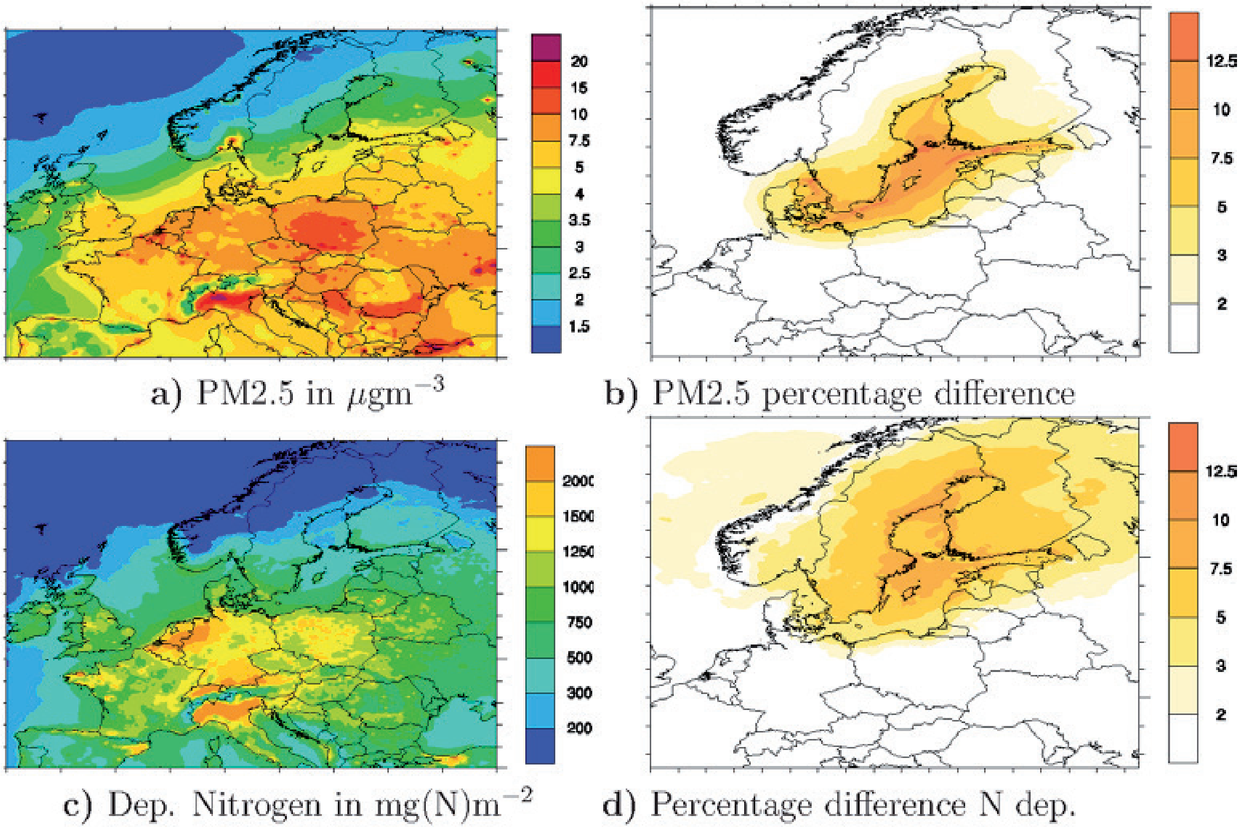
Figure 1.3.1.a shows the concentrations of PM2.5 calculated for year 2010. PM2.5 levels reflect the emissions, both from primary sources and from gaseous precursors forming particles through processes in the atmosphere. Northward from central Europe PM2.5 levels in general decrease with latitude. Figure 1.3.1b shows the percentage contribution to PM2.5 from ship emissions in the Baltic Sea. At sea the contributions are up to 10%. There are also marked contributions in coastal regions, but decreasing rapidly inland. Although the limit values from EU and WHO (World Health Organization) are not violated in the countries around the Baltic Sea, air pollution may still cause health problems. Table 1.3.1 lists the number of YOLL (Years Of Life Lost) in the countries around the Baltic Sea due to particulate matter. Also listed in Table 1.3.1 are the YOLL attributed to ship emissions in the Baltic. The largest contributions to PM2.5 from shipping occur along the coasts, close to the shipping lanes. These are in general also the areas with the largest population densities.

Figure 1.3.1 PM2.5 concentrations (a). Percentage contribution to PM2.5 concentrations from Baltic ship emissions (b). Depositions of toal Nitrogen (c). Percentage contribution to total nitrogen depositions from Baltic ship emissions (d).

We have also made a calculation where the 2009 ship emissions in the Baltic and the North Seas are replaced by 2011 emissions. The main differences between these two calculations are the stricter regulations of sulphur emissions at sea and in EU ports (see section 1.2), resulting in substantial reductions in both sulphur and PM emissions. The differences in YOLL calculated with 2011 versus 2009 ship emissions are also listed in Table 1.3.1. When comparing the effects of Baltic ship emissions and the emission reductions from 2009 to 2011 it should be noted that the latter also includes

	DK	SE	FI	EE	LV	LT	PL	DE
2009	664401	934556	630737	168858	562939	986758	18100364	26190780
FROM BALT	33162	60041	26871	7122	13990	19786	159288	231564
2009 - 2011	15905	22022	6204	1292	2493	2493	34680	101038

Table 1.3.1. Calculated YOLL (Years Of Life Lost). Top row (2009) is the total YOLL calculated with 2010 land based emissions and 2009 Baltic Sea emissions. From Balt denotes the calculated contribution to YOLL from Baltic ship emissions, 2009 - 2011 denotes the reduction of YOLL due to emission reductions between 2009 and 2011 in both the Baltic and North Seas. DK: Denmark, SE: Sweden, FI: Finland, EE: Estonia, LV : Latvia, LT: Lithuania, PL: Poland DE: Germany.



Figur 1.3.1 PM2.5 concentrations (a). Percentage contribution to PM2.5 concentrations from Baltic ship emissions (b). Depositions of toal Nitrogen (c). Percentage contribution to total nitrogen depositions from Baltic ship emissions (d).

the effects of emission reductions in the North Sea. In particular for Denmark and parts of Sweden and Germany the effects of North Sea emissions will be larger than from the Baltic Sea.

Figure 1.3.1 c shows the deposition of total nitrogen in Europe. Depositions are highest over central Europe. Depositions of nitrogen contribute to acidification and eutrophication. North of Central Europe depositions decrease with latitude. The percentage contribution to nitrogen depositions from Baltic ship emissions are shown in Figure 1.3.1 d. Throughout large parts of northern Europe and the Baltic Sea there are marked contributions. The percentage contributions south of the Baltic Sea are small mainly because the contributions from other sources are larger here.

CHAPTER 2:

ENVIRONMENTAL REGULATIONS AND ENFORCEMENT

2.1 REGULATION

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KRZYSZTOF KOLWZAN (POLISH REGISTER OF SHIPPING)

IMO ship pollution rules are contained in the "International Convention on the Prevention of Pollution from Ships", known as MARPOL 73/78. In 1997, the MARPOL Convention was amended by Annex VI titled "Regulations for the Prevention of Air Pollution from Ships" which came into force in 2005. MARPOL Annex VI sets limits on NOx and SOx emissions from ship exhausts, and prohibits deliberate emissions of ozone depleting substances. The Annex VI was further revised in 2008 (MEPC 176/58, 2008), becoming into force in 2010.

Annex VI includes a global cap of SO_2 and contains provisions allowing for special SOx Emission Control Areas (SECA) and NOx Emission Control Areas (NECA) to be established. Alternatively, ships must fit an exhaust gas cleaning system or use other technological methods to limit their emissions. In Figure 2.1 the global cap and the SECA limits of sulphur fuel content are plotted. Noteworthy, is the fact that from 2015 the Sulfur Fuel Content (SFC) used by vessels operating in SECAs must not exceed 0.1% and by 2020 ships worldwide are restricted to 0.5% SFC. The global SOx cap may be postponed until 2025 dependent from the result of a IMO fuel availability review in 2018.

The Baltic Sea Area, the North Sea and English Channel and the coastal waters around USA and Canada are designated as SECAs. In addition, the latter area is also designated as a NECA.

Following IMO annex VI the EU commission has adopted a legal framework of its own starting with the EC Sulphur directive (1999/32/EU) and further amended by Directive 2012/33/EU in order to align the EC regulations on sulphur content of marine fuels with the IMO revised MARPOL Annex VI regulations. The Directive is applicable in all EU member states, who are also obliged to implement the regulations on their respective territorial waters.

The key elements of the EU regulations are

1. The EC regulations are aligned with the revised MARPOL Annex VI, both inside and outside EU SOx Emission Control Areas (SECAs) including Baltic Sea, North Sea and English Channel.

2. All ships at berth in EU waters have to use low sulphur fuel (0.1 %) since 2010.

3. The 0.50% limit outside EU SECAs will apply in EC waters from 1 January, 2020, regardless of the outcome of the IMO fuel availability review, which is due by 2018;

4. Emission abatement methods (e.g. exhaust gas cleaning systems, mixtures of marine fuel and boil-off gas, and biofuels) are permitted for ships of all flags in EC waters as long as they continuously achieve reductions of SOx emissions which are at least equivalent to using compliant marine fuels.

The IMO regulation regarding ship emissions is more complicated for NOx than for sulphur, since NOx is produced in the combustion process rather than coming from the fuel. IMO has therefore chosen a limit that corresponds to the total NOx emission in gram per axial power produced from the engine in kWh. This limit is hence dependent on the fuel efficiency of the engine in use. Large ships, such as container vessels and tankers, usually run with slow stroke engines with a rated rotational engine speed of around 100 rev/min. These ships are fuel efficient (down to 165 g/kWh) but due to the long residence time of the exhaust in the cylinders they produce high amounts of NO_x. Ferries and intermediate sized ships usually use medium stroke engines with a rated rotational speed of around 500 rev/min and these engines are less fuel efficient (175-250 g/kWh), but on the other hand they produce less NOx compared to the slow stroke engines.

Due to the complexity described above an emission curve as a function of rated engine rotational speed has been put forward by IMO as shown in 2.2, NOx Technical Code [MEPC 177/58, 2008]. The NOx emission limit corresponds to weighted emission factors for typical loads versus rated rotational speeds. The regulation requires all ships built after year 2000 to fulfil the IMO Tier 1 emission values, and for ships built from year 2011 to fulfil Tier 2. Ships built between 1990 and 2000 will also be forced to retrofit NOx abatement equipment, if a cost effective upgrade is available.

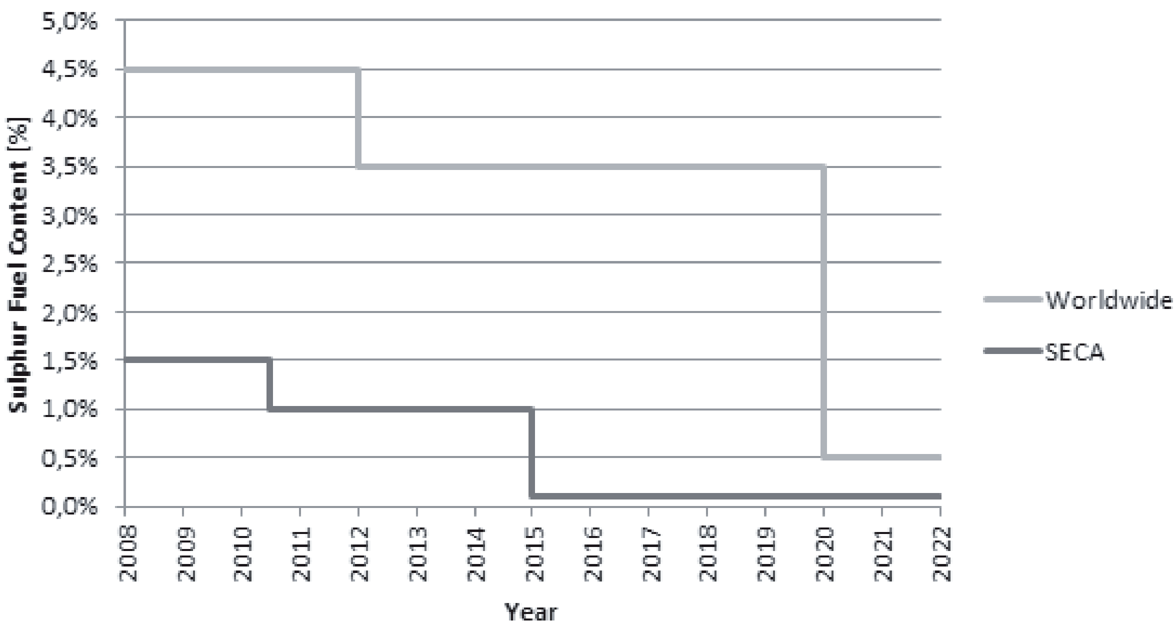

Figure 2.1 Regulation of sulphur fuel content [%] in the world and SECA areas. The Worlwide cap in 2020 may be postponed until 2025, depending on fuel availability.

According to the revised annex, the rather stringent limits of Tier III will be applied to all ships constructed after 1st of January 2016 and operating inside NECAs. However at the last IMO-MEPC meeting in London in May 2013 an amendment was discussed that may postpone the Tier 3 starting year to 2021.

The IMO code within MARPOL annex VI protocol requires that all ships flying flags of the states that have ratified the protocol (i.e. about 90% of the gross tonnage of the world's merchant fleet) respects the emission limits of Annex VI on international water and in SECA areas. For ships flying flags of states that have not ratified the protocol this is only required when operating in other countries exclusive economic zones.

According to the EU sulphur directive (2012/33/EU) effective sampling and dissuasive penalties throughout the community are necessary to ensure credible implementation of this Directive. Member States should take enforcement action with respect to vessels flying their flag and to vessels of all flags

while in their ports. It is also appropriate for Member States to cooperate closely to take additional enforcement action with respect to other vessels in accordance with international maritime law. The latter is usually done through various agreements (Memorandum of Understandings, MoU), as discussed below.

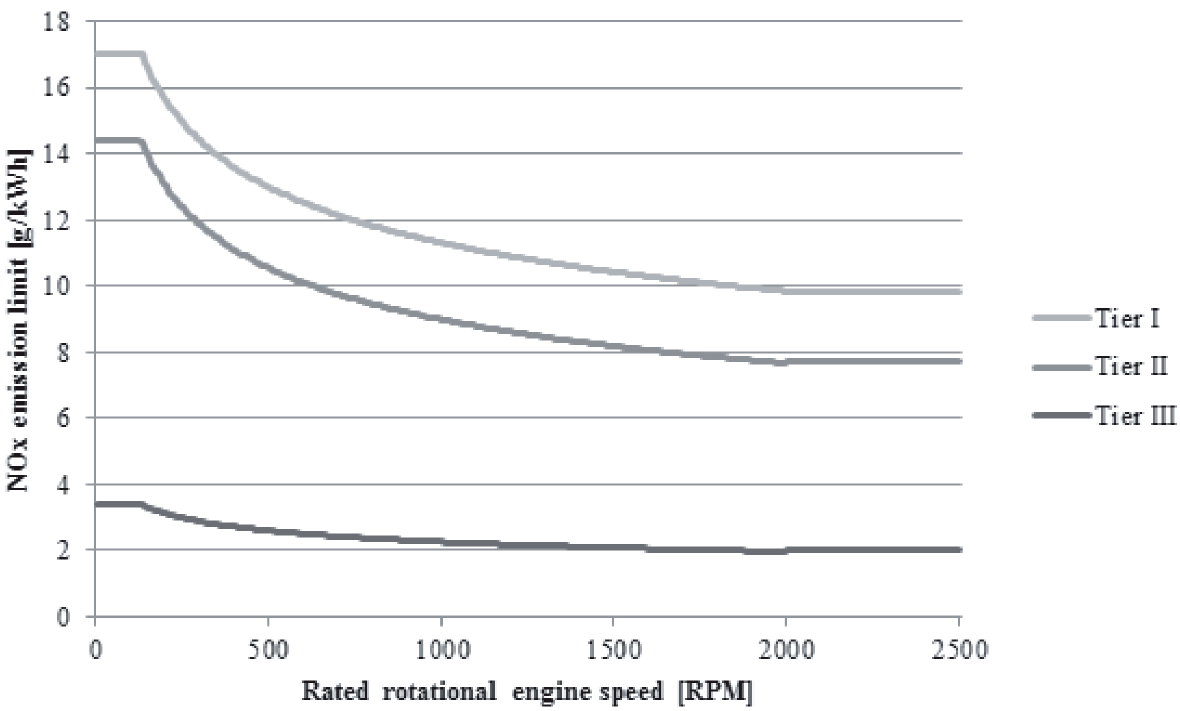

Figure 2.2 NOx emission limits versus rated engine rotational speed (rev/min) for ships built after 2000, Tier 1. Tier 2 corresponds to the limit for 2011 and Tier 3 for future foreseen limits for NOx Emission Control Areas.

2.2 ENFORCEMENT

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Port state control authorities have the right to inspect ships on internal waters (harbours, inland waters) and can also carry out enforcement actions such as detaining ships in harbours and even imposing civil penalties. The enforcement actions and penalties vary from country to country, although the states have tried to harmonize their control according to the Paris MoU, and other similar agreements.

When ships are outside internal waters but in the exclusive economic zone, on board inspection can only be carried out if there are clear grounds to suspect that the ship is not respecting the regulations, according to the United Nations Convention on the Law of the Sea (UNCLOS 1982) and the MARPOL code. On international waters inspection control is not possible but instead a complaint to the flag state should be filed, if there are grounds for violation of the IMO code.

ADDITIONAL ACTIONS FOR ENFORCEMENT

The SO_2 emission from a ship is directly proportional to the sulphur fuel content (SFC) in use. However, since there is a large price difference between fuel with low (0.1%) and high (1%) SFC, there is considerable economic advantage in ignoring the regulation. To prevent this and to promote fair competition within the shipping industry enforcement actions are needed.

Port state control authorities presently conduct on board inspections in harbours checking fuel logs, bunker delivery notes and occasionally collecting fuel samples. If the SFC of the samples in the fuel line or day tank is above the IMO limit, enforcement action can be taken since this corresponds to what the ship has recently been running on. It is however much more difficult to prove that ships have been running on high SFC during part of their voyage to the destination port since then a detailed audit of the fuel log and fuel balances is required. Note that ships often carry different fuel qualities which are mixed in the day tanks, so it is not enough just to identify that high SFC is carried in one of the fuel tanks. All in all, on board inspections are inefficient and only few ships have been detained for this reason, for instance during 2011, 32 ships were detained in European harbours due to having deficiencies related to annex VI, following statistics from the Paris MoU.

In addition, when ships are operating outside internal waters, such as transportation routes, on board compliance checks are generally not carried out, since clear evidence for violation of the IMO code is then needed, as discussed above.

In order to reduce, control and to get an overview of the distribution of the emissions from the shipping sector there is a need for the development of measurement systems for effective compliance control done remotely, without stepping on board the ships. This is acknowledged by for instance EMSA and HELCOM.

Within the BSR-project a new compliance monitoring system for remote measurements has been demonstrated in St. Petersburg, operated from a helicopter (MI-8) and a harbour vessel. About 40 ships were measured from the air and several hundred from the ground, showing that 95% of the ship traffic in Neva bay complied with the MARPOL annex VI protocol, Figure 2.1. The river barges showed rather large emissions of NO_x however.

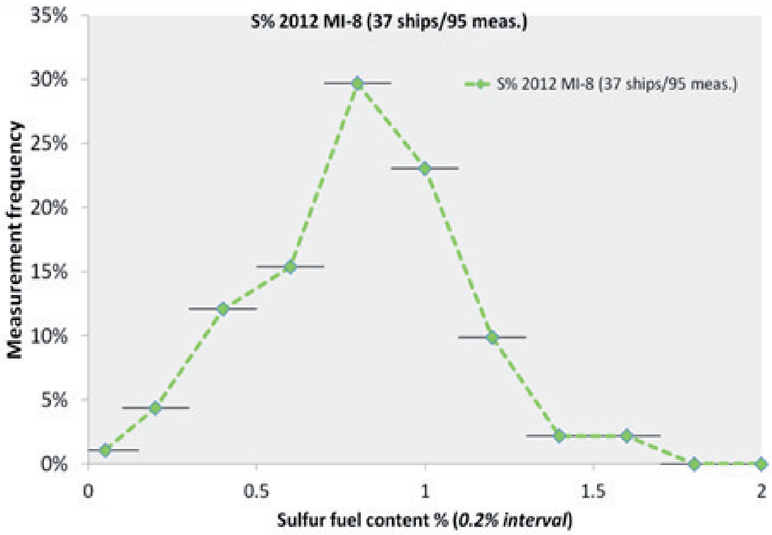

Figure 2.3 Ship compliance measurements were carried out from a MI-8 helicopter and a harbour vessel in Neva bay during June 2011 and 2012. The results for the different campaigns are shown as frequency of ships sorted in SFC intervals

The compliance monitoring system has been developed at the Chalmers University of Technology as part of a Swedish national project named Identification of gross polluting ships (IGPS) (Mellqvist, 2010) , aimed at developing a remote surveillance system to control whether individual ships obeys the IMO legislation of reduced sulphur fuel content (SFC) and NOx emissions.

The measurement system consists of an optical module (Berg and Mellqvist, 2010) which measures total emissions of SO_2 and NO_2 in g/s and a sniffer system measuring the ratio of various pollutants against carbon dioxide (x/CO_2). From the sniffer system the following parameters are obtained: sulphur fuel content, NOx emission per fuel unit and particulate emission per fuel unit. The estimated uncertainties for the sniffer and optical systems are 25% and 40%, respectively. Within the IGPS project airborne ship compliance measurements have been carried out on several hundred ships around the coasts of Sweden and North Sea. The IGPS system has been tested against other measurements in a validation campaign in Rotterdam (Alföldy, 2012)

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CHAPTER 3: BEST PRACTICES AND RECOMMENDATIONS FOR SHIPPING

3.1 EXHAUST GAS TREATMENT SYSTEMS GUIDANCE

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The revised MARPOL Annex VI [MEPC 176/58, 2008] was adopted to further develop emissions control in marine transport on the basis of the MARPOL 73/78 treaty. There is an option for alternative methods to control SOx emission, if they are equally effective as the prescribed limits for sulphur content in fuel. In such cases, ship engines may be supplied with fuel containing more sulphur than allowed by limit, as long as SOx removal system can decrease emission to the designated sulphur content levels. At present, to achieve SOx emission limits two options are relevant: low-sulphur fuels or SOx scrubber system. In the EU, ECA SOx continuous emission monitoring system is required if SOx abatement treatment on board is going to be installed. In case of wet scrubber, a wash-water treatment plant, equipped with dedicated water monitoring system needs to be taken into account. The recommended solution depends greatly on the amount of time that the ship is expected to spend inside ECA-SOx.

Another important regulation is Regulation 14 of MARPOL revised Annex VI which concerns NOx emissions from marine diesel engines and related limits. The limits' introduction schedule is allocated as Tier and depends on ships' construction dates. The NOx limit represents a set of weighted, specific emission factors applicable to engines, differentiated by rated rotational speeds. Marine engine testing and survey for NOx certification demonstrates a complex issue that is included in IMO's NOx Technical Code [MEPC 177/58, 2008]. It appears that only exhaust gas treatment, particularly SCR (Selective Catalytic Reactor) system can resolve the NOx reduction issue to satisfy Tier III limits.

SCOPE AND MATURITY OF SOX SCRUBBERS APPLICABLE TO SHIPS IN BSR WATERS

Regulations regarding sulphur release from ships in the SECA areas will be the most stringent globally. The reduction is measured as sulphur concentration in the fuel or in the exhaust. In the exhaust, the compliance is demonstrated via SO_2 to CO_2 volumetric ratio. The ratio is insensitive to fuel efficiency, unlike in the regulation for NOx (g/kWh).

At present there are four types of SOx scrubbers for ships presented in Figure 1: fresh water (FW, 'closed loop'), sea water (SW, 'open loop'), and a hybrid thereof (SW/FW) plus a dry scrubber (DS). In principle, these offer a feasible SOx reduction technology to meet expectations of the operators and their fleet. As the Baltic Sea contains brackish water with low alkalinity, probably the most common EGCS (Exhaust Gas Cleaning System) type, i.e. the SW scrubber, being commercially mature today, is not applicable to BSR.

The baseline for designing SW scrubbers is therefore certain minimum level of alkalinity in the wash water over the route, for efficient SO_x trapping. With the FW scrubber this is accomplished by supplementing the scarcity of alkalinity in the sea water with caustic soda reagent solution. With regard to water alkalinity the applicability of SW technology starts from the Danish straits. Basically the SW system could still operate at low alkalinities, but sufficient cleaning efficiency would require increased water volumes and/or alkaline reagents added. With the former option, lower than allowed discharge pH values may result, and there might be a risk of lower than acceptable reduction rates.

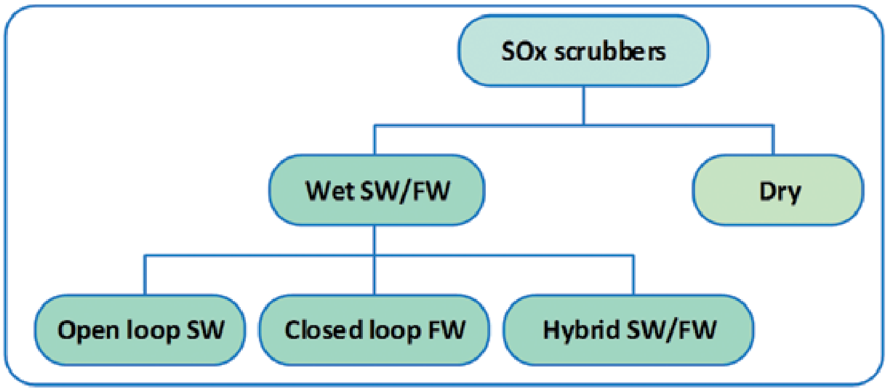

Figure 1. The SO_x scrubber types

FW/SW applications are also available, which could be used in FW mode in the restricted areas and in ports of high environmental sensitivity such as Gothenburg, and in SW mode in the North Sea and further.

In theory, dry scrubbers using granulated CaOH2 reagent are independent of water quality and applicable to all ship types. Chemically, they also permit consecutive NOx abatement with SCR.

MATURITY OF EGCS TECHNIQUES

As the forthcoming fuel sulphur regulations apply also to the current fleet, the main concern is therefore retrofitting the vessels already in use.

In FW scrubbers much less water volumes are needed than in SW concepts due to the use of an alkalinity increasing substance, commonly NaOH. The used water passes into a process tank, is subsequently cleaned, and circa 99% is recirculated inside the system. 1% is discharged into the sea to let in new liquid batch of neat chemicals. By now, the development of more costly FW scrubbers, has been slower than that of SW applications. The cost benefits are related to the operational design of the FW scrubber. The lower is the alkalinity of water in the designed operating area, the higher are the investment costs due to the increasing scrubber size caused by the FW function. This principle applies also to the FW/SW scrubber.

There is intensive testing of pilot installations going on in the BSR countries of the FW and FW/SW scrubbers. In Sweden, for instance, an application has been recently submitted to the Ten-T programme for the EU financial aid to test a hybrid EGCS system in the Gulf of Bothnia and in the North Sea region of the SECA. In Finland, the testing of a full-scale FW scrubber for Containerships VII is still on the way. However, by now, there are no known (to the author), approved and operating full-scale FW, FW/SW or DS scrubbers in the SECA area.

There are numerous orders placed for 2012-2013 and some orders for SW and/or FW/SW scrubbers may even be realized worldwide at the moment. There is a sufficient number of EGCS suppliers for them.

The first sign of maturity of dry scrubber technology (based on slaked lime) is the commercial order in summer 2012 for a Canadian newly built ConRo-vessel.

All in all, the development of the EGCS technologies goes hand in hand with the expected increase in the demand. The demand is expected to increase

only from 2015 onwards. In 2010, still, the EGCSA considered scrubbing system to be an immature technology and did not expect it to play an important role in 2015 yet.

A selection guide for the technological stage of February 2011 is presented in /US Transport, 2011/. The suggestions should be taken cautiously, as many developments were not ready at that time, more than two years ago, as even now they are still not. There are no long lasting operational experiences of any of the EGCS technologies in practice yet either /Walter & Wagner, 2012/.

ECONOMIC AND PRACTICAL CONSIDERATIONS

In those instances on which scrubbers have been installed, the experiences suggest how important design is and that it is still to be learned along with other operational issues. However, there is only a limited period of time for further development, installation and testing of the systems, as investment decisions for 2015 compliance should be made soon. So far the technology is continuing to develop and will likely remain a long term solution.

There is no one standard solution for exhaust scrubbing. The operational safety and reliability of the EGCSs are difficult to achieve under demanding conditions such as changing modes of operation, vibrations, space constraints, ship stability, and maximum efficiency, while using as little energy as possible. Selection criteria of the wet and dry scrubbers with these considerations have been studied by /Walter & Wagner 2012/ for the use of small and medium-sized shipping companies.

The scrubber systems also have constraints, like the fuel heating and purifying, large space requirements also for the stack, scrubbing chemical and waste stream management: handling, storage and disposal plus vessel weight and stability issues. Estimated is that technically EGSCs could retrofitted to 40-60 Finnish flagged ships. International shipping stakeholders' estimate for both technical and economic viability limits the share to 33-40 % of fleet in ECA. With SW scrubbers it proved that retrofitting would be difficult and costly due to the sludge cleaning equipment occupying space onboard which is not easily available. The amount of sludge itself from a SW scrubber is, however, smaller than that from in-vessel fuel treatment systems. Ships older than 20 years have been estimated to be beyond reasonable pay-back times and revenue generating potential from scrubber installations.

In dry freighters, container ships and tankers, there is normally place for positioning the EGCS. Auxiliaries are beyond this due to their usage in port operations and berthing. With 4-stroke engines and variable pitch propellers the use of MGO is the cheapest approach for short term, transient operations close to port i.e. for maneuvering. Also space availability with RoRo, RoPax and ferries is much more limited, and with dual-shaft systems two separate scrubbers may be needed /Walter & Wagner 2013/. Shorter pay-back times are obtained with ships having large engines, as the cost for the scrubber installation is relatively lower.

In addition to the fuel price differentials, operating time in the restriction area and the age of the vessel, the efficiency of an EGCS (scrubber) is influenced by the cost of materials used, the cost of repairs and maintenance, and disposed waste, as well as loss of load capacity, storage volume and stability due to the facility. The classification society Lloyds Register has published the LR ECA calculator for estimating the profitability of scrubber investment vs. switch into MGO fuel for various sailing and operating profiles. In result, the amortization period for the investment is calculated /Walter & Wagner 2013/.

The weight of a FW wet scrubber is typically between 30 – 55 tons (excluding wash-water and treatment systems and the required holding tanks), and the increase in energy consumption is 0.5 – 1%, excluding wash-water and treatment systems. It is understood that a FW/SW system normally has sufficient capacity to maintain the wash-water on board only for 2-3 days /Amec 2013/. The weight of the SW system is also 30 – 55 tons, and 1 – 2% extra fuel consumption is expected. In the combined FW/SW technology, there is always a rise in EGCS size due to the inclusion of the FW part. A typical increase is 10-25%. The EGCS is positioned downstream of the exhaust gas boilers and no post-heating of the exhaust is made (to minimize corrosion risk). Depending on the ship type and the number of scrubbers the water within the scrubber system may weigh as much as 250 tons. An example of the flow-through water requirements with SW technology is, for instance, the test ship Ficaria Seaways with a 21 MW 2-stroke engine: it used 3500 kg/h of fuel and 1000 m^3/h of sea-water at high load. In some cases this can raise vessel stability problems.

Both FW and SW scrubber technologies have already met problems with complying with the dischargeable effluent water properties, which are defined by IMO 184(59), 2009 regulation.

With the FW technology most of the non-liquid exhaust gas components are being removed mechanically and retained after appropriate waste water treatment with chemicals. With this technology direct untreated effluent discharge into the sea is not permitted. A small share, of the order of 1 %, of the treated circulating wash water is discharged continuously. This enables introduction of fresh NaOH reactant solution into the washing cycle. Problems with the quality of this effluent have partially remained unsolved.

The discharged amounts of effluents from a FW scrubber are very incremental compared with those of a SW scrubber (circa 1:500). In that sense, it is worth noticing that the IMO regulated species discharge are measured as concentrations (PAH, NO^3, turbidity, pH, T, additives), not as emissions. On the other hand, in the future there may be total 'zero discharge' areas, in which any discharged amounts will be forbidden. In that case large enough storage tanks will have to be prepared for retaining all effluents. Additional freshwater may also be required due to water evaporation. This water has to be produced on board or carried. In some concepts also sea water can be used in FW applications.

With SW technologies it is possible, that the whole wash water amount is discharged unprocessed into the sea, if it complies with the IMO 184(59) regulations. This means additional loading of the sea with new wastes, like soluble sulphurous compounds, fuel elements/metals, organics and particle components (neither of which are directly regulated now), in much higher amounts than from the FW scrubbers. The IMO regulations based on concentrations also make it possible to dilute for compliance the effluent with additional water before release. Some SW technologies include a wash water treatment unit for partial mechanical separation (e.g. cyclone precipitator) of solid particulate matter and liquid hydrocarbons.

With the SW systems of regulated water characteristics, problems have been experienced with the (low) pH of the effluent. In the BLG subcommittee of IMO's MEPC, there have been very recent demands for revision of the regulation of pH from the current 6.5 to as low as pH 3, when operating in the open sea. There is a likelihood that in the future changes will appear also in other IMO wash water criteria.

Sludge separation, amounts and disposal themselves are not an environmental concern in any wet EGCS technology.

As the current dry scrubbers use non-regenerable chemicals, like granulated CaOH2, a storage system on board is required, both for the reagent & liquid and dissolved waste, as well as appropriate delivery and storage infrastructure in port. These units typically weigh between 250 – 300 tons, including circa 150 – 200 tons of granules stored on board. The additional energy use is 0.15 – 0.20%. The granules will need to be exchanged for fresh supplies every 10 – 14 days, which presents a logistics challenge during port visits. Additionally, dry scrubbers will typically reduce the vessel's deadweight once retrofitted and will likely use cargo space up to 5 cargo units. A cargo ship has recently had a dry scrubber retrofitted and has added 3 – 4 large containers in front of the vessel's accommodation as storage space for the reagent. Such retrofit may be possible on cargo freight ships, but not on large RoRo passenger vessels. Neither would be fit for this kind of a vessel design. The practical experience is that dry scrubbers are not feasible for passenger vessels or passenger ferries.

Unlike wet scrubbers, which are quick to regulate, the dry scrubber is essentially a static system which can only adjust slowly to fast-changing operating conditions. For being active enough the granulate is heated up to around 100°C, though, it can be started cold. Efficiency is at best at over 230°C. As the reaction is exothermic lower exhaust gas temperature is sufficient. As an advantage, dry scrubbers need only a few components to work, which reduces likelihood of system inoperability.

VIEWS FOR THE FUTURE

Thinking of the possible future need for combined, simultaneous NOx and SOx reduction technology for newbuilts, suitable scrubber solutions are still under development. Problem-free, operational T for the SCR with high fuel S contents is circa 320-340°C. This is accessible mainly with 4-stroke engines. In case of a relatively cool exhaust, like with 2-stroke engines, the NOx trap is positioned before the turbocharger to reach high enough temperatures. Any mature scrubber technology may be positioned downstream. If the scrubber is planned to be positioned first (to avoid SCR deactivation), the only choice today is the dry scrubber. It favors high Ts, and its reactant generate an exothermic reaction with SO_2 enhancing adequate exhaust temperature for subsequent reactions in the SCR catalyst. With 4-stroke engines SCR catalytic converter can then be successfully installed downstream.

Slow steaming may be a more frequently employed practice in container shipping (with 2-stroke engines). As the ECA areas represent limited areas, it may be reasonable to design scrubber systems for reduced main engine outputs. This would mean both possibilities for new retrofits in vessels that were not possible before and also faster amortization.

The new approach of Green Ship of the Future / Klimt-MØllenbach 2013/ has evaluated technical solutions for SOx abatement for new and existing ships. In an ECA Retro-Fit study different solutions for a tanker were compared: MGO-EGCS-LNG. The conclusion was that scrubber is one potential solution depending on the share of stay time within the ECA and MGO-HFO price differentials. For LNG launch no obstacles have been found, as the pay-back times were very comparable with those of the scrubber with certain CAPEX assumptions.

TECHNICAL AND ECONOMICAL ATTRACTIVENESS IDENTIFIED BY SHIP OPERATORS

As ships are very complex technical entities with many "side effects" occurring when changing emission and energy efficiency regulations, the maritime industry desires a technically sound holistic consideration of all related aspects, not just sustainability issues. The anticipated but as yet unknown changes in the wash water quality criteria by IMO also make investors hesitate.

Aspects of reliability of the scrubbing systems have not been analysed in detail, mainly because they are relatively new technologies with limited applications and testing. Long term empirical data is lacking. Technical insecurity and economic recession curtail investments at this moment. As an example, in the instance of EGCS failure, not all ships can be prepared for carrying even three different quality fuels.

One reason for not having many FW systems on the market until now, for ships operating outside the low-alkalinity sea areas, is, to some extent, the extra cost involved, compared to SW scrubbers (other reasons may be the technology being not yet ready). For limited stays in low-alkalinity waters, fuel change may also be preferred.

The Finnish Ship-owners Association (FSA) has 27 shipping company members (of the total circa 30) who altogether own 116 ships. A recent survey showed that there was a very modest interest in retrofitting. There is one fresh water system being ordered and under installation, 4 shipping companies were thinking of the fresh water option, 2 of the dry scrubber and 0-1 of the hybrid. This is despite governmental support that can be applied for retrofit installations until the end of May 2013. One reason for the lack of interest in the funding instrument is the required pay-back time of > 5 years. Typical pay-back times of 1-2 years have been estimated for the scrubber retrofit systems.

It is predicted that in the beginning of 2015 most of the current Finnish fleet will switch to MGO, at least as a first approximation. Thereafter, within 1-2 years 5-10% of this fleet would be equipped with new retrofit scrubbers. The very recent technical review for the UK Chamber of Shipping / Amec 2013/ is also making conclusions as to the three possible means for the UK short sea shipping industry to comply with the 2015 Marpol Annex VI regulations. Given the technical and practical unavailability of scrubbers and LNG in the nearest future, out of the retrofit scrubber systems, retrofit conversion to LNG or use of lower sulphur fuel, the only viable means will be resorting to the last option. Reliability of the scrubber operation in the long run has been, as yet, confirmed to a low degree. This makes ship owners wary and has, thus far, postponed their opting for this solution.

The new report /Amec, 2013/ shows, that scrubbing has potential to be a viable technology in the future. However, a review of the current state of development and the operators' direct experience of test pilot systems does not yet provide sufficient confidence that the investments made would result in emission reductions required to ensure compliance.

There is very little information available of the experiences of EGCS installations and operability on-board, either pilot or full scale. Feedback from operators who have installed scrubbers to date, have highlighted some issues:

- Loss of revenue. Installation times are longer than those needed for standard maintenance every other year.
- Length of time from installation to full commissioning. The gap may be 2 ½ years for FW and 6-12 months for SW EGCS.
- On-going post installation modification is required.
- Issues related to the reliability of the system, lack of continuous running and maintenance requires intervention by the crew and/or manufacturer.

General uncertainty of the technical performance has been frequently indicated to. Both wet and dry technologies are expected to be potentially viable, but the risk of non-compliance is still high in early 2013. Attention is given in particular to performance under different loads, different exhaust gas temperatures, different S content fuels, reactions in the case of a sudden load change, impact on exhaust gas boilers, maximum permissible duration of operation in the FW mode, possibilities for future NOx and SOx abatement technology combination and reliability between the maintenance schedules. Other technical concerns stated are connected with port logistics for the fresh or used chemicals, with dry EGCSs and fresh water consumption, storage and disposal issues, with FW/SW systems. The installation of the scrubber as the ship owner's, not the shipyard's responsibility is also perceived too demanding.

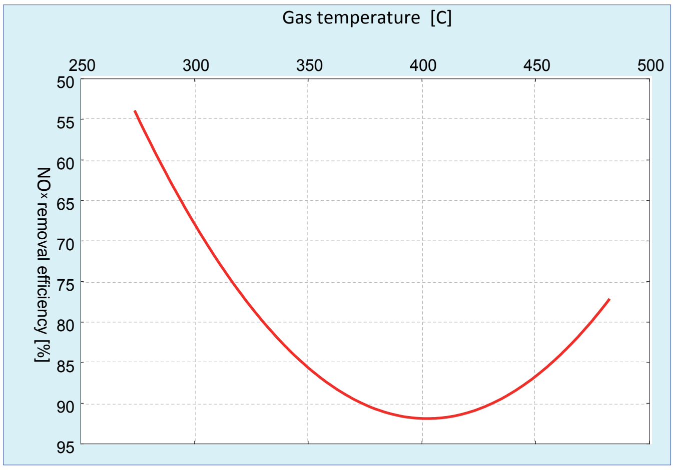

Figure 2. NOx removal versus process temperature

Maritime classification service company ABS has a new advisory on EGCSs designed to help ship owners consider scrubbers as a possible solution for meeting environmental requirements /ABS, 2013/. Aspects for newbuilts are also pointed out. For newbuilts, LNG (dual-fuel) is envisaged to be a future alternative to EGCSs and MGO/LSFO.

NOX SELECTIVE CATALYTIC REDUCTION - GENERAL CONSIDERATION

SCR technology is based on the reduction of nitrogen oxides by means of a reductant on the surface of a catalyst. With this method, the exhaust gas is mixed with ammonia before passing through a layer of catalyst at a temperature between 320 and 400°C, whereby NOx is reduced to N_2 and H_2O [Derek Johnson, 2008]. The temperature of the exhaust gas is very important and subject to constraints: maximum temperature – in order to avoid oxidation of the reductant and the lower temperature for preventing the formation of undesired by-products such as ammonium sulphates. These by-products may subsequently clog and deactivate the catalyst. The latter is particularly an issue with fuels containing higher sulphur contamination, such as those present in typical heavy fuel oil (HFO) qualities available today, which calls for even higher minimum temperatures in the catalyst.

Figure 2 shows distinctive dependence of the NOx removal efficiency as a function of temperature for a typical metal oxide-type catalyst. The graph below reflects general exhaust gas temperatures stimulation of and the rate of the NOx removal that increases with temperature up to a maximum level between 370°C to 420°C. If exhaust gas temperature increases above 450°C, the reaction rate and the resulting NOx removal efficiency will decrease.

There are two different approaches to installing the SCR module in marine diesel engine exhaust gas systems, differentiated by process pressure and temperature. Location of the SCR module depends on the engine type. In case of medium or high speed four-stroke engine, the SCR module is located in low pressure part of the outlet gas system, after turbocharger turbine in the exhaust duct. Another approach is required for large bore, slow speed and two-stroke engines. The SCR module is situated between the exhaust receiver and turbocharger turbine in high pressure zone. These two typical cases are presented in Figure 3.

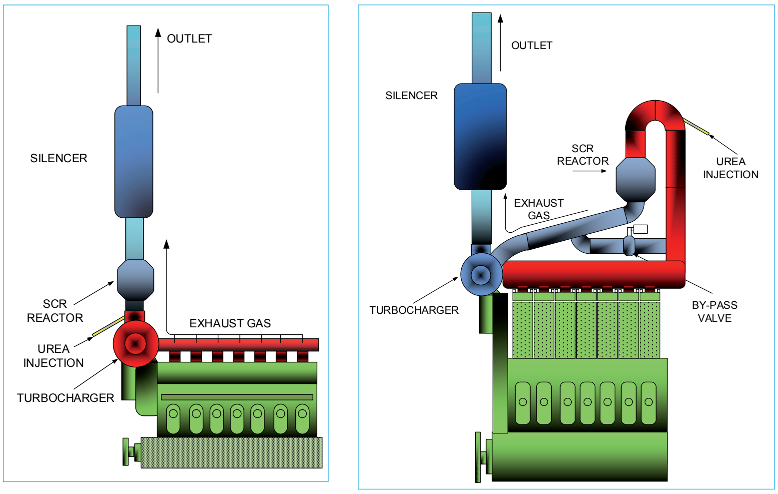

Figure 3. The SCR unit location in MS four-stroke (left) and SS two-stroke engine (right).

MS FOUR-STROKE DIESEL ENGINES SCR INSTALLATIONS

Medium speed, four-stroke, marine engines are common movers in electric generator sets and, to a lesser degree, main ship propulsion. The main propulsion engines being operated intensively (estimated ca. 7000 hours per year and average 65-80% of nominal power) are particularly eligible for co-operation with SCR systems [EPA, 2009]. With regard to the specifically high exhaust gas temperature in the exhaust systems (after the turbocharger), it is suitable to incorporate the SCR unit in this part of the system. Such locations of the SCR module can irreversibly increase exhaust gas back-pressure. However, it does not introduce notable technical complications in the engine arrangement. The SCR can be installed independently with its own control system. There are reports that a properly designed urea Selective Catalytic Reduction (SCR) system can reduce NOx emission by more than 98%, but this is most likely with very low sulphur fuel.

SS TWO-STROKE SLOW SPEED DIESEL ENGINES SCR INSTALLATIONS

SCR is a commonly-used after-treatment technology for diesel engines that can achieve 90 to 95% reduction of NOx emissions in marine applications, but another kind of approach is required for large-bore slow-speed and two-stroke engines. To date, a very small number of two-stroke low-speed engines have been equipped with SCR systems [MAN B&W, 2008].

For two-stroke diesel engines, temperatures typically range from 230°C to 320°C after the turbocharger. Ideally, for optimal SCR process inlet gas temperature should be around 350°C, when the engine is in service. This temperature condition has called for a solution where the SCR is situated on the high pressure side of the turbine.

Application of SCR in marine propulsion systems is also related to many aspects of continuously developing technologies and it includes several performance parameters. The rate of reduction reaction determines the amount of NOx removed from the flue gas. Major design and operational factors that affect the NOx removal performance of SCR are as follows:

- reaction temperature range;
- residence time available in the optimum temperature range;
- degree of mixing between the injected reagent and the combustion gases;
- molar ratio of injected reagent to uncontrolled NOx;
- uncontrolled NOx concentration level;
- ammonia slip;
- catalyst activity;
- catalyst reaction selectivity.

Nowadays only two major engine manufacturers conduct research on SCR installations: MAN Diesel & Turbo and Wärtsilä. This is due to the need to intervene directly in the exhaust system (technical and safety reasons).

The first MAN Diesel & Turbo complete project with two-stroke engine took place in Japan with Hitachi Zosen Corporation in 2010. The 6S46MC-C8 type of MAN B&W engine, capable of an output of almost 7 MW, was constructed in 2010 by Hitachi Zosen Corporation at its Ariake works in southern Japan. The engine is bound for a general cargo carrier, to be built at the Nakai shipyard. The first engine-start took place in 2011. During the trials it was verified that the engine and SCR system was able to meet the IMO Tier III NOx limits. The results were confirmed by ClassNK (Nippon Kaiji Kyokai) in 2011 - the SCR system ensured a NOx cycle value of 2.8 g/kWh, which is below the IMO Tier III limit of 3.4 g/kWh [MAN DIESEL&TURBO 2012].

SCR SYSTEM CONSTRAINS

The exhaust gas temperature it is not the leading issue – in existing SCR installations. There are also several operational complications:

- **Clogging** is mainly caused by presence of sulphur which together with ammonia and calcium forms ammonium sulphates and gypsum. This phenomenon may be further accelerated due to vanadium in residual fuels, which facilitates oxidation of SO_2 to SO_3. These problems may be avoided by increasing gas temperature, but it needs to be confirmed by actual tests provided by manufacturers.
- **Pressure Loss** – flue gas pressure decreases as the flue gas flows across the catalyst. The decrease in pressure is a function of catalyst length and the catalyst configuration. Deposition of fly ash and other particulates on the catalyst over time increases this pressure drop across the catalyst.
- Catalyst pitch is a term used in association with honeycomb and metal plate catalyst and affects the flue gas velocity in interstitial spaces. Appropriate catalyst pitch is important to assure that ash does not deposit and bridge over catalyst cells and pores. Plugging of the catalyst reduces the effective surface area by decreasing the number of active sites available for the NOx reduction reaction.
- Catalyst Deactivation – catalysts lose their activity over time for numerous reasons:
  - poisoning - certain fuel constituents which are released during combustion act as catalyst poisons. Catalyst poisons include calcium oxide and magnesium oxide, potassium, sodium, arsenic, chlorine, fluorine, and lead;
  - thermal sintering - high flue gas tempera tures within the SCR reactor cause sintering, a permanent loss of catalyst activity due to a change in the pore structure of the catalyst. Thermal sintering can occur at temperatures as low as 230°C;
  - blinding/plugging/fouling - ammonia-sulphur salts, fly ash, and other particulate matter in the flue gas cause blinding, plugging or fouling of the catalyst. The particulate matter deposits on the surface and in the active pore sites of the catalyst;
  - erosion - impingement of particulate matter and high interstitial gas velocities erode the catalyst material. Catalysts with hardened leading edges or increased structural strength are less susceptible to erosion;
  - aging - catalyst aging is a change in the physical and chemical properties of the catalyst pores that occurs over time.

In the end, it may be said that efficiency of marine SCR can reach up 98% value, but this is possible only during stable condition at high load (above 75%) of the engine; at the low load operation mode (from 10% to 50% of engine load) efficiency of SCR system can achieve much lower values – from 25% to 50%.

Marine SCR systems require reagent e.g. AUS40 (Additive Urea Solution), which is a high quality 40% urea solution that meets technical standard and is non-toxic, safe to handle, transport and store, with a freezing point below 0°C, making it practical for use on ships.

SCR SYSTEM APPROVALS

SCR system requires certification to verify that the equipment meets the required performance criteria, and classification society approval. The certification procedure is needed to show that the equipment does not present an unacceptable risk to the ship.

For statutory approval, the equipment manufacturer should provide equipment with all of the approved documentation required to demonstrate compliance.

Class unit approval includes an assessment of all of the hazards introduced by the system and any proposed measures. Typically, the documentation requires construction drawings and schematic drawings of associated systems and is not based on an actual installation. In all cases, the equipment manufacturer is required to submit a comprehensive risk assessment of their system. Hazards might include backpressure, corrosion, loss of containment of hazardous chemicals, fire, overpressure and flooding.

Class approval of installation is required for a ship to remain in 'class' with its classification society. The approval includes a document review and onboard survey.

The approval focuses on the system's impact on the safety of the ship and covers ship-specific piping installations, electrical and control installations, as well as structural modifications.

Type approval service provides equipment manufacturers with independent confirmation of the performance of their products. It is applicable to series production of equipment whose critical components remain unchanged and typically the units are surveyed on a sample basis. To apply for type approval the equipment manufacturer submits documents and plans and, depending on the scope of the approval, performance tests may also be required. Specific rules for SCR systems will be available from July 2013 (e.g. Lloyd Register).

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3.2 REDUCING THE COSTS OF MARPOL ANNEX VI REGULATIONS BY USING ABATEMENT TECHNOLOGIES (SCRUBBERS)

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AIM OF THE PAPER

Following chapter presents results of the additional cost estimates for international shipping inside the European SECA, and discusses whether it is possible to decrease the additional costs by adopting sulphur scrubber technology.

There are several ways how ships are able to comply to the regulations for sulphur in marine fuel from 1.1.2015 onwards.

1. Fuel switch
   - a ship will configure its fuel system to work only on fuel under 0.1 percent sulphur, in practice marine gas oil (MGO)
   - dual fuel system, a ship will configure its fuel system to work on heavy fuel oil (under 3.5 percent sulphur) outside the SECAs and before entering inside the SECA it will switch to MGO
2. Exhaust gas cleaning system (EGCS), technology which will treat the exhaust with com parable efficiency to the fuel switch. Different kind of scrubbers as an example.
3. Use of sulphur free fuels as LNG and biofuels.

All these methods are possible for existing ships but the cost efficiency varies depending on ship characteristics and activity inside the SECA.

ADDITIONAL COST OF FUEL SWITCH

STEAM model fuel consumption estimates are used to forecast the additional cost of MARPOL Annex VI after 1.1.2015. Total fuel consumption for the 13 studied ship types (Table 1 in subchapter 1.4) was 13 million tons in 2009. Assuming that 15% of marine fuels were already MGO leaves the rest 85% to be affected by the regulation. Taking into account the traffic growth (Table 1 in subchapter 1.4) and a fuel price forecast (price scenario 1 in Figure 1) would lead to additional costs of 4.7 billion US dollars in 2015 (price difference of 417 US$ between MGO and HFO (<1,0%-S) in 2015).

Additional costs presented here are only including the fuel switch cost from HFO to MGO and based on the assumed price difference between them (Figure 1). However, there will be also other costs directly affecting the vessels for example installing technology which would make the fuel switch possible. Indirect costs are not estimated in these scenarios but they can be various: . costs of modal shift, congestion, increase of road diesel price etc.

PRICE SCENARIOS

Several different price scenarios were created to test the sensitivity of marine fuel prices to feasibility of scrubbers and additional costs. The scenarios include real fuel prices until 2011 for MGO, HFO (<1,0%-S) and HFO (<3,5%-S) in US dollars per metric ton. Estimate for the price of HFO (<3,5%-S) is needed to estimate the operation costs when the scrubbers are in use because of their capability to use high sulphur fuels.

Estimation for brent price is used as the base (in price scenario 1) for marine fuel estimates so that the price of MGO is 19% more expensive than

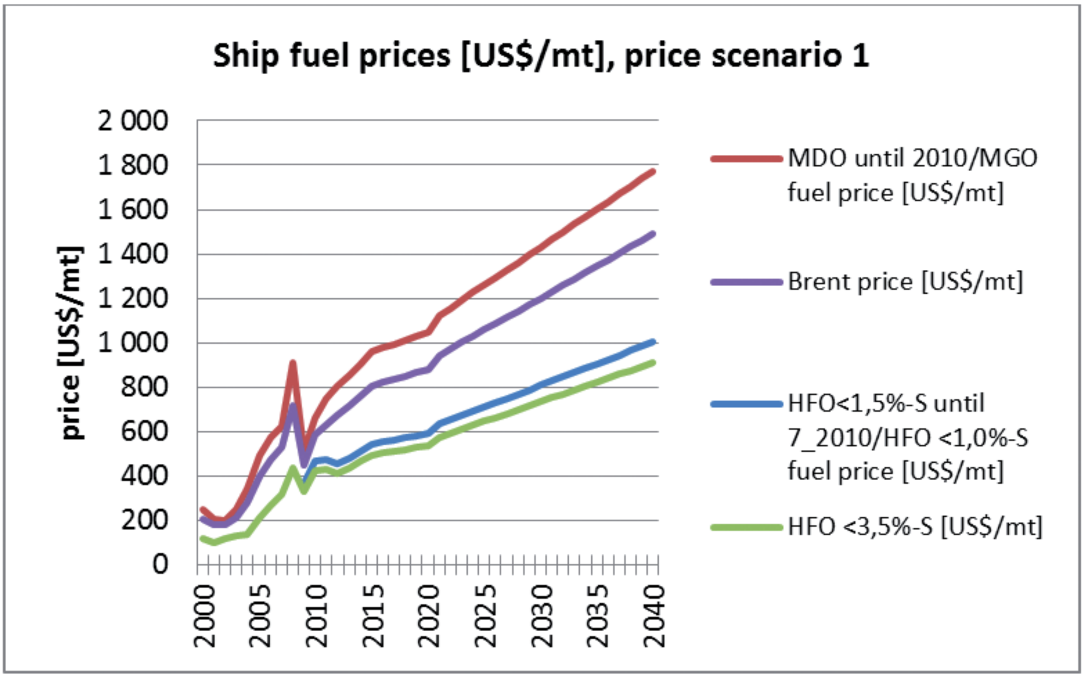


Figure 1 Ship fuel price scenario 1 used in estimation of additional costs.

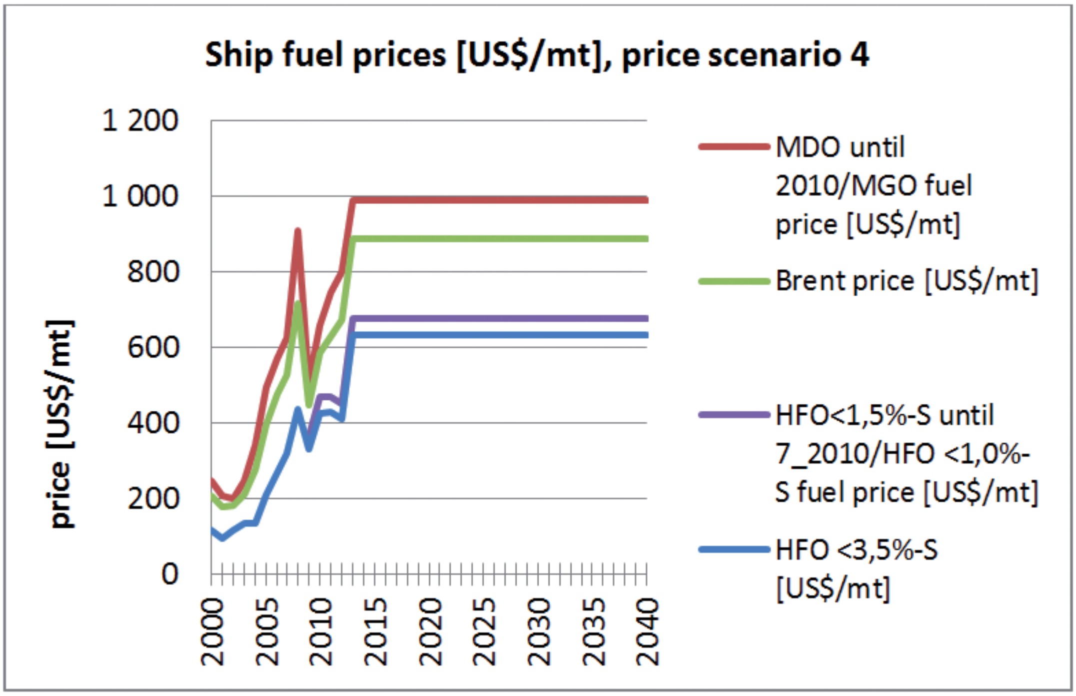


Figure 2 Price scenario 4 with constant prices of marine fuels.

brent. HFO (<3,5%-S) is assumed to be 40% cheaper than brent and HFO (<1,0%-S) is assumed to be 10% more expensive than HFO (<3,5%-S). This leads to price difference of 417 US$ between MGO and HFO (<1,0%-S) in 2015.

Price scenario 4 assumes that the marine fuel prices will stay constant from 2013 to 2040. Price difference between MGO and HFO (<1.0%-S) is 312US$. However, price scenario 4 is utilized only in the scrubber NPV calculations (Model 2) presented later in this chapter.

FEASIBILITY OF SCRUBBERS TO EUROPEAN SECA FLEET

There are several types of exhaust gas cleaning systems in the market and under development. In this chapter only the costs of the closed loop scrubbers are studied and an economic feasibility for European SECA fleet is estimated.

The estimates do not take into account the technical feasibility of the scrubbers but the feasibility from the economic point of view is estimated separately for every ship. The STEAM model provided data for all ships visiting European SECA in 2009 and 2011. Combining fuel consumption estimates with ship-specific detailed technical information (main and auxiliary engine power, number of engines, ship age etc.) it is possible to estimate which vessels could economically benefit from retrofitted scrubbers.

Share of middle distillates already in use before scrubber installation.	15 %
Equipment lifetime (project time period, loan time), years	10
Ship lifetime, years	27
Discount rate	10 %
Capital costs	
Equipment cost	Based on installed engine power of a ship (Figure 3)
Install/comission (share of total capital costs)	120,00 %
Operation costs of a scrubber	
Chemical consumption (compared to total fuel consumption)	3,00 %
Scrubber parasitic loads	1,00 %
Distillate Calorie Correction	4,00 %
HFO Process and Heating	0,80 %
Personnel Inflation Rate	3,00 %
Equipment Inflation Rate	3,30 %
Engineer cost per year [US$]	292 000
operating engineer (share of work allocated for scrubber)	50,00 %
maintenance and repair costs annually (% from equipment cost)	4,00 %

Table 1 Assumptions used in the modeling to estimate economic feasibility of a closed loop scrubber retrofit.

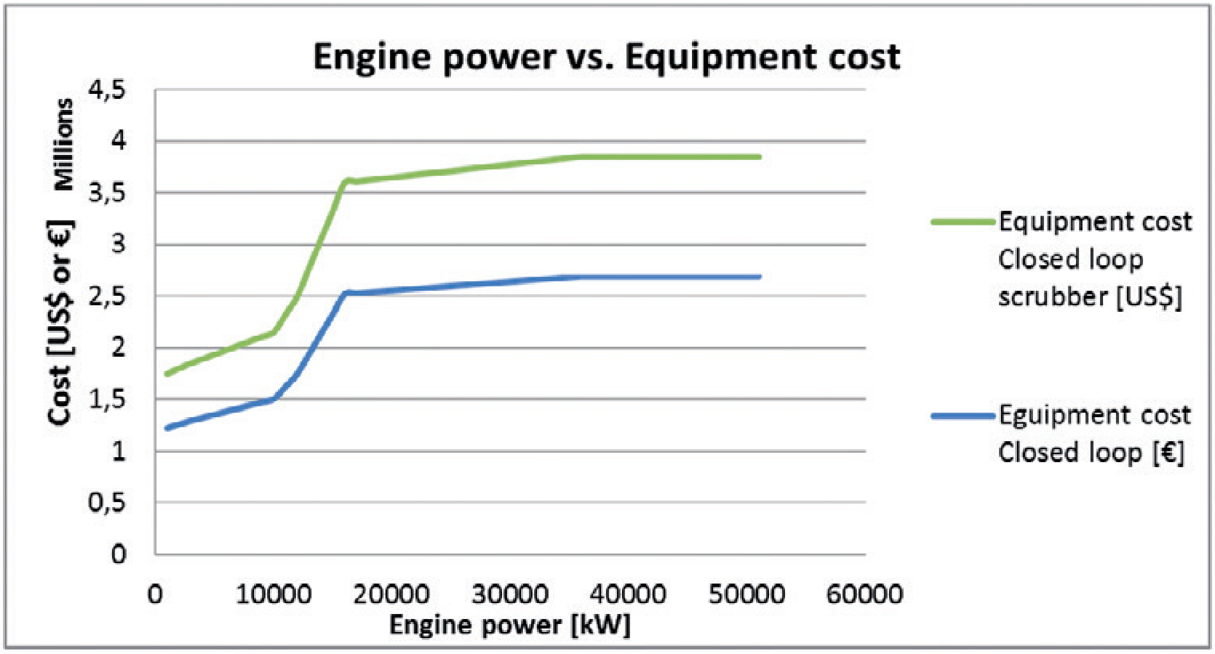


Figure 3 Equipment cost is estimated by multiplying installed engine power with corresponding unit cost [€/kW] according to this cost trend.

Capital and operation costs, ship's fuel consumption inside the SECA and price difference between HFO (under 3.5% sulphur) and MGO are the main factors affecting the economic feasibility of the scrubber. Two different models (Model 1: fuel consumption model and Model 2: NPV model) were built to estimate whether a scrubber retrofit is economic for a ship or not. Because the STEAM creates fuel consumption estimate separately for each vessel it was possible to estimate the feasibility for all ships separately.

Reynolds (2011) presents several factors affecting the capital and operation costs of the scrubbers. Table 1 show the assumptions used in both models (Model 1 and Model 2) which are mainly based on results of the Reynolds's study. However, there are

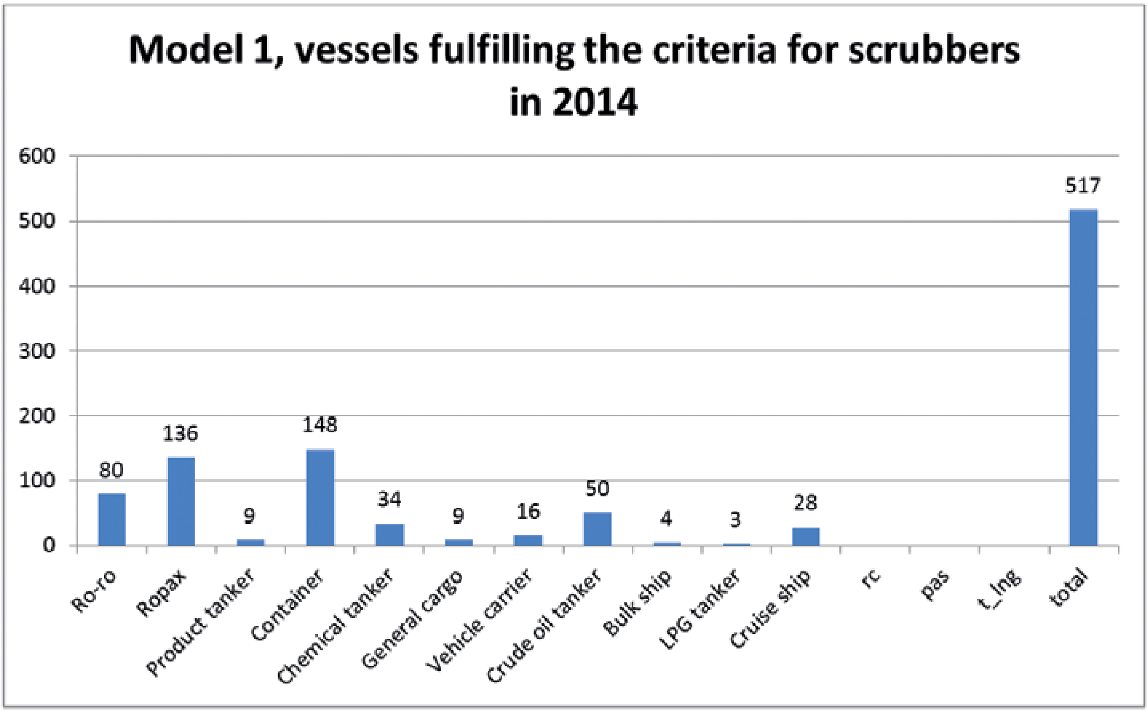


Figure 4 Amount of ships passing the criteria of more than 4000 tons fuel consumption inside the European SECA.

few exceptions. Install and commission cost was estimated by Reynolds to be 50% of the equipment price ignoring the revenue loss. Sweco (2012) presents estimation by Stena Line that the equipment price would be only 38% of the total capital costs due to owners and yard delivery, revenue loss and other expenses (install and commission). Therefore we have adjusted the install and commission costs to be 120% of the equipment price including the revenue loss and falling between the assumptions of Reynolds and Stena Line.

Project life time is assumed to be 10 years with 10% discount rate. Assumed average lifetime of a ship (27 years) is taken into account and in the Model 1 ships older than 25 years are not assumed to install scrubbers. However, Model 2 which calculates the net present value (NPV) for the investment has no similar restriction because NPV formula itself includes the remaining lifetime of a ship. Fleet is assumed to renew as the old ships (older than 27 years) are replaced with similar new vessels.

Reynolds (2011) has estimated the operation costs as presented in the Table 1. These operation costs are taken into account as well as the fuel costs.

Closed loop scrubber equipment cost is estimated and based on the installed engine power. Figure 3 presents engine power versus equipment cost curve by Reynolds (2011). According to Reynolds a ship needs one scrubber for main engines and one for the auxiliaries. However, this is not necessarily true. Today manufacturers are offering one scrubber solutions which are able to treat exhaust gases from both engines. The models assume only one scrubber for a ship which leads to decrease of the investment cost estimation compared to Reynolds study.

Reynolds (2011) recommends that all ships that have fuel consumption more than 4000 tons per year inside the SECA should consider investment on sulphur scrubbers. Model 1 results for the amount of feasible vessels are shown in the Figure 4. There are 517 vessels which fuel consumption is over 4000 tons per year and in 2014 they will be under 25 years old. Results show that the main ship types which are potential for scrubber

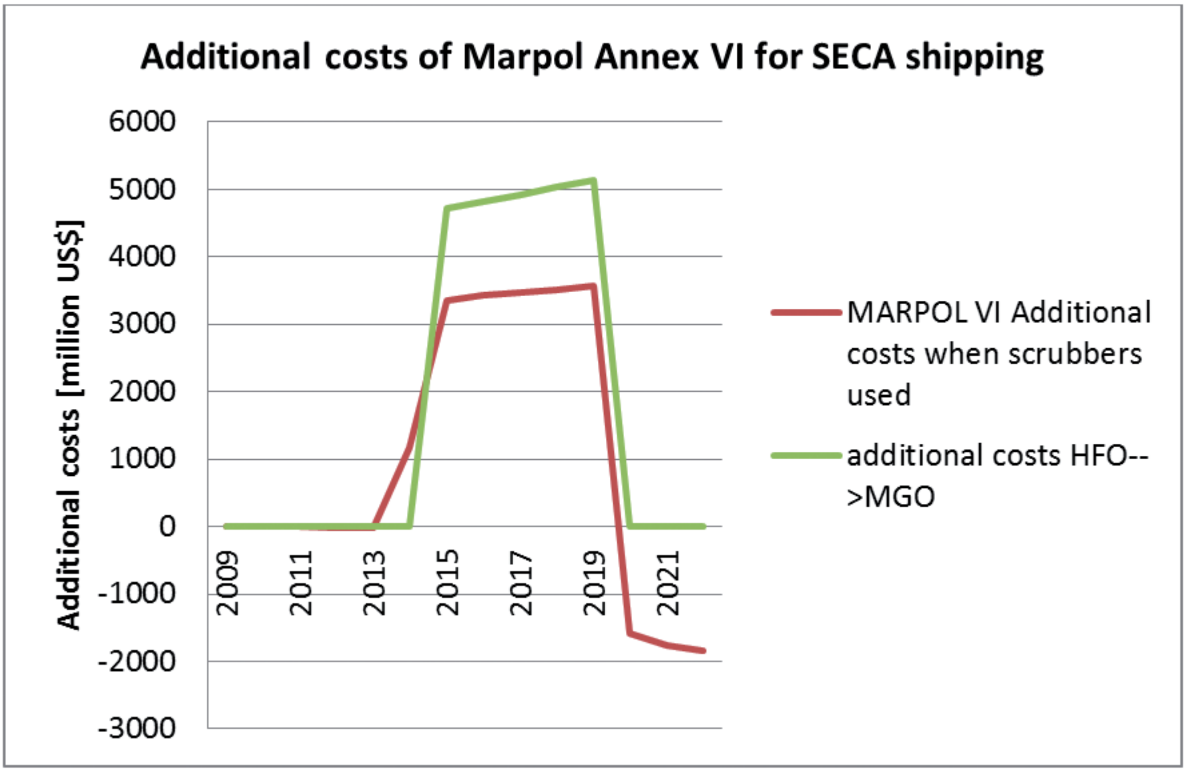
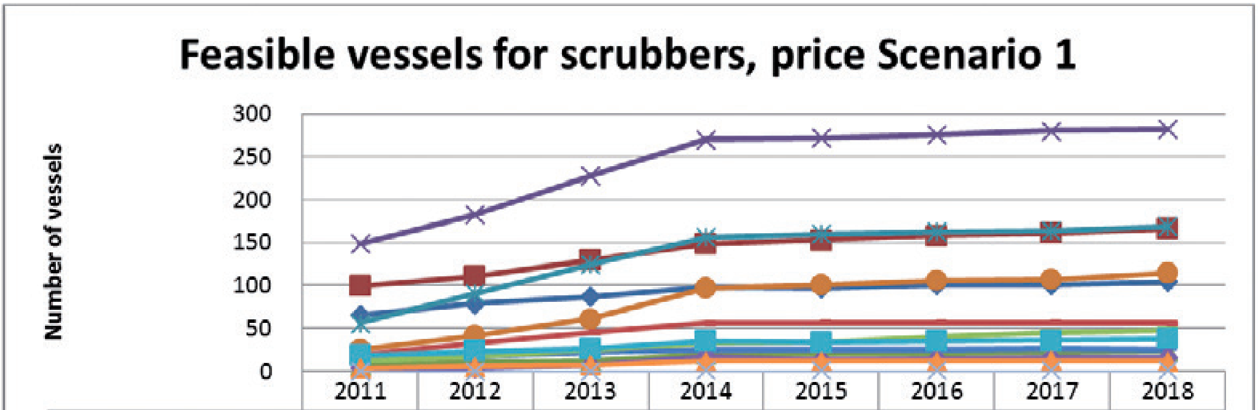


Figure 5 Additional costs of the fuel switch from HFO (<1.0%-S) to MGO for European SECA fleet.



	2011	2012	2013	2014	2015	2016	2017	2018
Ro-ro	65	79	87	98	97	100	101	105
Ropax	99	111	130	148	153	158	161	166
Product tanker	7	11	12	20	21	21	23	24
Container	148	183	228	270	272	276	280	282
Chemical tanker	56	90	124	156	160	162	163	168
General Cargo	25	41	61	97	101	106	107	114
Vehicle carrier	15	17	22	25	25	25	26	25
Crude tanker	19	33	45	56	57	57	57	56
Bulk	13	18	25	33	34	40	45	48
LPG tanker	3	4	8	17	14	15	16	16
Passenger cruiser	19	23	26	35	34	35	36	38
Reefer	4	6	8	12	12	12	13	12
LNG tanker	0	0	0	1	1	1	1	1
SUM (NPV)	473	616	776	968	981	1008	1029	1055

Figure 6 Number of feasible vessels for retrofitting of closed loop scrubbers (economic point of view).

installations are ro-ro, ro-pax and container vessels. These vessels generally have more traffic inside the area when comparing to the other ship types which only occasionally visit the SECA area.

Figure 5 presents the additional costs of MARPOL Annex VI if ships will comply regulations by fuel switch or ships with fuel consumption more than 4000 tons retrofit a closed loop scrubber (results of the Model 1). Model 1 was developed to estimate the potential of scrubbers to diminish the additional costs and to estimate amount of vessels feasible for scrubber retrofits. Results for additional costs show a decrease from 4.7 billion US$ to 3.4 billion US$ if feasible ships will install scrubbers. The fuel price scenario 1 is used in these results. Base year for the Model 1 is 2009 (STEAM results for year 2009).

Model 2 was developed to improve the feasible vessels estimate created by the Model 1. The use of NPV in the estimation takes into account the equipment costs of the scrubber and the fuel cost savings which are not included to Model 1 criteria to choose feasible vessels. Model 2 estimates the net present value for a ship including the assumptions on remaining lifetime, capital cost, operation costs and saved fuel costs of using high sulphur fuels compared to MGO. When NPV is positive it shows that scrubber investment could be economically feasible. Base year for the Model 2 is 2011 (Steam results for 2011).

Figure 6 presents the number of feasible vessels in different ship categories having a positive NPV value with price scenario 1 and Figure 7 presents the results with price scenario 4. Results show that there would be 968 vessels in 2014 with positive NPV (feasible for scrubbers with price scenario 1) and with constant price difference (price scenario 4) the amount of feasible vessels would decrease to 457. Ro-ro, ro-pax and container vessels are still the major ship types showing potential for scrubber retrofits as in the Model 1 results. However, NPV modeling finds vessels with fuel consumption less than 4000 tons per year also feasible for investment. For example number of feasible chemical tankers and general cargo vessels has increased compared to Model 1 results.

Model 2 results are also presented in the Table 2 and Table 3. Results show that 9% of the fleet is feasible for the scrubber retrofitting with price scenario 1 and 4% with constant price difference (price scenario 4). If the traffic would stay constant, the table also presents separately the fuel consumptions of the total fleet and the scrubber potential ships.

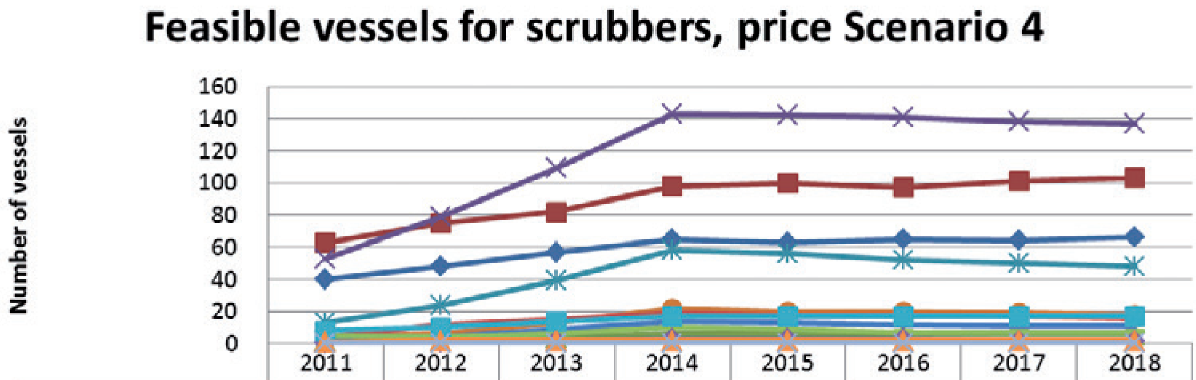
Figure 7 shows that the amount of economically feasible vessels will be lower (457 in 2014) compared to price scenario 1. Here only 4% of the total fleet is estimated to be feasible for scrubber retrofitting. Still 30% of the ro-ro and 23% of the ro-pax vessels (Table 3) can be considered feasible for retrofits.

CONCLUSIONS

Complying with the regulations of sulphur in marine fuels will affect remarkably the fuel cost increase for ships sailing inside SECA. Studies show

FUEL PRICE SCENARIO 1	NUMBER OF SHIPS IN THE EUROPEAN SECA FLEET	SHARE OF SHIPS POTENTIAL FOR SCRUBBERS	SCRUBBER EQUIPMENT COST FOR NPV POTENTIAL SHIPS [MILLION $]	TOT FUEL CONSUMPTION OF THE FLEET [KILOTONS]	FUEL CONSUMPTION OF SHIPS POTENTIAL FOR SCRUBBERS (NPV) [KILOTONS]
year	2011	2014	2014	2014	2014
Ro-ro	207	47 %	250,0	827,8	600,8
Ropax	437	35 %	350,4	1 693,7	1 019,4
Product tanker	463	5 %	50,4	346,4	78,0
Container	1222	22 %	740,8	2 702,8	1 293,0
Chemical tanker	1628	10 %	334,9	1 455,3	544,1
General Cargo	3105	3 %	172,9	1 976,8	254,9
Vehicle carrier	414	6 %	48,0	327,6	81,5
Crude tanker	667	9 %	187,1	710,7	283,9
Bulk	2031	2 %	46,5	1 082,8	76,7
LPG tanker	252	6 %	27,2	193,8	38,4
Passenger cruiser	122	28 %	115,1	328,6	210,6
Reefer	333	4 %	11,3	274,3	15,7
LNG tanker	71	1 %	3,9	50,4	3,9
SUM	10952	9 %	2 338,6	11 970,9	4 501,0

Table 2 Results of the scrubber feasibility. Table presents the number of the fleet in the European SECA by ship types and their feasibility for closed loop scrubber retrofit (price scenario 1).

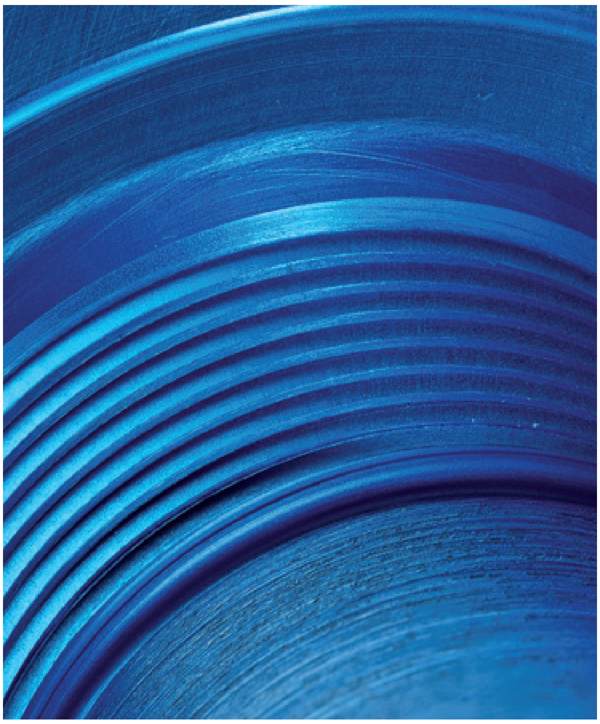


	2011	2012	2013	2014	2015	2016	2017	2018
Ro-ro	40	48	57	65	63	65	64	66
Ropax	63	75	82	98	100	97	101	103
Product tanker	2	2	4	6	6	6	6	6
Container	53	79	109	143	142	141	138	137
Chemical tanker	13	24	39	58	56	52	50	48
General Cargo	4	6	13	22	20	20	19	18
Vehicle carrier	2	4	9	14	13	12	11	11
Crude tanker	4	12	15	19	18	18	17	16
Bulk	5	4	6	10	9	7	7	7
LPG tanker	0	1	2	3	3	3	2	2
Passenger cruiser	8	10	14	17	17	17	17	17
Reefer	1	2	2	2	2	2	2	2
LNG tanker	0	0	0	0	0	0	0	0
SUM (NPV)	195	267	352	457	449	440	434	433

Figure 7 Results of NPV estimates with current price differences (price scenario 4).

that for 90 to 95 % of the fleet, the fuel switch to middle distillates is the most cost efficient way to comply the rules. Fuel price difference between currently used heavy fuel oil and middle distillates (MGO) in 2015 will create the additional cost faced by SECA maritime transport. Assuming a price difference of 417 US$ between MGO and HFO the additional fuel costs would be about 4.7 billion US dollars in 2015.

Retrofitting sulphur scrubbers can be profitable for 5 to 9 percent of the fleet. These vessels are mainly container, ro-ro and ropax ships which have sufficiently fuel consumption inside the SECA. Net present value estimates show that fuel consumption even less than 4000 tons could be enough to compensate investment with 10 percent discount rate. However, the fuel prices are the most sensitive variable affecting the economic feasibility and difficult to forecast.



FUEL PRICE SCENARIO 4	NUMBER OF SHIPS IN THE EUROPEAN SECA FLEET	SHARE OF SHIPS POTENTIAL FOR SCRUBBERS	SCRUBBER EQUIPMENT COST FOR NPV POTENTIAL SHIPS [MILLION $]	TOT FUEL CONSUMPTION OF THE FLEET [KILOTONS]	FUEL CONSUMPTION OF SHIPS POTENTIAL FOR SCRUBBERS (NPV) [KILOTONS]
year	2011	2014	2014	2014	2014
Ro-ro	207	30 %	171,8	827,8	497,0
Ropax	437	23 %	256,8	1 693,7	896,6
Product tanker	463	1 %	16,9	346,4	34,7
Container	1222	12 %	363,3	2 702,8	826,2
Chemical tanker	1628	3 %	117,1	1 455,3	257,3
General Cargo	3105	1 %	34,9	1 976,8	74,1
Vehicle carrier	414	3 %	26,9	327,6	51,7
Crude tanker	667	3 %	60,5	710,7	123,1
Bulk	2031	0 %	12,8	1 082,8	33,1
LPG tanker	252	1 %	5,8	193,8	11,9
Passenger cruiser	122	14 %	65,5	328,6	152,0
Reefer	333	1 %	1,9	274,3	4,3
LNG tanker	71	0 %	0,0	50,4	0,0
SUM	10952	4 %	1 134,2	11 970,9	2 961,9

Table 3 Results of the scrubber feasibility. Table presents the number of the fleet in the European SECA by ship types and their feasibility for closed loop scrubber retrofit (price scenario 4).

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3.3 GUIDELINES FOR SHIPS FIRING LOW SULPHUR OIL FUELS

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TECHNICAL OUTLINE FOR THE USE OF LSFO ONBOARD

Number of issues has been identified in recent years by engine manufacturers, ships' class societies and scientists in respect of LSFO (Low Sulphur Fuel Oil) intended for burning on ships. They can be divided into fuel and ship related technical issues.

ISSUES RELATED WITH LSFO

Low flash point: Safety Aspect, the flash point of fuel is < 60°C;

Low viscosity: Leakage in the injection systems and cavitation in fuel systems,

Compatibility: Poor compatibility with heavy fuel can lead to:

- clogging of fuel filters,
- increased sludge amount,
- sticking of fuel injection pumps,
- formation of deposit on the engine components.

Lubrication oil: 2 stroke engines with a high BN cylinder oil:

- calcium carbonate deposits on the piston crown,
- the deposits can be minimized by reducing the cylinder oil feed rate to the lowest possible safe level.

ISSUES RELATED WITH A SHIP

Ship related issues are those related to the design and construction of the fuel oil installation and their interaction with other ship systems, particularly during ship operation. The existing experience point outs to conduct certain measures for modifications of fuel oil piping and fuel oil storage system to comply with both legal and technical regulations.

MACHINERY SYSTEMS DESIGN ISSUES APPLICABLE TO LSFO USE

Design issues related to ship fuel oil piping and engine related systems are widely described and so they can summarized to the following requirements:

1. All fuel pumps must be suitable for operation with of LFSO (0.1%S fuels). Pumps used for HFO may have difficulties with suction of the light gas oil (LSFO) because of reduced fuel oil viscosity and lubricity. Accordingly, due to lack of lubrication, this may eventually result in excessive overheating of the existing HFO pumps (if not designed to handle LSFO). At least two pumps are to be provided to provide backup pumping ability.

2. Fuel pumps are to be of approved design as LSFO possess lower lubricating properties and that may lead to excessive wear within the fuel pump. The problem may also appear in fuel injection pumps which may require replacement with a special pump (e.g. Tungsten Carbide Coated Fuel Injection Pump).

3. LSFO operation suitable fuel handling and management system including fuel injection and combustion control systems dedicated to the installed engines and boilers.

4. Technical modifications of the fuel oil installation both related to the fuel handling and fuel combustion must be done with approval of applicable bodies) manufacturers, class, administration) in general to comply with MARPOL Annex VI. Major modification may need legal requiring recertification of the engines or associated equipment.

5. Fuel oil installation, fuel management and control systems must have ability for control of viscosity using all means approved by equipment manufacturers. Maintaining the fuel oil temperature in the required range to avoid "sticking" of fuel system components. Providing the minimum viscosity of 2 cSt it may need installation of cooler(s) or "chillers" together with appropriate controls in the design of the modified fuel oil system.

6. Engine lubrication systems are to compliant with guidelines of engine manufacturers and ought to be tested in practice for effective lubrication and mitigation of the viscosity issue. Separate, low-BN cylinder oil tank(s) are to be provided.

7. LSFO number of tanks (including capacity) and systems should be arranged to facilitate effective change over. Installation of dedicated MGO/ LSFO service tanks may be necessary due to operational considerations.

8. Shipboard HFO and LSFO piping systems (including pipe fittings and equipment) should be arranged to allow effective flushing of HFO from the system.

OPERATIONAL ISSUES RELATED WITH SHIPS USING LSFO

One or more of the below described events could lead to malfunction of ship machinery and possible unexpected shut down of the main or auxiliary engine(s) or boiler(s).

- Fuel changeover from HFO to low-sulphur fuel

such as MGO (LSFO) leads to fuel exposure on kind of heat shock because the pipes and other parts of the fuel oil pumping system are heated when using HFO. Vaporizing of LSFO when flowing through the same hot piping may occur in creating vapor locks. That may lead to occurrence of irregularities in fuel flow to injectors and consequently it could result in engine stoppage. Therefore, LSFO is not to be used through heated pipes of main engines, auxiliary engines and also boilers.

- Sticking/scuffing of high pressure fuel oil injection components: When changing engine operation from HFO to LSFO, rapid or uneven temperature change could cause thermal shock creating uncontrolled clearance adaptation which can lead to sticking/scuffing of the fuel valves, fuel pump plungers, suction valves or fuel pump seizure.

- Accelerated piston ring/liner wear: Prolonged engine operation with incompatible crankcase or cylinder lubricating oil could result in accelerated piston ring/liner wear.

- The loss of sufficient oil film thickness may occur due to liner lacquering.

- Engine manufacturer guidance on lubrication is to be followed. Lubricating oil with high levels of alkaline additives, i.e. high-BN (base number) oil is recommended by many manufacturers for use with HFO. Therefore, a lower TBN (total base number) crankcase oil for medium speed engines (i.e., trunk-type) or cylinder lube oil for slow speed engines (cross-head type) should be selected if LFSO (MDO or MGO) is going to be used permanently or for a prolonged period of time. Suitable amounts of lubrication oil must be secured for ship operation in SECA area.

- Adjustment of the cylinder lubrication feed rate to match the total alkaline content of the cylinder oil with that in the fuel oil in accordance with a specific formula is to be provided. If LFSO are used predominantly, low-BN cylinder oil is generally recommended by manufacturers, either BN40 or BN50 oil as compared to the typical BN70 cylinder lubricating oil used with HFO. Where frequent fuel oil changes are necessary due to the vessel's trading pattern, it is recommended that a second grade of cylinder lubricating oil with a lower base number (BN) than the first be considered.

- The purifier maker's instructions are to be followed during LSFO purifiers operations.

- During the change-over process it may be necessary to re-set or re-adjust various components (such as control valves, temperature sensors, viscosity meter/controller etc.) fitted in the monitoring and control systems, unless this is realized automatically. Where manually adjusted, this should be in accordance with the engine maker's recommendations.

- As a strong recommendation, the following general guidelines are suggested for fuel oil bunkering, specification, storage, testing and avoidance of potential fuel contamination:

1. Operators/owners/charterers are recommended to buy fuel oil from reputable suppliers whenever possible, require a bunker delivery notes, keep samples onboard and make all necessary arrangements to test the fuel oil to ensure its compliance with the stated specification – by law compliant with ISO 8217:2010 std.

2. Low-sulphur fuel oils, including marine gas oils, are to be stored onboard separate from other deliveries. If problems arise with a particular fuel the issue can be contained and other known performance fuel oils can be prevented from degrading as a result of mixing.

3. Care is to be exercised during the shipboard loading, storage, transfer or treatment of LSFO to ensure that they are not mixed with other higher sulphur and "cat-fines" content fuel oils – either by intent or due to remaining quantities in ship's tanks or pipes.

The list is based on data collected in available technical literature, but that this is not a full list of potential problems. With more experience gathered the list may be amended.

SHIP PROPULSION LOSS RELATED WITH OPERATIONAL PROBLEMS WITH LSFO

Lost of propulsion (LOP) may occur due to ME engine operation on LSF. Potentially the problem

may turn into dangerous situation, further could be subject of claims to underwriters, technical and operational counter measures, including crew training and awareness, should be taken.

The following scenarios are identified as fuel related:

Engine failures resulting in the LOP are due to the inability of the main engine, operating with LSFO/MGO/MDO, to overcome the forces on the propeller from the forward momentum of the ship.

Failures resulting in a LOP are associated with the loss of fuel oil pressure to either the fuel pumps or fuel injectors.

Failures resulting in LOP are associated with the loss of fuel oil pressure or the loss of flow in sufficient quantities to maintain operation.

LSFO RECOMMENDATIONS FOR SHIP-OWNERS OR OPERATORS

The owners/operators are required to take all applicable and appropriate measures in case of engines, boilers and other associated machinery and equipment scheduled for operation with LSFO by systematic surveys and maintenance of related systems taking into consideration the potential risks listed below.

1. A detailed fuel change-over procedure (or manual) should be developed by vessel owner/operators in consultation with engine/machinery manufacturers and placed onboard. If the engines or boilers are capable of operating on low-sulphur marine fuel such as LSFO, although they were originally designed to operate on HFO/LSFO, this fuel change-over procedure (or manual) should still be developed and placed onboard.

2. Fuel oil suppliers should be consulted to selection of proper LSFO to be bunkered.

3. Manufacturers and associated systems providers should be consulted to determine whether or not their existing fuel systems/arrangements require modifications or additional safeguards for the intended fuels.

4. Engine and boiler manufacturers should be consulted regarding any service or maintenance requirements when operating on LSFO. It is required to create and implement inspection and maintenance schedule for the fuel system and its components.

5. System seals, gaskets, flanges, and other fittings should be carefully maintained since fuel seepage and leakage may occur from the use of LSFO in systems which have previously used HFO/LSFO.

6. System purifiers, filters and strainers should be maintained.

7. Control systems including pressure and temperature alarms, flow indicators, filter differential pressure transmitters, etc., should all be operational.

8. Crew training (initial and periodic) should be conducted. Their training needs assessments should be kept up to date.

9. Fuel change over should be completed well before entering the SOx Emission Control Area.

10. Cylinder lubrication consumption should be carefully monitored since a high consumption may be indicative of liner lacquering

The vessel owner is responsible for the vessel and its safe operation. It is recommended that the engine manufacturer or another entity recognized by the engine manufacturer be employed to carry out the design evaluation and oversee any modifications

COMPLIANCE WITH SHIP CLASSIFICATION REQUIREMENTS

All new ships will be designed in compliance with actual Rules of ship Classification Society selected by the shipowner. Hence the problems of technical and operational documents will probably be managed according to new international standards and regulations. There could be problems expected with existing ships or with some conversions, where it will be required to carry out modifications of fuel oil installations for diesel engines and boilers require technical details to be approved by relevant ship classification society. In every such case, the technical documentation of modernized systems and components details should be available onboard ship. In some cases, where no modifications has been done, ship-owner is to take measures to have suitable evidence that fuel oil system is capable to be used when LSFO is used for diesel engines and boilers. Due to the fact that it is considered to be safety issue, the technical evidence or report confirming the safe operation of ship systems with LSFO is to be available only for consideration during ISM audits as evidence that safe operation has been considered.

The approved technical documentation must cover all aspects of ship operation using all possible fuel types under all normal and abnormal modes and is

to include in general the following: scenarios:

- Switch over to HFO from LSFO.
- Maneuvering in congested waters /harbor while switching over.
- Long idle times.
- Starting engine at berth or anchorage.

MODIFICATIONS OF THE FUEL OIL SYSTEMS.

In case of modified fuel oil systems, a ship classification society will require the following:

- Design modifications, if any, are to be done by the original equipment manufacturer or a competent entity that will be responsible for the technical design of modified systems.
- In case of any modification to existing ship installations (including piping and tank arrangements, control systems, fuel treatment units, switch over equipment, valves and other fittings), those are to be subjected to class survey ors review and approval for both design assessment and survey. The scope of technical documents and the system data (design evaluation and detailed technical description of the modifications completed) in general is to be the same for all IACS (International Association of Classification Societies) ship class societies. The technical drawings and the required data will have to include: general piping specification (such as pipe materials suitability, pressure, and fittings), automation and controls systems and other safety requirements in accordance with the applicable rules.
- In case of the installation of new fuel oil pumps, they are required to be type approved i.e. certified by the attending Surveyor at the manufacturer's plant to confirm compliance with the requirements of the ship class Rules.

- All applicable to LSFO use modifications are to be carried out in accordance with approved drawings/details to the satisfaction of the attending class surveyor.

LOW SULPHUR FUELS STANDARDS IN RELATION TO MARPOL ANNEX VI REQUIREMENTS

The revised by marine industry, legal standard for international shipping has been issued by ISO as ISO 8217:2010 and started to be obligatory from 1.06.2012. The ISO 8217:2010 standard represents a significant advance over the previous 2005 version. The changes which have been incorporated into this 4th edition of the Standard are designed to promote the safer use of marine residual and distillate fuels recognizing demand for multi-blend products driven by ever increasing environmental regulation i.e. SOx pollution reduction. ISO 8217 is a commercial standard under which a supplier will agree to provide a product to the purchaser's selected specification. As an ISO standard its development handled by cross industry experts and is therefore readily able to be adapted to meet evolving issues. MARPOL Annex VI is independent of the ISO 8217 Standard and is primarily an air pollution control measure applicable to the ships of signatory parties together with those ships of other flags while operating in waters under the control of signatories. Therefore the background, direction and means of implementation between the two are quite different. Nevertheless, the nature of the changes to the General Requirements clause are such that fuels ordered to ISO 8217:2010 will provide additional, rather than alternative, controls to those required by MARPOL Annex VI so there is no conflict between them. The knowledge of all standard content is recommend as parts of it do not provide all data that may be needed for fuel quality assessment.

3.4 SLOW STEAMING AS A SHIPPING OPTION

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ECONOMIC CONSIDERATIONS

Since its initial introduction in 2008, the slow steaming idea has been adopted by the shipping companies. Against economic uncertainty, the shipping industry is also confronted by a rapidly changing operating environment, in which some trends are reshaping the trade's future. Featuring high on the list of these trends are:

- Rising bunker fuel prices and operating costs,
- Regulatory measures for GHG emissions control and energy efficiency for ships,
- Air pollution from ships and establishment of new emission control areas (ECAs),
- Tonnage overcapacity,
- Shift in global economy and transport pattern.

In response, slow steaming has converted into a simple measure that reduces bunker fuel consumption and benefits to absorb available tonnage capacity. Currently, slow steaming is implemented in shipping market particularly in container trade [EEA, 2013]. The container ship cruising speed cutting starts from approx. 10% in 2010 and is continued by an average 30% [UNCTAD, 2012]. Future rising fuel oil prices and increasing environmental regulation may evolve ship speed management as profitable, economical option. However, there is a widespread expectation that, as the economy and markets pick up and excess capacity is brought back into service, speeds will increase again over time, to meet the growing demand.

Regulated slow steaming is relatively easy to monitor and enforce, both by ships and by regulators and ensures that emissions in the shipping sector will be reduced from usual levels, regardless of the fuel

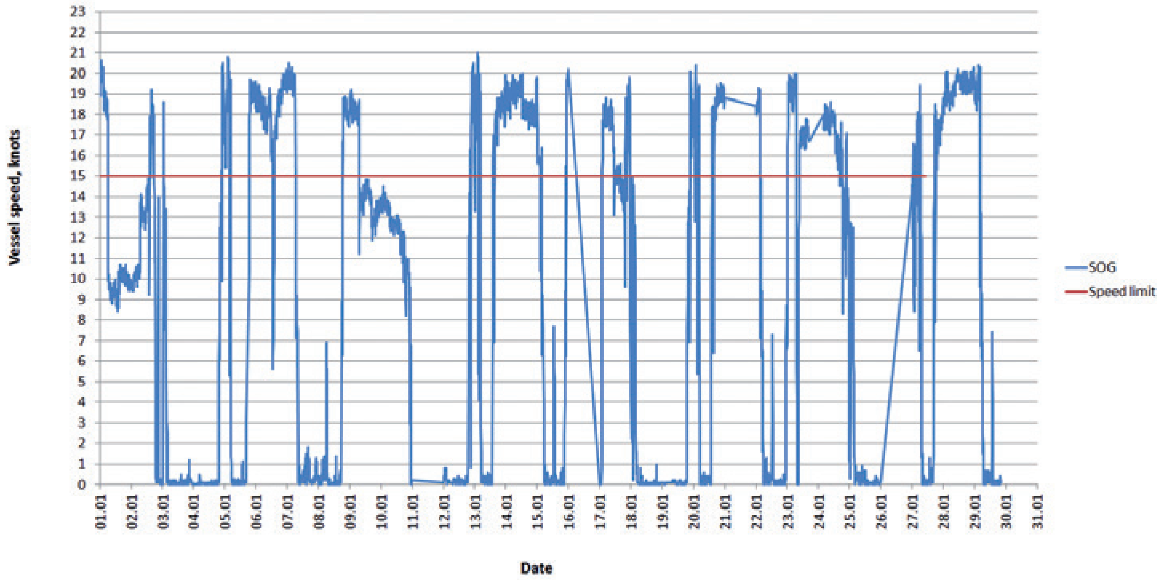


Figure 1. Speed profile of a RoRo Cargo vessel in the Baltic Sea, January 2011 (Blue line). The red line indicates the slow steaming speed limit with 30% speed reduction. The area above the red line indicates the parts of the journey affected by the speed reduction, which in this case is 208 hours. With the speed reduction, vessel operations are slowed down by 28 hours, but fuel consumption is reduced by 35%.

price and demand for shipping [Faber et al, 2012]. Within most ship speed ranges, fuel consumption and consequently emissions of carbon dioxide and sulphur oxides are reduced in line with the energy consumption.

The benefits of slow steaming vary according to the transit time: if short - the bunker costs saving diminishes. The advantage of slow steaming is reduction of the fuel oil consumed by each vessel in service, which is consequently beneficial to emissions decrease. The calculated percentages of fuel savings do not reflect the overall operational savings of the vessel. Sailing schedules have nothing to do with slow steaming introduced. Generally, arrival and departure reliability can be improved due to the speed buffer available for each vessel to maintain the timetable.

The disadvantage of slow steaming is that the transit time is extended, which requires the engagement a surplus vessel that is in correct size range. It is then necessary to weigh bunker cost savings against increased costs related to carrying adequate amount of cargo. Typically this is the cost of maintaining an extra vessel, filled with additional containers and increased charges i.e. time charterer rate or bare boat charter rate plus: crew, maintenance, and management costs. There is also the additional cost of leasing extra container boxes needed to fill the slots on the extra vessel.

SLOW STEAMING IN THE BALTIC SEA

The concept of slow steaming, voluntary speed reduction, of vessels is an interesting way of reducing the fuel consumption and exhaust emissions. In practice, several issues should be taken into account which will have an impact on the decision whether traveling speed should be reduced or not. The operational profile of a vessel is a significant contributor to the usefulness of slow steaming. If the vessel spends most of its time in port loading/unloading cargo, slower speed will have a marginal impact on the fuel consumption. Fast vessels, like RoRo cargo, RoPax, vehicle carriers and containerships, with high normal operating speed will benefit the most from slow steaming. In case of passenger carrying ship classes, like RoPax, the disadvantage of slower speeds may lead to inconvenient harbor arrival/departure times, which may require significant planning and restructuring of vessel schedules.

It is likely that cargo carrying vessels are less prone to this problem.

An example of a speed profile of a high speed RoRo cargo vessel is depicted in Figure 1. This indicates that this vessel had 13 harbor visits during January 2011 in the Baltic Sea area. Speed reduction of 30%, from 21 knots to 15 knots, affects 208 hours of the monthly journey and helps to conserve 35% of normal fuel consumption. However, the operation time is increased by 28 hours, which means that the ship will lose income from that time. In this case, it means lost revenue from one day in a month. The ship owner evaluates the cost savings and the lost revenue very carefully and then decides whether it is feasible to reduce speed or not.

Another example of slow steaming, but with a crude oil tanker, is illustrated in Figure 2. In this case, the time spent cruising is shorter than that of a RoRo carrier, because cargo handling necessitates longer port visits. Slow steaming with 30% speed reduction affects 250 hours of operation time and reduces travel speed from 15 knots to 10 knots. Total voyage time is increased by 44 hours and fuel consumption is reduced by 25%.

For this work, two scenarios were considered, a voluntary speed reduction of 10% and 30% if vessels travel over 10 knots. In the former case the total fuel consumption of the Baltic Sea fleet is reduced by 6% and in the latter by 13%. It should be noted that more fuel is spent in auxiliary engines if the duration of the trip is increased. The benefits of voluntary speed reduction are reasonable for ves-

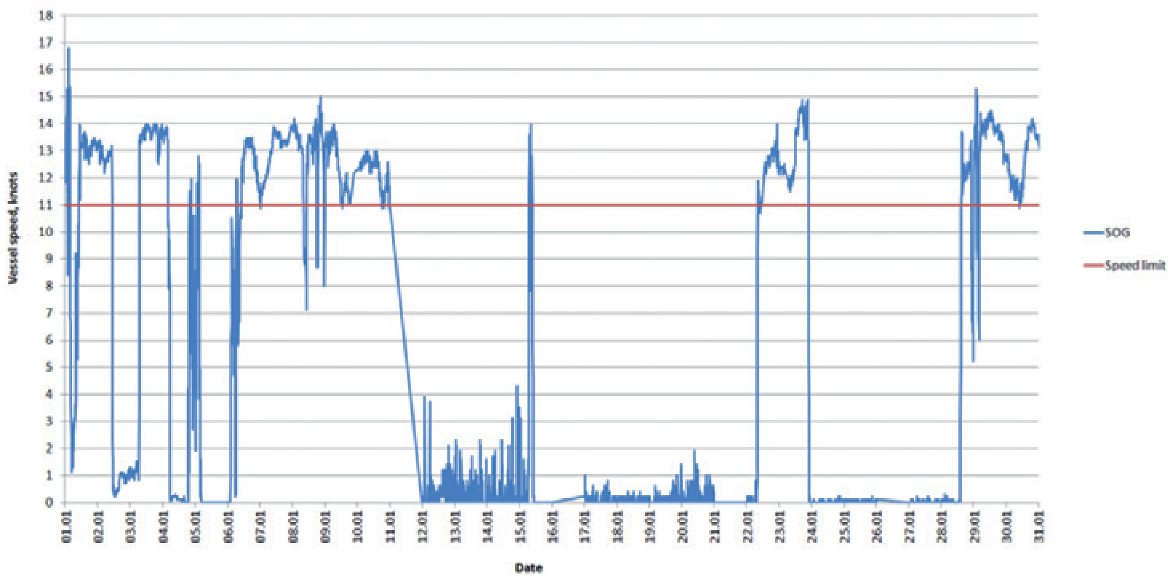


Figure 2. Speed profile of a Crude oil Tanker in the Baltic Sea, January 2011 (Blue line). The red line indicates a 30% voluntary speed reduction, which affects 250 h of voyage. This reduces fuel consumption by 25% and increases vessel operation time by 44 hours.

SLOW-STEAMING (30%)									
	SHARE OF TOTAL	ΔMAIN FUEL	ΔOPERATIONAL	ΔFUEL COST	ΔCO2	ΔNOX	ΔSOX	ΔPM2.5	ΔCO
SHIP CATEGORY	FC 2011 [%]	cons. [%]	time [%]	[%]	[%]	[%]	[%]	[%]	[%]
CONTAINER SHIP	19.4	-34.5	12.2	-13	-14.4	-22.6	-23.8	-13.9	5.5
ROPAX	10.1	-34	9.7	-25	-26.3	-29.9	-32	-29.2	13.6
CHEMICAL TANKER	8.3	-31.4	8.9	-15.5	-17.1	-24.4	-27.2	-22.9	19.6
BULK CARGO	6.7	-31.1	9	-16.2	-17.7	-24.8	-26.7	-23.1	26.8
CRUDE TANKER	4.6	-31.7	8.1	-20.6	-21.8	-28.8	-28.2	-25.8	26.4
RORO	4.5	-42	15.8	-31.2	-32.9	-36.7	-40	-34.4	6.9
VEHICLE CARRIER	2.1	-41.5	12.9	-22.5	-24.3	-33.9	-34.6	-24.2	14.2
REFRIGERATED CARGO SHIP	1.7	-39.7	9.6	-14.9	-16.9	-26.6	-31	-20	13.2
PASSENGER CRUISER	1.4	-30.8	9.2	-18.2	-19.7	-22.6	-26.5	-21.8	7.3
LPG TANKER	1.1	-34.4	9.2	-15	-16.8	-25.2	-28.8	-22.7	19.1
SLOW-STEAMING (10%)									
	Share of total	ΔMain fuel	ΔOperational	ΔFuel cost	ΔCO2	ΔNOx	ΔSOx	ΔPM2.5	ΔCO
SHIP CATEGORY	FC 2011 [%]	cons. [%]	time [%]	[%]	[%]	[%]	[%]	[%]	[%]
CONTAINER SHIP	19.4	-14.5	3.8	-5.9	-6.5	-9.9	-10.4	-7	3.8
ROPAX	10.9	-14.6	2.9	-10.8	-11.4	-12.5	-13.8	-12.8	3.4
CHEMICAL TANKER	8.3	-14.6	3.4	-7.4	-8.2	-11.2	-12.7	-10.9	9.9
BULK CARGO	6.7	-13.6	3.4	-7.3	-7.9	-10.6	-11.8	-10.3	12.2
CRUDE TANKER	4.6	-14	3	-9.2	-9.8	-12.4	-12.5	-11.5	12.7
RORO	4.5	-17.8	4.6	-13.3	-14.1	-15.4	-17	-15.5	4.2
VEHICLE CARRIER	2.4	-17.5	3.9	-9.8	-10.6	-14.2	-14.8	-11.8	8
REFRIGERATED CARGO SHIP	1.7	-16	3.1	-6.3	-7.1	-10.7	-12.7	-9.4	7
PASSENGER CRUISER	1.4	-13.7	2.9	-8.4	-9.1	-10.1	-12.2	-10.4	1.2
LPG TANKER	1.2	-15.2	3.3	-6.9	-7.7	-11	-12.9	-10.6	9.3

Table 1. Predictions for the slow-steaming scenarios, assuming speed reductions of 30% (a) and 10% (b).

sels which have high operating speed, i.e. RoRo, Vehicle carriers, RoPaxes and Containerships. Baltic Sea–wide application of slow steaming will increase emissions of carbon moNOxide if engines cannot be re-tuned to accommodate lower operating speeds and lower engine loads. Table 1 lists the impact of slow steaming on various vessel types in the Baltic Sea.

Taken from Johansson et al. ACPD 13 (2013) 16113. Speed reductions have been applied only for instantaneous speeds exceeding 10 knots. 'Share of total FC 2011' refers to the estimated share of total fuel consumption in the ECA in 2011. Operational time is the combined duration of berthing, maneuvering and cruising. High positive and negative values have been highlighted with red and blue colors, respectively.The table lists ten ship types, which benefit the most from slow steaming.

The schedules of these vessels may be such that harbor arrival/departure times have been optimized for passenger transport. In these cases the use of slower speeds will trigger a need for complete re-design of vessel schedules, because passengers may not like to board/leave the vessel during night time.

RECOMMENDATIONS

From practical experience as well as from the considered scenarios, optimization of vessel operation in such a way that minimizes unnecessary waiting periods because of harbor congestion (ship is waiting for access to a pier) and using that time for slow steaming would bring the largest benefits. This requires two-way communication and information exchange between the ship and the harbor, but from technical point of view it is feasible.

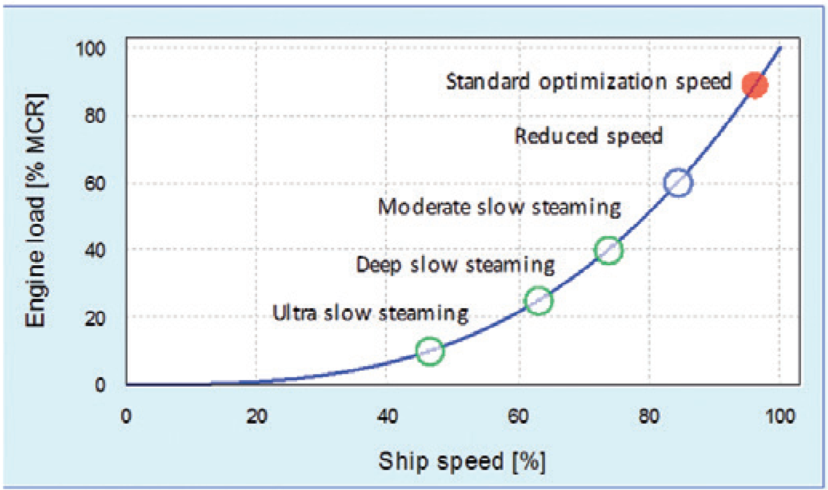
Slow steaming could be seen as a reasonable solution in a case where unnecessary capacity exists, like in the case of economic downturn. Slower speed and decreased cargo turnover can be compensated with existing vessels, which all travel at reduced speed and would otherwise utilize less of their cargo transport capacity.

If a vessel has multiple engines, like RoRo and Ro-Pax vessels usually do, slower speed facilitates the use of smaller number of engines. If engine power requirement is fulfilled with a smaller number of engines, unnecessary engines can be switched off. This will optimize the use of remaining engines, because they would be used at optimal engine loads without the need for re-tuning for slower speeds. If higher speeds are required at times, then all engines could be used again to increase the travel speed.

TECHNICAL CONCERNS AND PREVENTION

Ships are designed and built for a certain specified main engine propulsion load and speed range, at which the system's total efficiency is optimized. Because of the fixed-pitch propeller's direct drive the main engine is optimized for operating rotational speed range. The optimal main engine load is placed between 70-85% MCR. The fuel efficiency of the ship propulsion, its operational parameters, systems, pumps, coolers, auxiliary systems and exhaust gas boilers are designed and optimized for that ship service speed range.

The exhaust steam boiler size is selected based on the exhaust temperature, volume of exhaust gas flow and the waste heat recovery in this range. Low load operation makes this waste heat recovery system ineffective and there is less production of steam, which increases the load on the oil fired boiler. The main engine turbocharger selection and matching to the optimal load are based on the quantity criteria of scavenge air that needs to be supplied to the cylinders for optimum combustion. Low load operations of the main engine lead to lower turbo-



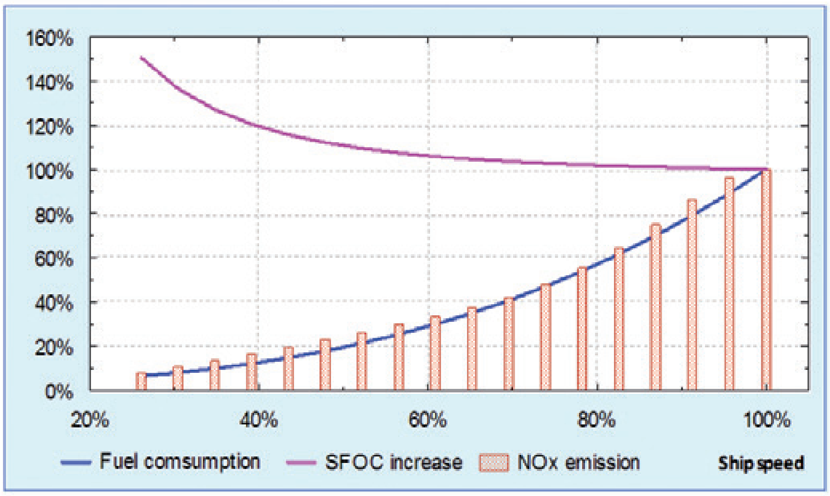


Figure 3. Slow steaming modes and correlation between the ship speed, fuel consumption, SFOC increase and NOx emission

1. Fouling; caused by poor fuel atomization and cylinder oil overdosing. Main propulsion engine and system elements to be affected are: injection nozzle, exhaust valves, turbochargers, exhaust boilers, silencers and SCR (if equipped).

2. Excessive wear; caused by surplus cylinder oil that burns into hard coke, resulting in abrasive wear down of liner and piston rings. Cold corrosion - overcooled cylinder liner area exposed to water condensation and acid formation.

3. Fire risk; caused by dripping fuel and cylinder oil accumulated in scavenging space. Piston rings clogging increases the risk of scavenging space fire. Exhaust boiler deposits increased.

charger rotational speed and less scavenge air. This leads to ineffective and incomplete combustion and higher CO, PM and HC emission.

The ship propeller is designed to give maximum efficiency for the ship service speed range. Due to lower rotational speed of the propeller, efficiency may drop. If shaft generators are designed and selected for optimal main engine load range, low load operation may make shaft generators unusable. Consequently, when the main engine is operated continuously in a load below the optimized range, the overall ship propulsion system performance, expressed by specific fuel oil consumption (SFOC) is affected (Figure 3).

The possible consequences of main engine operating continuously at reduced load are:

4. Enhanced deterioration; auxiliary engine blowers caused by frequent cut-in/cut off or continuous operation. Corrosion and abrasive wear of turbine and nozzle ring resulted from intensive turbine washing.

Main concern caused by continuous engine low load operation is unburned fuel and lubricating oil accumulation in exhaust manifold and steam boiler. Such deposits can ignite after the engine load is increased and may result in severe damage to the turbocharger or exhaust boiler. Therefore, periodical increase in main engine load is recommended. Traditionally, conventional engines require a load increase (when running with low load) of 1hr every 12hrs at 75% load, which equates to 14hrs a week. With modern design engines the load increase requirement is reduced to just 2hrs every week at 75%

load. The increased engine load to highest possible range (at least to 75%) in order to blow through any accumulated carbon deposits.

In relation to the expected increased depositing of soot in the internal parts of the engine and turbocharger, special attention should be paid to turbocharger cleaning, which should be carried out more frequently than stated in the instruction for normal operation. Whilst operating at these increased loads, turbocharger washing and soot blowing of the economizer should be undertaken in order to reduce fouling.

The long-term low load operation increases the risk of exhaust gas boiler fouling, caused by a build-up of carbon. Furthermore, the exhaust gas velocity is so low at low engine load that deposits cannot be removed. Depending on the boiler configuration, it may be recommendable to install a bypass of the exhaust gas boiler, so that all the exhaust gas can be sent through this by-pass connection at low loads. Uncontrolled building up of soot in the exhaust gas boiler can lead to fires.

Modern marine engines are better suited for continuous low-load operation, due to their high flexibility of engine control, which allows optimization of the parameters in the lower load ranges as well. Such features include selective fuel injector cut-out at very low loads and optimized turbocharger efficiency through bypassing a part of the exhaust gas flow at high loads.

In addition, marine engine makers offer an upgrade- and retrofit solutions that fit specific low load operational requirements, and the following solutions are available:

- Flexible turbocharger cut-out solution. The turbocharger cut-off is done in a controlled and fully automated way. This retrofit is available for engines having more than one turbocharger.
- Cylinder pulse lubricating system that ensures precisely timed injection of the lube oil into the piston ring package, which optimizes the lubrication, while the piston ring pressure is increased and the speed decreased during low load operation.
- Combustion monitoring system continuously monitors cylinder pressures and several parameters during the full combustion cycle. It enables the analysis of the monitored data in order to adjust the engine's performance.
- Cylinder cut-out system, to be used at low load allows the engine to operate with only half of the cylinders, resulting in increased load on the operating cylinders with improved operating conditions for the fuel system as a result, thereby ensuring stable running conditions.

NAVIGATIONAL SAFETY

The specific concerns seem to be that slow steaming would interfere with the safe passage of the ship and some have raised ship safety issues, related to operating at too low ship speeds. Consequently, assessment of the ship speed reduction influence on the navigational safety performed, in order to prove it the simulations were carried out using the computer based Transas Navi-Trainer Professional 5000 (NTPRO 5000) Simulator. The results were analysed in terms of determination the typical sea trials parameters such as: turning circle and zigzag manoeuvre. Additionally, anti-collision manoeuvres were conducted and the course-keeping ability in different external conditions was assessed.

Simulations were carried out for two sizes of container vessels, both in fully-loaded condition. The type and the sizes of vessels were chosen with consideration of the characteristic type and size of the ships in the Baltic Sea area. Sea trials area was chosen as a location with high traffic density and typical external conditions for southern part of the Baltic Sea. Depths in chosen area are about 50 m, so it can be assumed that their influence on ship motion is negligible. Simulation were carried out for three wind forces (0, 10 and 20 m/s) and for three relative directions (000°, 090°, and 180°). Heights and directions of waves were determined in accordance with wind force and direction. The main issue related to the speed reduction is the ability to maintain on the course in bad external conditions. It was noticed that during adverse weather conditions the vessels had not been able to keep the desired course, while proceeding with reduced speed. Reduction of speed does not have significant influence on spatial distribution of manoeuvres but it has strong effect on the rates of turn (ROT) values, durations of manoeuvres and the roll angles. Due to this, it should be taken into consideration that all manoeuvres should start earlier. Main conclusions:

Speed reduction does not have significant influence on the dimensions of turning circles. Distinct change was noticed only for bigger ship and minimal speed.

Distances travelled during anti-collision manoeuvres are similar for all initial speeds, but the times of manoeuvres differs significantly.

Restrictions in speed reductions resulting from minimal speed necessary to maintain the desired course were observed. For smaller vessel and for wind speed 20 m/s, from 090° relative direction, minimum speed is higher than 20 knots.

Observed rudder angles higher than 15° will significantly influence effectiveness of steering system and increase rudder dragging forces.

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3.5 ACTIVITIES AND INTENTIONS OF SHIPPING COMPANIES TO COMPLY WITH EMISSION REGULATIONS

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SURVEY TARGETED TO SHIPPING COMPANIES

In order to get a clear understanding of the activities and plans of shipping companies of the Baltic Sea countries in the field of environmental regulations, a survey had been conducted in 2012. The following findings are based on the answers of shipping companies operating about thousand vessels representing 12 different vessel types. 40% of the shipping companies' fleet was operating only in the Baltic Sea and 42% only in the SECA. Although some vessels were operating regularly in these areas, it was highlighted that it is not always the same vessel, because the contracts with the customers are affecting the operation area.

FUEL SWITCH MODIFICATIONS, FUEL USE AND AVAILABILITY

Complying with the forthcoming regulations through modifying vessels to be able to switch fuel from HFO to MGO have not yet been realized among the majority of the respondent shipping companies. Approximately 60% of the respondents had not any plans to modify their vessels, which reflects also general impression received from discussions on this subject. At the same time, some shipping companies are prepared at least to some degree; one fifth of the companies have plans concerning modifications, and one fifth has made actual investments (for example pumps and pipes upgraded for the use of MGO) on vessels in order to enable the fuel switch. In many cases the vessels are modified so that the fuel switch can be realized gradually.

Using fuel with lower sulphur content than necessary under current legislation is based on voluntary decisions. Over 60% of the respondents expressed that in main engines they are not using low sulphur fuels, while 33% are using such fuel all the time. The reasons to use low sulphur fuels ranged from the company policy to the usage of marine gas oil, and besides, some of the shipping companies are operating also in the North American ECA, where stricter regulations are already in use. Auxiliary engines of ships are mainly used in ports where the allowed sulphur content of the fuel is currently lower than at sea. In EU ports for vessels staying over two hours and in inland waterways, the limit has been 0.1% as of 2010. Two thirds of the respondents used MGO at berth and HFO at sea in auxiliary engines, and the rest used MGO all the time. Switch between different fuels might cause problems, but according to answers there have not been any recorded deviations due to fuel switch between MGO and HFO.

According to the answers, there will be a high demand for MGO as of 2015 due to the limited time to purchase necessary devices to comply with regulation of 0.1% sulphur in fuel. The general opinion was that there will be no difficulties with availability, but the price of the low sulphur fuel will be high. Upon regulations coming in force refineries will produce and supply fuels containing 0.1 % with higher prices. As a consequence of high prices, the oil companies can invest in cracking units which will result in higher throughput in refineries. The geographical aspect was seen as a possible obstacle; MGO will be available in main bunker ports, but might be scarce in smaller ports.

EMISSION ABATEMENT – TECHNOLOGIES AND INVESTMENTS

The means of the shipping sector to adapt to the forthcoming requirements can vary from the different methods to the implementation of new technical solutions. According to the survey, the plans to invest in a technology that reduces consumption of the fuel in the near future was believed to realize in 38% of the companies and the rest did not have any plans yet. The technologies that companies have invested in could be divided to the operational improvements and investments in new devices. Examples of the former were engine modification, more efficient port operations and slow steaming. The latter option included new propellers and engines of higher energy efficiency.

According to the answers, approximately 75% of the respondents have not invested in the emission abatement technology, while the rest have put different type of technology devices into operation. Based on the answers, the implemented devices included selective catalytic reduction (SCR), fuel slide valves on main engines and scrubbers. Those who have devoted themselves to develop their operations have achieved significant savings in costs, such as by slow steaming a decrease of direct fuel consumption with over 20% during five years. It was highlighted that emission abatement is a complex system between energy, fuel consumption, emissions, costs etc. where reduction in one section could cause increase in another. (Fig.1)

Despite the general sceptical opinion related to the scrubber technology it is regarded as the best option among the technology available at the moment; 20% of the respondents have plans to install a scrubber in the near future. However, only 15% of the respondents have plans to install a scrubber before 2015 when the stricter regulation on the sulphur content of the fuel comes into force. There exist also other means than pure technol-

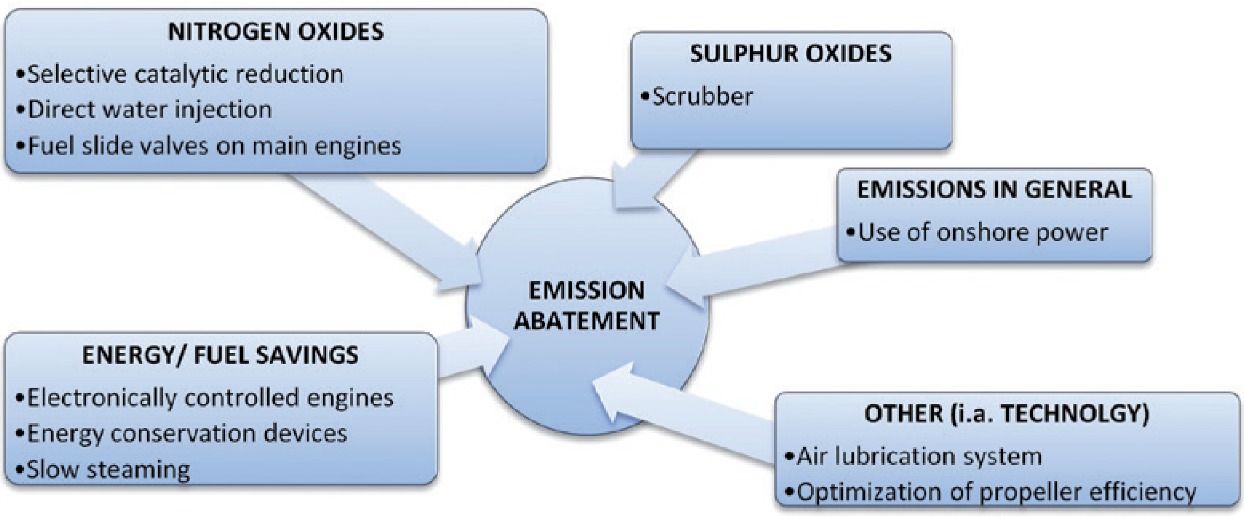


Figure 1. Emission abatement solutions in shipping.

ogy to reduce emissions such as biofuels and LNG. Actually, according to some answers LNG is regarded as the most realistic means to reduce the atmospheric emissions in the near future. In general, alternative fuels were considered reasonable to use in newbuildings, because the retrofitting of the existing vessels is not cost-effective. Besides the alternative fuels, there are other means, such as slow steaming, to control emissions. According to 68% of the respondents, the slow steaming is believed to be a fast and efficient alternative to reduce greenhouse gas emissions through decreased fuel consumption. Actually, it is used in quite many shipping companies, not only liners, but also bulkers and tankers, as a response to higher fuel costs and lower freight rates. Anyhow, the efficiency and usability of slow steaming is dependent on various issues such as the schedule of the vessel. Also opposite opinions of slow steaming's feasibility were expressed; line operation does not enable its use, and according to some opinion, the final intention of the slow steaming is to optimize the company's profit by reducing fuel costs. The advantages and disadvantages of slow steaming are reflecting the market situation; freight rates, fuel prices, general economic situation etc. have strong influence on usage of slow steaming.

LOW SULPHUR FUEL VS. SULPHUR REDUCING TECHNIQUES

Low sulphur fuel and sulphur reducing techniques were regarded almost as equal alternatives when comparing their costs. Opinions supporting the use of low sulphur fuel were the expensive cost of installation of scrubbers, uncertainty related to space needed on board, supply of caustic soda and reception facilities for residue. Another part of the respondents were of the opinion that sulphur reducing technique is cheaper than use of MGO, because the payback time is expected to be short after 2015 and because the technique is a one-time investment. Also the availability of MGO in the future causes uncertainty among the shipping companies. Regardless which of the alternatives is chosen, the vessel's size and estimated remaining lifetime are issues which should be taken into consideration when investment plans are made. Eventually, it is impossible to predict the most reasonable means, because the cost-effectiveness of different alternatives is strongly dependent on the price difference between HFO and MGO which is difficult to predict.

According to the responses, the most important issue affecting scrubber investment decision is the fuel consumption inside the SECA, the second is the usability of the equipment and the third is the device choices. The three least important issues are weight and change of centre for gravity, energy consumption of the equipment and combining the engine and scrubber. In addition to the most important issues, the most problematic issue was a loss of cargo/passenger space. About 60% respondents believed that the scrubbers are based on a reliable technique and a real alternative to the low sulphur fuel, but most of them believed it happen not until sometime in the future. Over half of the respondents (60%) assessed that the estimated remaining life time of a vessel to still be feasible to install a scrubber is about ten years. It was highlighted that the remaining lifetime of the vessel is dependent on many issues such as vessel type, trade line and timing as well the price of HFO vs. MGO/MDO and the technology used for scrubbing. In general, the possibility of the investment recovery affects to the readiness of the shipping companies to make decisions.

ALTERNATIVE ENERGY SOURCES

One third of the respondents was of the opinion that renewable energy as a source of energy on the vessels is feasible, while the rest assumed that it is not feasible at all. Hesitation concerning plans

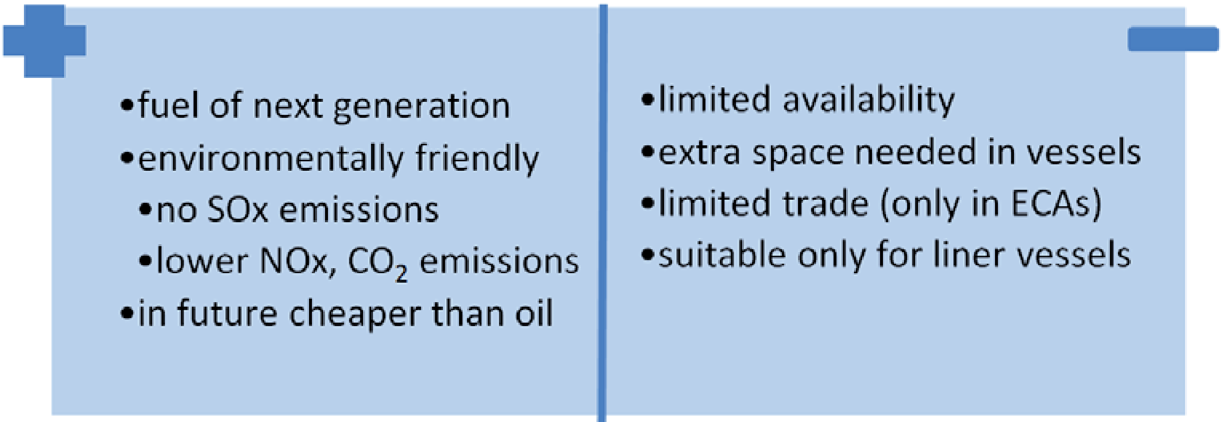


Figure 2. Advantages and disadvantages of LNG.

to invest in renewable energy sources in the near future was also common among the respondents; almost 60% answered that they do not have any plans to invest in renewable sources. The reasons for uncertainty were unavailability of reliable technology, small vessels with limited lifetime and relatively higher prices compared to conventional sources. In spite of the general hesitation concerning the alternative energy sources, 20% of the shipping companies informed their strong confidence in them, and according to the responses they also have an extensive knowledge concerning these types of energy sources. According to the answers, the installed technology in the future could be biofuel used in new buildings, solar and wind power and batteries. In general, LNG was regarded as a realistic alternative to be used in vessels with many advantages, although many disadvantages were expressed (Fig.2). According to the responses, one third of the respondents have planned to invest in LNG.

SHORE-SIDE ELECTRICITY – USAGE AND IMPLEMENTATION

According to responses, 25% of the shipping companies have vessels using shore-side electricity during port visits. In general, the experiences of the shore-side electricity are mainly positive. It was highlighted that for longer stays it is cheaper and also greener, but under eight hours' visits there is no difference. It was expressed that shore-side electricity is not widely available and it was demanded to be mandatory equipment (at least 125A con-

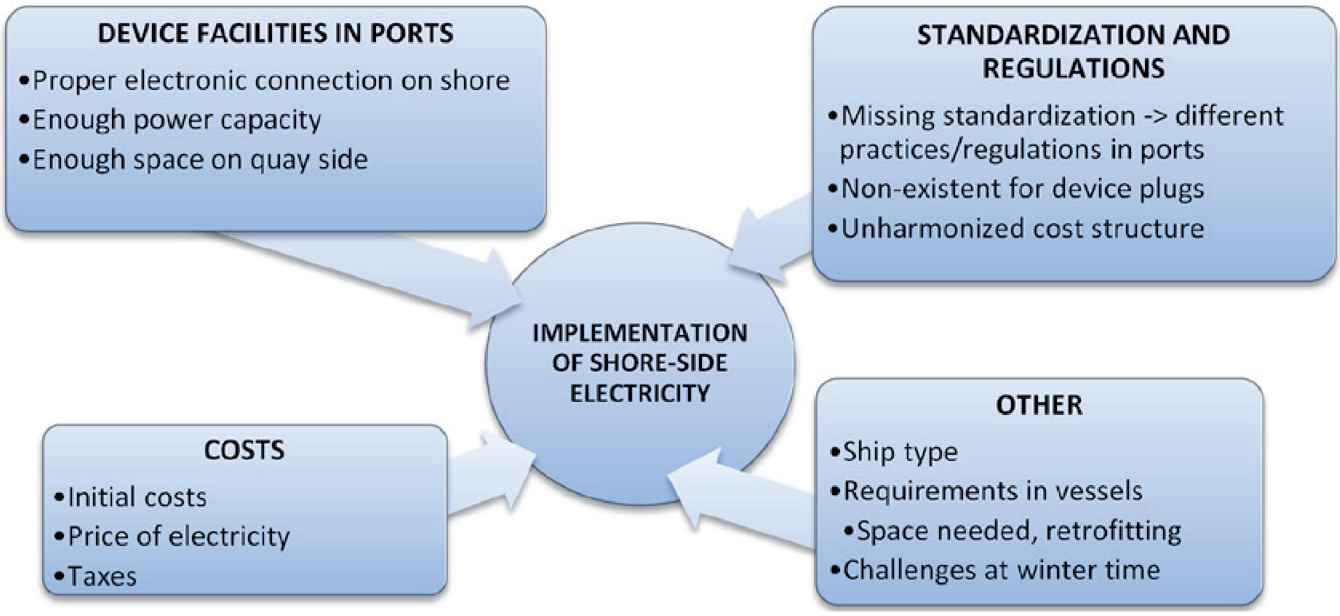
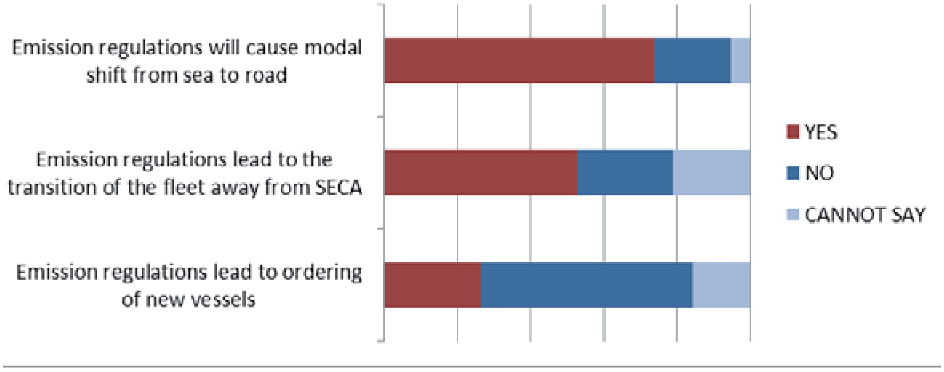


Figure 3 Issues affecting the implementation of shore-side electricity.

nection) in all ports. Opposite opinions of shore-side electricity related to problems with power, insufficient pumping and responsibility questions in case of a power failure. One third of the respondents have calculated the cost efficiency of shore-side electricity with promising conclusions; it has been estimated that shore-side electricity is almost always cheaper if port stay is over six hours. However, opposite opinions were expressed such as the more economical use of auxiliary engines and the minor difference between used fuel and shore-side electricity. The most important factors affecting the implementation of the shore-side electricity could be divided to four categories. (Fig.3)



FigureX4. General economic impact of emission's regulations.

ECONOMIC INCENTIVES AND NEW MARKET POSSIBILITIES

Examples of market-based methods to implement and develop emission abatement include reduction in low sulphur fuel prices, taxes and tax refunds and schemes comparable to Norwegian NOx Fund for SOx and CO_2. It was suggested that there should be "a worldwide ECA", but not "a current island" solution in order to take effect the same global requirements. Investment subsidies and compensation from government for example for scrubber implementations were mentioned as possible supportive actions. According to some respondents, no economic control is required, because the incentives are always disturbing the market and it should be allowed to make investments to achieve the most profit. Besides, the economic incentives would lead to emission trading schemes or emission pools. Based on these opinions it is reasonable to spend money in clean fuel technologies like LNG and improved engines.

According to the responses the threats and challenges in new market situation after 2015 are exceeding the possibilities. The general economic impact of emission regulations is regarded as a significant threat to the whole maritime sector; three out of four believed they will cause modal shift from sea to road, which will reduce the cargo transported at sea and half believed they will lead to the transition of the fleet away from SECA (Fig.4). Instead, regulations are not believed to lead to the ordering of new vessels.

The emission regulations affect the general economic situation and will impact the shipping companies' own situation negatively. Almost 80% of the respondents believed that emission regulations create a risk to the company's operations. Despite the challenges caused by the sulphur limit, also new market possibilities for shipping companies can be forecasted. Especially companies that comply with new regulations can obtain competitive advantage compared to other companies. The possibilities of LNG are seen as an alternative to adapt to the new situation. Because the forthcoming situation is largely affected by different factors such as fuel prices, general economic situation, regulations etc., it is impossible to predict how strongly and in which way the maritime sector will be affected without a thorough multimethod analysis.

CHAPTER 4:

BEST PRACTICES AND RECOMMENDATIONS FOR PORTS AND CITIES

4.1 CURRENT PREDICTED EXPOSURE AND HEALTH RISK IN KOTKA/HAMINA, FINLAND

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The focus of the local scale air quality studies in BSR InnoShip was directed to a collection of port cities in various Baltic Sea countries. Port of Kotka/Hamina was selected as an example from Finnish harbors, because of its active role as container and transit traffic point to Russia. Other cities included in the health impact evaluation were St. Petersburg (Russia), Tallinn (Estonia), Riga (Latvia) and Klaipeda (Lithuania). In all of these cases, harbors are located in the city center where significant human populations exist. This concerns especially the city of St. Petersburg, which has over 5 million people and three harbor areas at the city centre (St. Petersburg, Petrodvorets and Lomonosov) and four more outside the most densely populated area (Vyborg, Vysotsk, Primorsk and Ust-Luga).

In each of the target cities, emissions from local traffic sources (car traffic ships) were evaluated in addi-tion to the background concentrations to assess the impact of harbor areas to overall air quality and hu-man health. Ships are large, sources of emissions, showing significant short-term contribution air con-centrations which last from minutes to few hours. Since the beginning of 2010, all ships in EU harbor areas were required to use low sulphur fuel (<0.1%) in port areas if the duration of their visit is longer than two hours. This requirement has a time limit, because fuel switch from residual fuel oil (HFO) to distillate oil (MGO) has to be done gradually due to large temperature difference (up to 100°C) of fuels. If not done gradually, large temperature differences may lead to accidental gasification of MGO in fuel lines.

The air quality limit values, for the protection of human health, set by the European Union (2008/50/EC) define the acceptable pollution levels, but are not directly applicable to Russia, which has its own air quality requirements. In the EU area, the limit for annual average for NO_2 is 40 micrograms/m^3. The daily and annual mean limit values for PM_{10} are 50 and 40 micrograms/m^3. For $PM_{2.5}$ annual mean limit value is 25 micrograms/m3. For SO_2, annual limit value is not defined, but daily limit is 125 micrograms/m^3. Breathable (coarse) Particulate Matter of size less than 10 micrometers are not primary combustion particules but can form as a result of dusty cargo handling (coal, grain, cement, sand etc.) or vehicle break wear or resuspension of road dust from land based sources. Particulate matter from combustion emitted as diesel exhaust usually has the size range from 0.001-0.5 micrometers. The size of PM increases in the atmosphere as aerosol processes affect the chemical composition and gaseous compounds can condense on the surface of small particles. Particulate matter is a combination of dozens, or even hundreds, of substances that are often associated to detrimental human health effects. Generally, most harmful part of PM has the smallest size and it can bypass the natural defense systems of the human body causing premature death in people with heart of lung disease, non-fatal heart attacks, aggravated asthma, decreased lung functionality and other respiratory symptoms. Children, the elderly and individuals with heart and lung diseases are most vulnerable to the effects of airborne particulate matter.

Sulphur is one of the most significant contributors the PM emitted from ships. Some sulphur is present in marine fuels even if sulphur has been practically eliminated from land based traffic fuels. Pres-

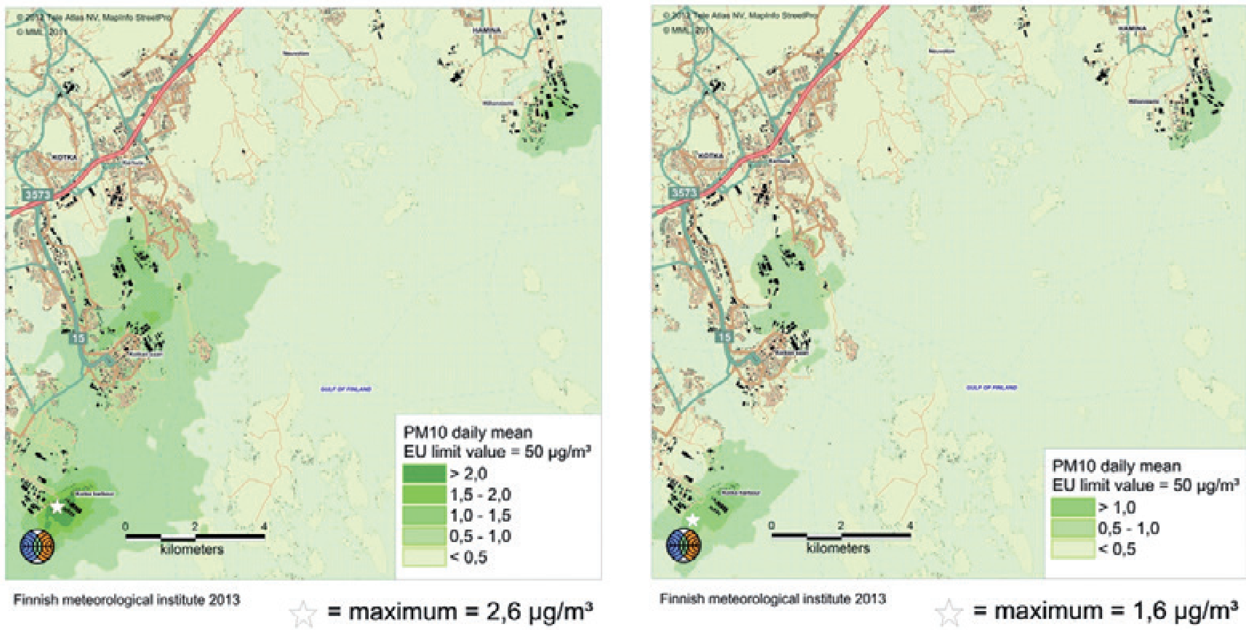

Figure 1 Emissions of Particulate Matter from ships in 2008 (left) and 2011 (right). The requirement of 0.1%S fuel use in harbor areas became effective in January 2010.

ently, only 0.1% of sulphur by weight is allowed in marine fuels used in harbor areas of the European Union. Re-duction of fuel sulphur content effectively removes a large portion of PM mass, but components like soot (elementary carbon), organic compounds and ash remain. Despite the sulphur reduction, these compo-nents are still produced by liquid fossil fuel combustion in ships. The sulphur reduction from 1.0% to 0.1% in the Baltic Sea has had a clear impact on the level of emitted particles from ships.

As can be seen from Figure 1, the levels of emitted PM from ships did not exceed the daily EU limit val-ues in Kotka/Hamina harbor area in 2008, before the 0.1%S fuel requirement of the EU sulphur directive. In 2011, the PM emissions from ships have reduced from their 2008 levels by almost 40% since less sulphur was emitted in particulate form. However, the overall daily PM air concentrations from 2008 to 2011 have increased because of the changes in PM background concentrations and the meteorological conditions.

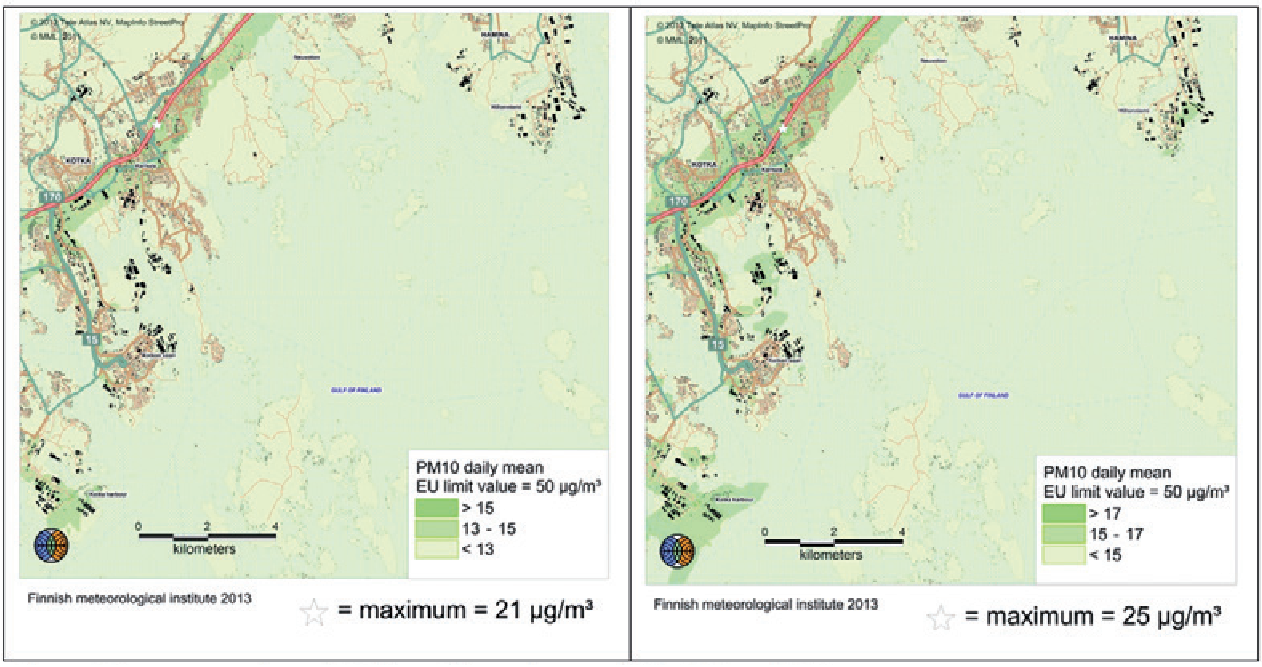

Figure 2 Air concentrations of PM from ships and car traffic in 2008 and 2011

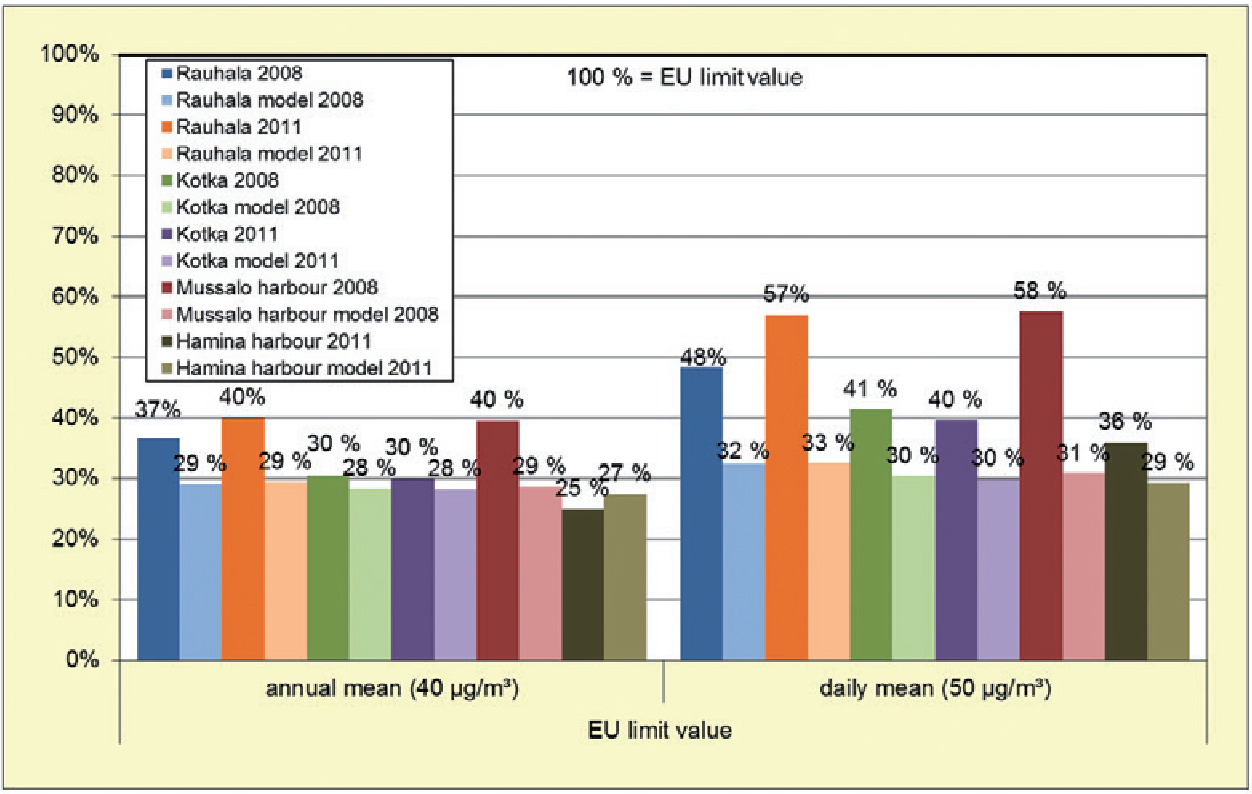

Figure 3 Measured and modeled air concentrations of particulates (PM10) in Kotka/Hamina area during 2008 and 2011

Human exposure to airborne PM is affected by air concentration, time spent in the polluted area and number of people in the area. In Kotka, the area which has the highest PM contribution from ships is the Mussalo area, which is the industrial section of the city. Human exposure in this area is low, because very few people live in this area. However, at the city centre there exist Kantasatama (passenger terminal) and Hietanen (RoRo cargo) harbors which have a larger contribution to human PM exposure in Kotka than the Mussalo harbor area.

The comparisons of model predictions to air quality measurements done in various parts of Kotka and Hamina are presented in Figure 3. In all cases, except the annual mean for Hamina harbor in 2011, the modeled air concentration of PM is slightly lower than the measured value. Most significant differences between the modeled and measured values can be seen in the daily means of Mussalo harbor during 2008. Emissions from loading/unloading dusty cargo is not included in the modeling work, which presumably could form a significant part of PM_{10}, but should not be present in $PM_{2.5}$ data which describes primary combustion PM. Considerable share of PM_{10} is also originating from the road traffic which is lifting the small sand particulates and other dirt from the top of the road surface depending on the meteorological conditions. Unfortunately, comparisons to $PM_{2.5}$ measurements is not possible because it is not a routinely measured quantity in smaller cities, whereas PM_{10} measurement is obligatory. It is noteworthy, that neither the limit values in 2008 nor in 2011 were exceeded regardless of the requirement to use 0.1%S fuel in port areas. The Rauhala station measurements in 2008 and 2011 show an increase in measured PM values, which may be due to increased car traffic (Rauhala is an industrial measurement station and local car traffic is the most significant source).

The EU sulphur directive has decreased the emissions from ships, because sulphur is a significant com-ponent of PM. However, there are other components of PM which are not connected to fuel sulphur con-tent. There are, and will be, health problems connected to PM whether the air concentrations are below the EU limit values or not. Clear threshold level without PM health contribution has not been detected, which means that harmful effects can be observed particularly among vulnerable population groups such as children, elderly people and people suffering from respiratory disorders even with low air concentra-tions. In the BSR InnoShip project, similar observations to Kotka/Hamina case were made with Tallinn, Klaipeda and Riga, which all report air concentrations below the EU limit values. The effect of PM is likely to be most pronounced in St. Petersburg, because a very large human population is exposed to PM emissions from ships and over 100 000 people live in an area which has very high contribution from emissions of ships at berth.

4.2 AIR QUALITY MEASUREMENTS IN THE VICINITY OF THE SEA PORT OF ST. PETERSBURG

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Air quality is a key point of the Environmental Policy of St. Petersburg approved by the City Government in June 2013. Development of the regional programs and action plans aimed to the air protection is one of the main targets of the Government of St. Petersburg. Identification of the major contributors to the air pollution in the city is the first and rather important step in the action plan development. Up to the last years only two major contributors were taken into account: car traffic and industry. Due to international cooperation in the year 2009 the first preliminary inventory of ship emission in the water areas of St. Petersburg was carried out. This inventory has confirmed that the ship traffic is the third important contributor effecting air quality in the city area.

Fig. 1. General sketch of fairway channels and harbours of the Sea Port of St.Peterburg.

The regional methodology of ship traffic emission inventory was developed in 2011. A systematic air quality measuring campaign aimed to identification of ship emission impact on the city area was organized first time in 2011. That is why the year 2011 is considered as a reference year for the assessment of ship traffic emission impact on the city area given in this paper.

SHIP TRAFFIC INTENSITY IN THE WATER AREAS OF ST. PETERSBURG

St. Petersburg is the largest logistic center in the North-Western Russia. The city is located on the junction of the internal and international waterways and roads. The main part of ship traffic is related to the Sea Port of St. Petersburg (Fig. 1). In addition to ship traffic related to 6 sea ports located on the Neva Bay shores within the city borders (Fig.1), more the 7 thousand ships cross the whole city annually by the river Neva. Since St. Petersburg is also a tourist center, the city is a point of internal and international cruises. Ship traffic intensity in the year 2011 is illustrated by Table 1.

POS. NO.	SHIP TRAFFIC TYPE	NUMBER OF VESSELS
1	Cargo sea port of St. Petersburg	24584
2	Passenger sea port of St. Petersburg	659
3	River cargo ship traffic	7022
4	River passenger ship traffic	1548

Table 1. Ship traffic intensity in the year 2011.

SHIP TRAFFIC EMISSION INVENTORY

Traditionally, ship emission inventory in Russian Federation is based on reporting on fuel sold in the particular region. However, St. Petersburg is a cross point for different ship traffic ways and most of fuel sold in the city is used in different regions of the Globe. That is why such a methodology is completely not applicable for the ship emission inventory within the city borders. The new regional methodology is based on data on the parameters

POLLUTANT)	SEA CARGO AND PASSENGER VESSELS	RIVER CARGO VESSELS	RIVER PASSENGER VESSELS	AUXILIARY AND MUNICIPAL VESSELS
NOx (T)	7 502	692	273	1 163
CO (T)	1 619	256	82.3	796
CH (T)	310	56.7	20.5	140.8
C (T)	303	57.9	17.0	92.0
SO_2 (T)	485	66.8	5.3	45.9
Total pollutant emissions in 2011 (t)	10 219	1 129	398	2 238

Table 2. Pollutant emission (T) by different kinds of vessels, operating in 2011.

of particular vessels and regimes of their energy plants. Types of the fuel used by different vessels and types of the energy plants are also taken into account.

The data on the ship traffic intensity in the Neva Bay of the Gulf of Finland are provided by the Federal Maritime Port Authority. Additional information concerning river ship traffic is provided by the State Volga-Baltic Basin Authority for Waterways and Navigation FSI. Ship emission calculations were based on algorithms listed in the "Guideline for assessing the mass of harmful substances (pollutants) emitted by the water transport in the atmosphere of St. Petersburg" (approved by the Committee for Nature Use, Environment Protection and Ecological Safety of St. Petersburg 05.06.2012 N 102-p).

Ship traffic emissions are given in Table 2, which illustrates that sea vessels, calling at ports of St. Petersburg, contribute the most part of pollutants emitted by ship traffic. Nevertheless, the role of other vessels operating in the water areas within the city borders can't be neglected too.

The inventory carried out in 2011 showed that ship traffic is the third important emission source in the city. Total emission of vessels is comparable and for some compounds even exceeds emissions of car traffic and industry (Table 3).

AIR QUALITY MEASUREMENTS IN THE VICINITY OF THE SEA PORT OF ST.PETERSBURG

The measuring campaign aimed to identification of ship traffic emissions impact on the city area was organized in 2011. The measurements were carried out by automatic monitoring station from June to November 2011. The monitoring point was located on the waterfront close to both, cargo and passenger sea ports. Thus, the winds of western directions transported pollutants from ship traffic ways to the observation point whereas the winds of eastern directions transported mainly pollutants emitted by cars and industrial sources. The wind rose for the observation period illustrates dominating of western and eastern wind directions. Location of the observation point was chosen after a number of preliminary measuring studies carried out in 2010 by mobile labs in 6 points close to the Sea Port of St. Petersburg (Fig. 3).

The short-term (20 min averaged) concentrations of NO, NO_2, CO, SO_2, and PM_{10} were measured.

POLLUTANT)	POWER PLANTS AND INDUSTRY	SHIP TRAFFIC	CAR TRAFFIC
NOx (t)	37290	9630	14813
SO_2 (t)	33980	603	196

Table 3. Emission of NOx and SO by industry, ship traffic and car traffic in 2011.

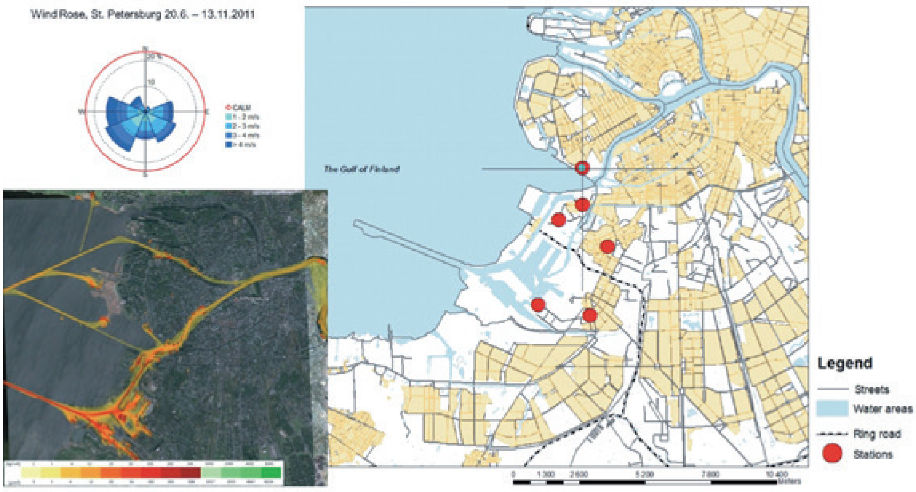

Fig. 2. Location of the monitoring site in the period from 20.06.2011 to 13.11.2011 is marked by crossing lines.

As far as NOx is a conservative admixture, its concentration has also been calculated (Table 4).

Concentration roses illustrate mean values of the pollutants concentrations corresponding to the eight compass points (Fig. 4).

The concentration roses show that the highest mean concentrations of NO, NOx, and CO correspond to western wind directions while the highest PM_{10} are transported to the monitoring site with the eastern winds. The highest SO_2 concentrations correspond to NE winds coming from the city center, and the NO_2 concentrations, on average, do not show strong dependence on wind directions.

COMPUTER MODELING OF POLLUTANT DISPERSION

Dispersion modeling was carried out using a Russian regulatory dispersion model OND-86. The model algorithm is realized in the commercial software ECOLOG.3. In order to assess ship emission contribution to the ambient air pollution on the city scale, more then 20 thousand industrial and car traffic emission sources were taken into account. The model is designed for estimating annual averages as well as 98th percentiles of the short-term (20-30 min averaging) concentrations; however, only the last ones were calculated because the measurement period didn't cover the whole year.

Comparison shows that only calculated CO concentration are satisfactory close to measured ones, with the ratio R98 of measured to calculated 98th percentiles close to the expected interval of 1± 0.25 corresponding to the error of 25%. The values of R98 for NOx and, especially, for SO_2 are too low, and it could be an indication of overestimation in NOx and SO_2 emission rates. On the other hand, ship traffic emission inventory does not give daily variations of ship traffic emissions, which can lead, together with other factors, to overestimation of the short-term emission rates.

POLLUTANT	MEAN (MG/M^3)	SIGMA (MG/M^3)	AMOUNT OF SAMPLES
NO	0.022	0.035	7385
NO_2	0.032	0.020	7385
NO_x	0.066	0.066	7385
CO	0.813	0.714	8819
SO_2	0.0036	0.0107	9909
PM10	0.0115	0.0092	8256

Table 4. Statistical characteristics of the observed concentrations.

Modeling of the annual average concentrations shows that nitrogen dioxide, emitted by ships significantly contribute to ambient air pollution in the city. Its concentration can ex-

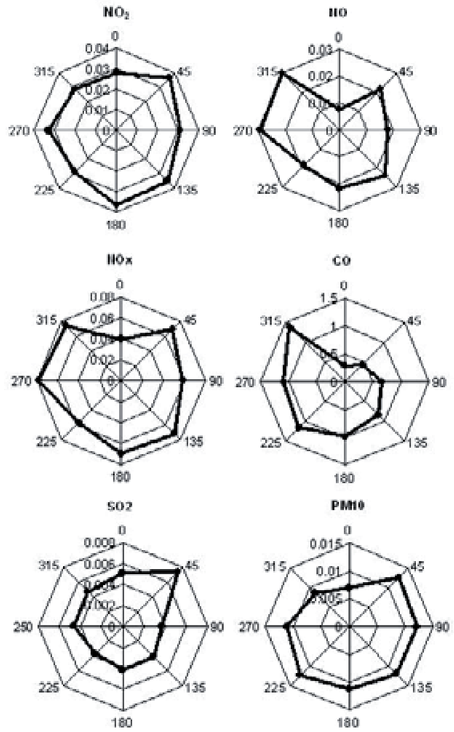

Fig. 3. Concentration roses of measured pollutants (mg/m3).

ceed maximum permissible level in the area close to the Sea Port of St. Petersburg.

The OND-86 model was used also to estimate share of ship traffic emissions in the air pollution in St. Petersburg. Modeling showed that only NO, NO_2, and NOx concentration fields are sensitive to the sea port emission. Its influence can reach as much as about 10%. This estimation leads to the conclusion that 576 dwelling houses are located in the area, affected by the ship traffic emissions. Consequently, 91.5 thousand citizens are exposed to the ship traffic emissions in St. Petersburg.

CONCLUSIONS

1. Ship traffic is the third important source of ambient air pollution in St. Petersburg.

2. The ship emission inventory methodology developed in St. Petersburg provides more reliable annual average data then the inventories based on AIS data because it takes into account emissions of auxiliary vessels and river barges which are not equipped with AIS.

3. The methodology of the ship emission inventory developed in St. Petersburg has to be improved in order to provide short-term emission data taking into account daily, weekly and monthly variations of emissions.

4. Measuring campaign has shown remarkable impact of CO and NOx emitted by ships on the city area while SO_2 and PM_{10} impacts are negligible.

5. It is strongly recommended to arrange measuring campaign covering the whole year in order to obtain reliable annual average measured data.

6. Nitrogen oxide and dioxide are the major pollutants emitted by ship traffic, which population of St. Petersburg is exposed to.

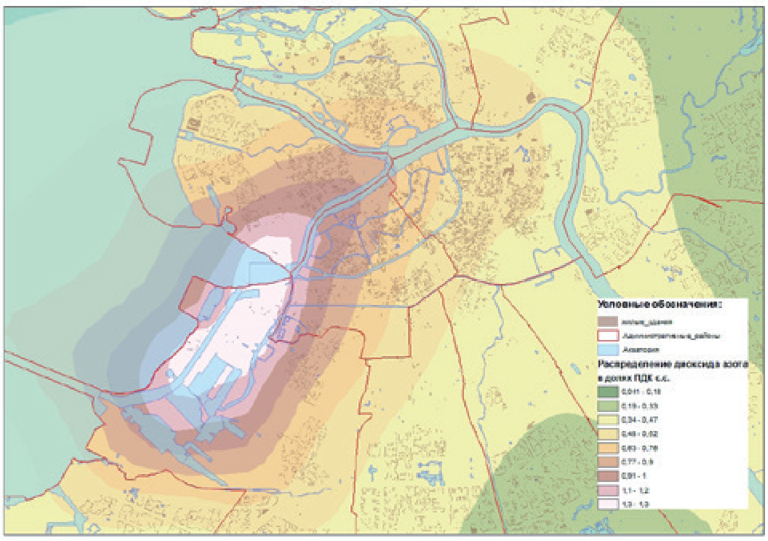

Fig. 4. Annual average concentration of NO2 emitted by ship traffic. The concentration values are given in fractions of the maximum permissible level (MPL=0.2 mg/m3).

4.3 ENVIRONMENTALLY DIFFERENTIATED PORT FEES – EXPERIENCES IN THE BALTIC SEA

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MARKET-BASED EMISSION REDUCTION STRATEGIES FOR NO_x REDUCTION

The pressure has grown to develop cost-effective emission reduction strategies in the Baltic Sea. The forthcoming stringent regulations of the International Maritime Organization for reducing harmful emissions of shipping in the Baltic Sea are causing increasing expenses for the operators. A market-based attitude towards pricing of economic incentives could be seen as a new approach for a successful application for the additional emission reduction of NOx. Possibility of proposing the Baltic Sea as Nitrogen Emission Control Area is currently under investigation. This would mean that all new vessels build after 2021 would automatically need to install the NOx reduction system. The drawback in Tier III effects to NOx reduction is that it only applies to new vessels and the turnover of the fleet is slow. According to current EU release EU Commission will propose "Principles for environmental charging and promote the exchange of good practices by 2015". In this field, in the Baltic Sea Region and especially in Swedish ports a lot of experiences have been gathered, already. In 1998, The Swedish Maritime Administration in co-operation with the Swedish ports and Ship owners decide to implement a system of environmentally differentiated charges to create incentives to use low sulphur oil and to reduce NOx emissions. The fair-way due is mandatory for vessels loading and unloading cargo or passengers in Sweden. Whereas, the port dues are recommended to be implement by Swedish ports. The system was completed by giving a financial support to installation of equipment or clean-burn technology. The objective of the system was to be income neutral.

These experiences are in the focus of this contribution.

PORTS	NOX/KWH	DISCOUNT SEK/GT (EUR/GT)
PORT OF STOCKHOLM	10g/kWh - 5g/kWh	0.15 (0.0177)
	5g/kWh - 1g/kWh	0.25 (0.0295)
	below 1g/kWh	0.30 (0.0354)
PORT OF MALMÖ	6-12 g/kWh	0.05 (0.0059)
	below 6g/kWh	0.15 (0.0177)
PORT OF GOTHENBURG	6-9.9g/kWh	0.05 (0.0059)
	2-5.9g/kWh	0.10 (0.0118)
	below 1.9g/kWh	0.20 (0.0236)
PORT OF PITEÅ	over 10g/kWh	addition +0.10 (0.0118)
	10g/kWh - 5g/kWh	0.05 (0.0059)
	below5g/kWh	0.10 (0.0118)
PORT OF SUNDSVALL	6-12 g/kWh	0.05 (0.0059)
	below 6g/kWh	0.15 (0.0177)

Table 1 shows current NO_x discounts in some Swedish ports
Sources: Port of Stockhom (2011); Port of Malmö (2011); Port of Gothenburg (2013); Port of Piteå (2013): Port of Sundsvalls (2011)

ENVIRONMENTALLY DIFFERENTIATED FEES IN SWEDISH PORTS

Even though the environmentally differentiated port fee system is voluntary in Sweden, by 2011, 33 major ports in Sweden have introduced the system. In order to receive a discount from NOx or SOx reduction, it is provided that the Swedish Maritime Administration has issued a valid Nitric Oxide Certificate or Sulphur Oxide Reduction Certificate in accordance with SJÖFS 1998:13. Normally the notification of a Certificate should be submitted to port when reporting a vessel's first call into port. The port fee system is based on two charging components:

- Gross Tonnage based (environmentally differentiated)
- Fee based on the amount of goods loaded/ unloaded (not affected by the differentiation)

According to Mellin & Rydhed´s (2011) article, experiences and attitudes concerning differentiated ports fees has been very positive among Swedish ports. In total 20 out of 30 ports responded that the implementation of differentiated port fees has been positive for the business and only one port responded that the effect has been negative. Also total 27 of 30 ports answered that implementing the system had a positive impact. By July 2009, total 37 ships had a valid NOx certificate, from which 34 had installed SCR. According to research by Mellin & Rydher (2011) and representative of Port of Turku the system of environmentally differentiated port fees has not create insurmountable economic disadvantage for ports.

EXPERIENCES FROM ENVIRONMENTAL DIFFERENTIATED PORT FEES IN OTHER PORTS

In addition to Sweden, also other particular ports environmentally differentiate their port dues. The Swedish experience could be brought together with international endeavors to introduce more coherent system in the Baltic Sea. In 2006, Port of Turku in Finland implemented a system of environmentally differentiated port fees to create a cause for vessels to operate more environmentally friendly. Port of Turku will grant a port fee discount with nitrogen limits below 5 g/kWh and 10 g/kWh, the rate of a discount is two per cent and one per cent. According to representative of Port of Turku the system of Turku has been implemented from Sweden. In Finland, certificates issued by Swedish Maritime Administration are also applicable. In Turku port 4 frequently visiting vessels are entitled to the discount (interview in 7.2.2013).

Since 2011 in port of Rotterdam ship owners can get 10 % discount of port fees when they register for international Environmental Ship Index (ESI). The object of the ESI is to grant discount for a vessel performing better than IMO regulations. The ESI formula is built up of different parts for NOx, SOx and CO_2, also additional bonus is granted for the presence of an Onshore Power Supply OPS. By October 2012, 1445 vessels and 16 ports worldwide have introduced the ESI. The advantage of ESI is in its international nature; it could be advisable for the Baltic Sea ports also to join international efforts. In addition, in particular ports by implementing the Green Award vessels receive a considerable reduction on port dues. In Norway Green Award Certificate was introduced in 2007, and also NOx tax and NOx fund was implemented. As an outcome from introducing the NOx tax, Norwegian NOx emissions were reported to reduce in 2007 by 8.7% as compared to 1990. The amount of tax is calculated based on actual NOx emission. Enterprises can apply for financial support from the Business Sector's NOx fund, receiving up to 80% coverage of the investment for installation of NOx reducing technology.

Concerning existing port fees it has been stated that the system does not take into account the distance travelled. Kågeson (2009) presents a possibility of an en-route charging system, where the charges would be based on the distance and time travelled in the Baltic Sea area. Such a system would thought be well justifiable by the fact that the charges would reflect actual NOx emission. However, the system would not take into consideration the costs of emission reduction to the ship owners and in addition collecting an en-route data would cause costs. While an en-route charging system might effectively limit emissions of pollutant, the system may exact relatively high costs in the process. Despite the concerns, the system advantage lies in the fact that the investments for decreasing of emission will be executed by those with lowest cost. When thinking economically the reduction should be conducted by optimizing the resource allocation.

CONCLUSIONS AND FUTURE CHALLENGES

At the moment there is no preferred solid environmentally differentiated port fee system in the Baltic Sea. The current system that gives a discount for both SOx and NOx reduction will have to be reformed after 2015 as the new sulphur directive will be introduced. As the sulphur emissions will be regulated by the directive it would create an opportunity to increase the discount granted for NOx reduction. A high effect for shipping companies is necessary, in order to cause voluntary investments. Regulatory pressure commonly causes firms to embrace environmental management strategies for example in case of SOx directive. Additional emission reduction is also required by the companies' external stakeholders including investors, customers, nongovernmental organizations, local communities and employees. Motivation for voluntary emission reduction as in this case NOx reduction at a large extends stems from a strategic choice and economic efficiency. Though, the investments cash inflows and outflows might be negative in voluntary emission reduction technology investments, the managers should bear in minds their long-term strategy concerning sustainability and its indirect effects on company profitability. The differentiated port fees in this case should impact as an economic incentive to evaluate the possibilities of voluntary emission reduction investments particularly in this case NOx reduction technology. According to main regularities of economics, investments cannot be unprofitable. If the investments economical value is in the long run negative, it is not profitable to make the investment.

METHODS TO REDUCE NO_x EMISSIONS

Currently the only standalone technology available for achieving the Tier III standards for NOx reduction is selective catalytic reduction (SCR). Also using the liquefied natural gas (LNG) as fuel meets the Tier III requirements. However, retrofitting a LNG-system asks for radical changes and therefore the focus should be on the installation of LNG-systems on new vessels. As the investments for NOx reduction technology would be estimated to be conducted for vessels with the lowest investments cost and biggest discount, the vessels with frequent liner traffic in the Baltic Sea port would be the primary vessels to introduce NOx reduction technology if a Pan-Baltic system would be introduced. As the object of the system is to be income neutral for ports, this would mean that vessels with infrequent visits to the Baltic Sea ports would have to pay the increased basic fee. To determine the effect of the port fee discount for shipping companies, different scenarios were created. Concerning the income-neutral aspect for shipping companies, Figure 1 illustrates the relationship between granted discounts to the annual SCR retrofitting costs for the Baltic Sea fleet ship owners. Also the num-

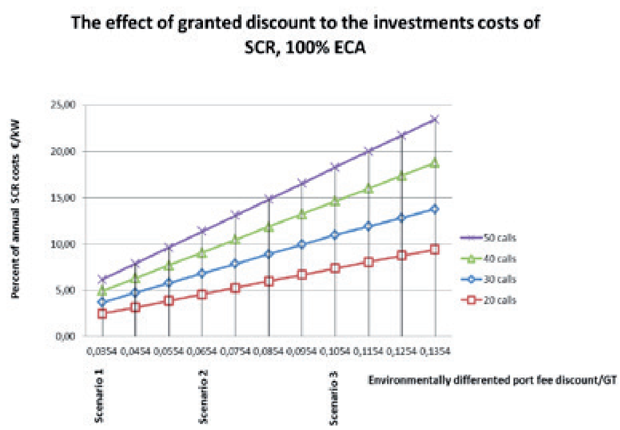

Figure 1: The effect of granted port fee discount to average annual SCR costs

ber of calls in the Baltic Sea port plays an important role in determining the rate of the incentive. The scenarios in Figure 1 present possible rates of discounts €/GT from port fees and their effects as an incentives for SCR investments.

POSSIBILITIES FOR AN INCOME-NEUTRAL SYSTEM

For ports the system could be designed as income-neutral. As a major of ports are public companies, ports pricing decisions are primary affected by the fact that on a long run the revenues must exceed the total costs. To get the average price to be income neutral regardless the volume of the traffic entitled to the discount, the rate of regular price must be raised. Table 2 presents an example port and a possible income-neutral pricing model with Scenario 1. The amount of granted discount in Scenario 1 is the actual discount granted for NOx below 1g/kWh in the Port of Stockholm.

An increase in price may cause customers to reject company or in this case port. In Swedish ports this is solved by the fact that all major ports in Sweden have introduced environmentally differentiated port fees so it does not create competitive disadvantage for a specific ports. In case of Pan-Baltic port fee system or worldwide system, this should be applicable also. As many ports are commercial operators, it is impossible to introduce a solid port fee system without giving port owners a large degree of flexibility to their pricing decisions.

Results indicate that in current levels environmentally differentiated port fees cannot function as an only incentive for investment to emission reduction technology as in this case to SCR. The port fees can function as an effective incentive to NOx reduction but the final investment decision in shipping companies is made with other criteria than merely on economic benefit. If the investment decision is made only with profitability considerations, with these Scenarios presented, no shipping company is willing to make the retrofitting investment to SCR. Sources will prefer to emission abatement as long as incomes from the given subsidy exceeds their abatement costs. Based on the results the Scenario 1 is too weak to have any added value. The Scenario 3 implemented at all Baltic Sea ports would, probably, become an important incentive, for ship owners to make investments in NOx-reduction technology, at least when ordering new ship buildings.

For a successful application of a market-based port fee system, it is essential that the given incentive reflects the market's perception of an accurate amount of discount. The investment decision is made with other criteria for example shipping companies' long term strategy concerning sustainability, governmental regulations or recommendation or the investment cost are to be paid by the customers in the final hand. The effects could be major but not efficient enough to lead into investment decision. As a conclusion, the system could be implemented to be income neutral for ports but concerning shipping companies a state compensation would be necessary. Governmental regulations or recommendation could function in this case as additional incentives to compensate the rest investment cost. The EU has also presented its opinion concerning the NOx fund in Commission Staff Working Paper by European Commission (2011): "The Commission services will explore ways

REGULAR PRICE	0.447 EUR/GT	0,4506 EUR/GT	0,4541 EUR/GT
VOLUME	90 %	80%	70 %
DISCOUNT PRICE	0,4116 EUR/GT	0,4152 EUR/GT	0,4187 EUR/GT
VOLUME	10%	20%	30%
AVERAGE PRICE	0,4435	0,4435	0,4435

Table 2 Calculation of prices with different volumes with Scenario 1

to encourage a bottom-up approach in encouraging the industry and public sector to set-up and manage a fund – similar to the Norwegian NOx Fund approach – by charging operators for emissions and then using the available funds for abatement technology, research etc."

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4.4 ELECTRICAL SHORE-TO-SHIP CONNECTION, BENEFITS AND BEST PRACTICES

AUTHORS: PIOTR TARNAPOWICZ AND TADEUSZ BORKOWSKI (MARITIME UNIVERSITY OF SZCZECIN)

BENEFITS OF ONSHORE ELECTRICITY FOR SHIPS

Environmentally harmful ship emissions of SOx, NOx, CO and PM pose a real danger, particularly in ports located in the neighborhood of populous urban agglomerations. Mobile-source, port-related emis-sions are generated by marine vessels and by land-based sources in ports. Marine emissions come pri-marily from diesel engines operating on oceangoing vessels, tugs, dredges, and other vessels operating within port area. Depending on the type and size of cargo ship, hotelling time can range from several hours to several days.

One of the efficient ways of limiting the negative impact of mooring ships on the environment is electric power supply from local electricity stations. Electrical shore-to-ship connection (also "shore-power" or "cold ironing") eliminates the need to run the auxiliary engines and significantly reduces air emissions associated with the burning of marine fuels at berth. In addition, when ships use shore power, they are significantly reducing emissions of greenhouse gases (GHG) which contribute to climate change.

The actual emissions from ships depend on the engine type and its technology, as well as the type of fuel that is being burned. The reduction of air pollution emissions will benefit the dock workers, people working on board and the neighboring communities. It should be noted that the use of shore-power does not completely eliminate ship emissions because steam generated by the on-board steam boiler is still needed for ship's operation at berth.

TECHNICAL SOLUTIONS FOR SHORE-TO-SHIP CONNECTIONS

While in port, ships use their engines to produce electricity for hotelling, unloading and loading activities. Shore electric power enables ships to turn off their auxiliary engines while berthed and connect to electric shore side power that uses specially designed equipment to supply the ship's electric receivers (e.g. lighting, air conditioning, communication equipment etc.). The electrical power is transmitted to the ship from a shore side transformer, via a cable management system. Once connected, the ship's auxiliary engines are switched off, simultaneously the corresponding amount of power is provided by the utility company to satisfy the ships' electricity demand.

Power infrastructure of port installation necessary for supplying the ships has to be designed in such a way so as to handle different ship types. It is complicated to the extent that all over the world ships are equipped with electrical networks of different ratings. Also, medium voltage (MV) in on-land power sup-plying grids vary across ports. Rated values of voltages within these grids are not as significant as voltage frequency. As for ship power

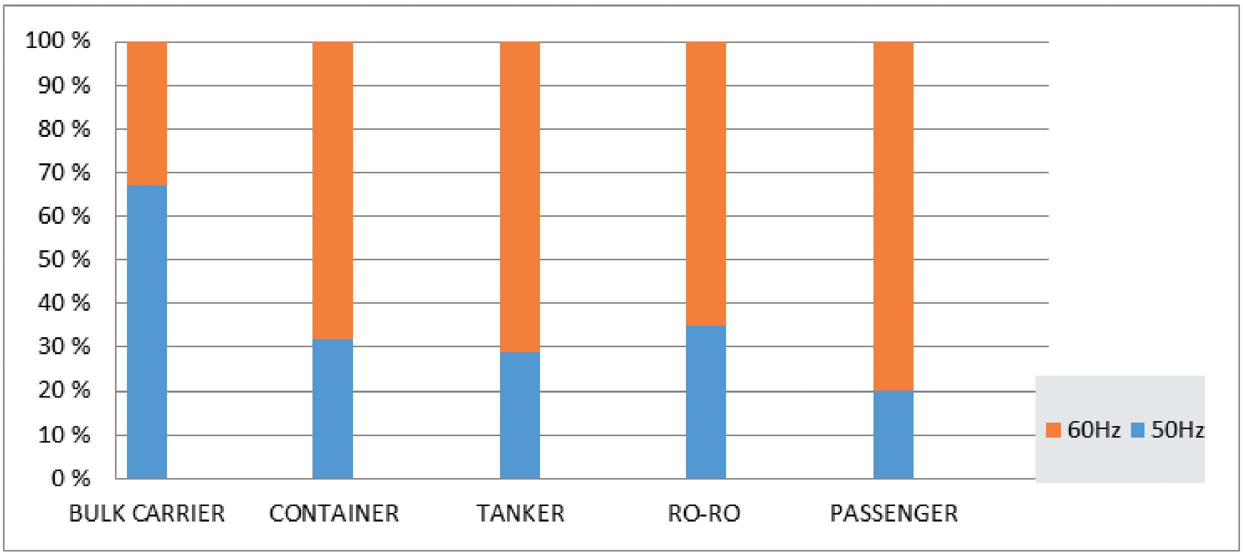


Figure 1. Ships electrical frequency system network

networks, both voltage and frequency are significant. Consequently, lack of standardization of voltage frequency and different values of low (U_{nom} < 1kV) and medium (1kV< U_{nom} <15kV) rated voltages, used on ships make shore-to-ship connection infrastructure a complex issue. The shore-side electric system and infrastructure requirements include an industrial substation to receive power transmitted from the local grid and a transformer to bring the voltage down, to be compatible with the ship's electrical network specifications.

Nominal parameters of voltages within ship net-

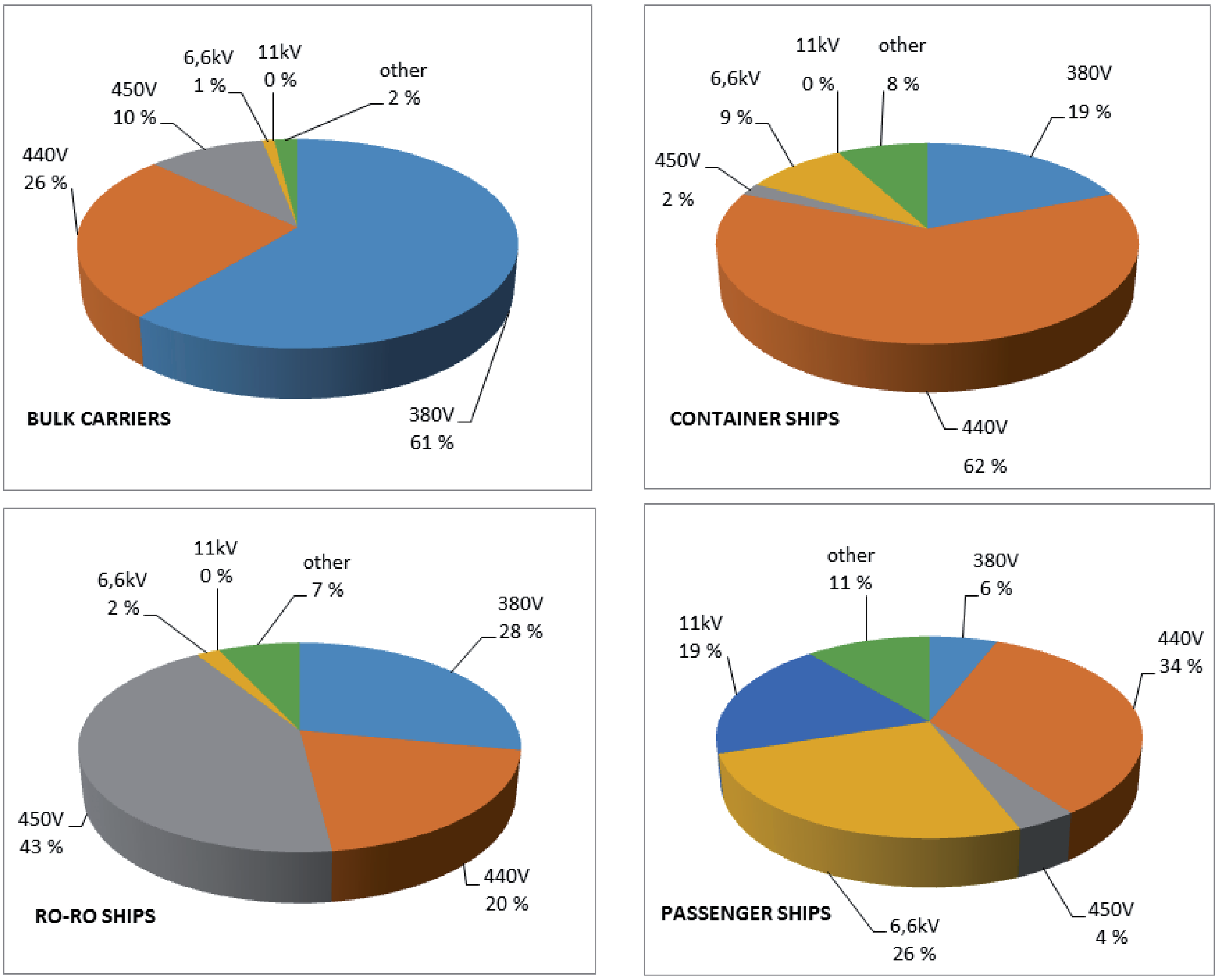


Figure 2. Ships electrical voltage network specification

Ship type	Average electric power demand at berth
Cruise ship	5 - 9 MW
Container carrier	1-6 MW
Tanker	5-7 MW
RO-RO	0.8 – 1.5 MW
Bulk carrier	0.3 – 1.0 MW
General cargo	0.5 – 1.2 MW

Table 1. Ships electric power requirements at berth

works differ with respect to the ship type, its size and flag state regional factors. Figure 1 presents a comparison of nominal frequencies within ship networks, while Figure 2 collates voltage levels. Voltage parameters differ with respect to the ship type and its size.

Historically, shore-power systems used low voltage shore-to-ship connections. Today, however, ships need more electric power and require high voltage supply when berthed. Table 1 summarizes average, predicted power requirements for different types of marine vessels at berth.

Therefore, high-voltage supply is considered as the most effective to connect ships to shore-side energy supplies. The benefits of high-voltage connection are clear: it reduces both shore-to-ship cabling needs and electric power losses. High-voltage connections make connecting ships to shore-side power supplies suitable. In addition, when ports are located near residential or industrial areas, high-voltage power is readily available - the case for ports in Europe.

There are two main shore-power system architectures:

1. without electric frequency conversion; i.e. 60 Hz to 60 Hz or 50 Hz to 50 Hz, connection can be low voltage (most often 440 V) or high voltage (6.6 kV and/or 11 kV) and several ships can be supplied at the same time by means of transformers.

2. with electric supply power frequency conversion where it should be dedicated to each individual shore-power system or centralized at terminal level. One or several ships can be connected to the high-voltage electric supply system using their transformers

Shore to ship connection has been implemented in Europe since 2000. Subsequently, EU recommenda-tions [EU 2006/339/EC] provided a proposed layout of the "Shore To Ship", presented in Figure 3.

A shore to ship system for ships at berth contains three elementary components:

A. Shore-side electrical infrastructure

B. Cable management system

C. Ship-side electrical system

A. A land-based electric power source, transmission system, and related infrastructure are required to provide electricity to ship terminals.

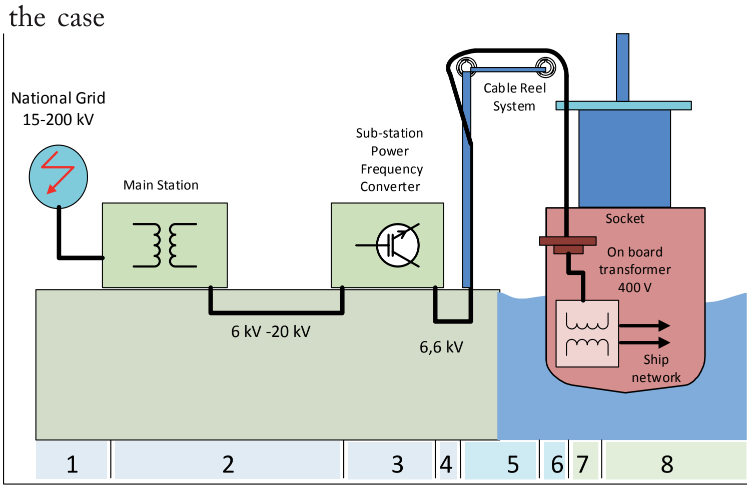


Figure 3. The electric supply system configuration according to EU 2006/339/EC recommendations

They consist of:

1. connection to the national network, transmitting electricity at a voltage of 1.5 - 100kV with local main station, where it is transformed into 6 – 20 kV level
2. connection cables to transmit power voltage 6 – 20 kV from the local main station to the port industrial substation
3. if necessary, the voltage frequency converter. Consequently, ships designed with electric network 60 Hz will need the processing power of 50 Hz to 60 Hz.

B. Cable management system to convey electricity to the ship.

4. cables for electricity transmission to the berth. Normally, installed underground inside existing or new cable channels
5. reel cable system
6. quick electrical connectors for easy handling and safety

C. Ship-side electrical system. An on-board shore-power system consists of:

7. receptacle panels
8. voltage switching board, circuit breakers, transformer, control and monitoring system.

The IEC/ISO/IEEE 80005-1 standard aims to facilitate cooperation between the shipping industry and port facilities, establish appropriate operating procedures, and encourage compliance with the standard, so that a number of ships can use high-voltage shore connection equipment at as many ports as possible. The standard guarantee simple, straightforward connection—eliminating the need for ships to make adaptations to their equipment at different ports. Currently, Classification Societies issued basic standards for on-board installation of electric shore connection certification and approval procedure of specific system design and type.

EXAMPLES AND EXPERIENCES IN THE USE OF SHORE-BASED ELECTRICITY IN EUROPE

Shore-power connections for ships have been in implementation in Europe since 2000. The port authori-ties recognized the need to protect the environment and a modern shore-power system has

Vessel type / Terminal	In service	Power, MVA	Frequency, Hz	Maker	Location	End-user
Ro-Ro & Ferry / Terminal 2	2001	1.25	50	ABB	Gothenburg	DFDS/Tor Line
Ro-Ro / Terminal 3	2004	1.2	50	ABB	Gothenburg	Stena Line
Container Terminal	2008	1.0	50/60	SAM	Antwerp	All
Ro-Ro / Terminal 3 Extension	2010	1.2	50	ABB	Gothenburg	Stena Line
Ferry Terminal	2010	2.5	50	ABB	Karlskrona	Stena Line
Ro-Pax / Ferry terminal I	2011	2.5	50	ABB	Trelleborg	Unity Lines, Stena Line
Ro-Ro & Ferry	2011	3.0	50/60	ABB	Gothenburg	Stena Line
Ferries / Ferry Terminal	2011	2.5	50	ABB	Oslo	Color Line
Ro-Ro & Container Terminal	2012	6.25	50/60	ABB	Ystad	All
Ro-Pax / Ferry terminal II	2012	2.5	50	ABB	Trelleborg	Unity Lines, Stena Line
Ro-Ro / Ro-Pax & Ferry Terminal	2012	6	60	ABB	Hoek van Holland	Stena Line

Table 2. Shore-to-ship existing installations

become a priority in many European ports. The early shore-power applications were mainly concentrated on RoRo and ferries. Shore power supply options for other types of ship such as containers, tankers and cruise ships are very rare and only available in a small number of locations. One key difference in shore-power among container, general cargo, cruise lines, RoRo ships and ferries is the power demand at dock for loading and unloading or operating other cargo. Each port has its unique operation, distribution of marine vessel types, and frequency of vessel calls. Furthermore, frequency of port calls by certain types of marine vessels provides an incentive for shipping lines to do business with these ports, since there is a direct relationship between overall cost-effectiveness of a shore-power program and the frequency of vessel calls. Therefore, the STS system can be individually tailored for a certain type of ship.

Without a doubt, the country in which the amount of STS installations in ports is the highest is Sweden. A consistent long-term policy in this field has resulted in numerous STS systems operating in Swedish ports, and particularly distinctive in this regard is port of Gothenburg. Currently, a large number of ferries and RoRo vessels, which are engaged in regular traffic in Europe, handle STS technology in this port. Port authority shore-power program aims to fully support all RoRo ships using the STS system by 2015. In addition, it is assumed that 40% percent of all calling ships will also benefit from the shore-power system. Table 2 shows examples of existing shore-power installations in ports. Shore-power systems particularly relevant are those which offer a choice of frequency (50/60Hz) and adopting standards.

PORT-RELATED COSTS

The major capital investment of shore-power is the shore electric power supply system. The shore-side electrical and infrastructure requirements include an industrial substation to receive power transmitted from the local grid. The required modifications to infrastructure are diverse due to distinctive layouts of ports. Primarily, this is due to variations in the distance to the nearest high voltage supply and transformer stations that require building or upgrading. Usually, supplementary costs may include overhead electricity lines or underground cables. The cost to bring electricity from a local grid to the wharf is in the range of € 1 million to € 8 million, depending on: shore-power system capability, port location, type of ships, power and energy demand

Port	Power, MVA	CAPEX, Million	Remarks
Gothenburg*	1.5	€ 1.7	RoRo Teminal (one berth) 30% of the vessels
Gothenburg*	9.2	€ 2.2	Container terminal (one berth) 30% of the vessels
Gothenburg*	7.2	€ 1.5	Tanker terminal (one berth) 30% of the vessels
Gothenburg*	6.4	€ 1.2	Tanker terminal (one berth) 30% of the vessels
Antwerp	1.0	€ 1.2	Container terminal
Oslo	2.5	€ 7.9	Passenger terminal
Ystad	6.25	€ 3.9	Ro-Ro, Ferry terminal
Rotterdam* Euromax	40	€ 28.5	Container terminals 20% of the vessels
Riga*	2.0	€ 5.7	Passenger Terminal (one berth)
ENTEC** Low-cost port	-	€ 1.2	One terminal (two berths)
ENTEC** High-cost port	-	€ 2.3	One terminal (two berths)

*Feasibility study, **Case study

Table 3. STS - estimated port investments costs

(i.e., voltage and frequency). Although actual capital cost is site-specific, the average estimate of the port and terminal arrangement modification is in the range of € 2 million to € 8 million per terminal. The main part is the cost of frequency converters and is roughly 75% of the total investment for all electrical gear. Table 3 outlines the estimates of total costs for shore-power infrastructure.

From an emission reduction perspective, shore-power is more expensive than conventional emission control equipment due to the high capital costs required for the shore-side and ship-side infrastructure improvements. Cost effectiveness is expressed in € per emitted mass unit and produced for Gothen-burg's condition as follows: NOx - € 10000 /Ton, SO2 - € 14000 /Ton and Particles - € 400000 /Ton.

SHIP-RELATED COSTS

Ships participating in shore-power electrification program will require the installation of shore-power as-sembly and an associated electrical management system. For ships already in service retrofitting of the current electric network system is necessary. Presently, for new builds the ship owner can request a shore-power system as part of the ship's electrical system design. Generally, shore-power is cost effec-tive with vessels that spent substantial time berthing. The frequent call vessels, often referred to as "fre-quent fliers", were identified to benefit the most from shore-power retrofitting. Costs for ship-side modifi-cation can range from € 200,000 to € 2 million depending on the application. However, an analysis of whether it is practical to connect specific ship to STS electricity entails numerous uncertainties.

CHAPTER 5: GENERAL RECOMMENDATIONS

5.1 CLEAN SHIPPING CURRENTS

AUTHOR: TAPANI STIPA (THE BALTIC INSTITUTE OF FINLAND)

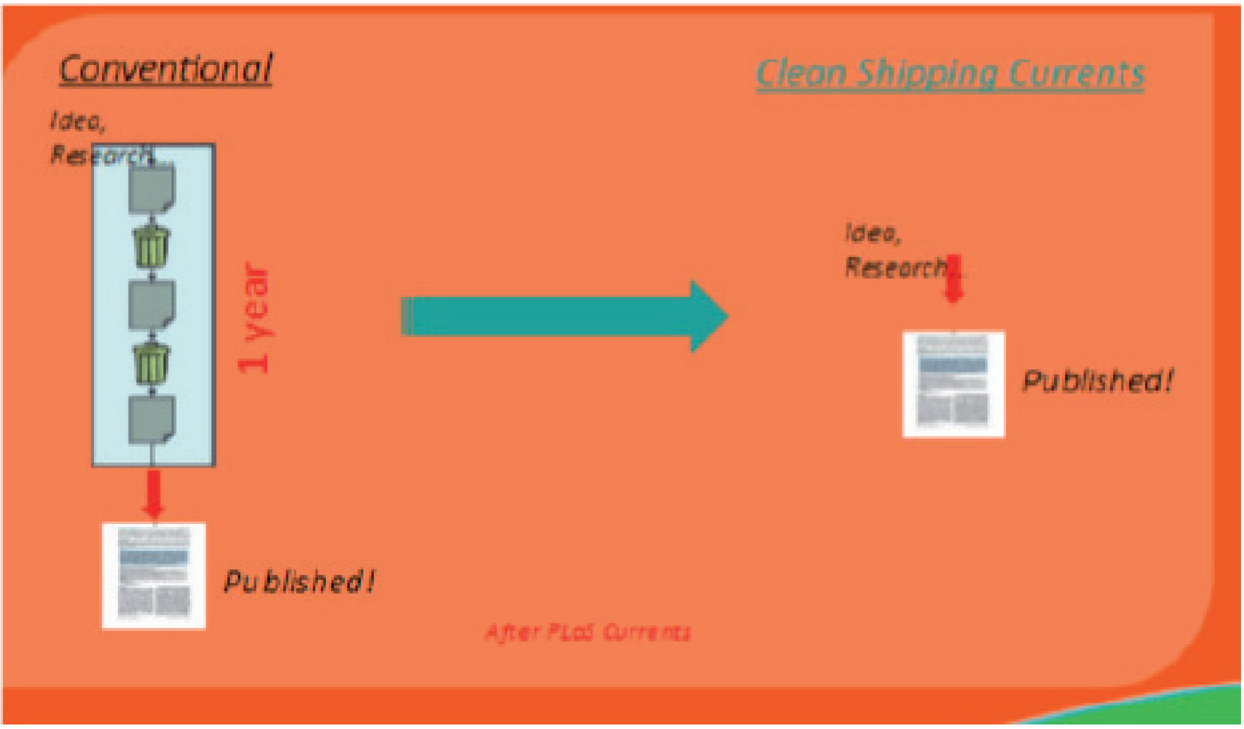
Information is a major building block for innovation. Transportation and communications are important means to exchange information and combine it in constructive new ways, resulting in innovation. Innovation, on the other hand, is at the heart of creative destruction, Schumpeter's gale.

Clean Shipping Currents is rapid dissemination platform for clean shipping related information (new technologies and solutions, research results). It facilitates the innovations needed to weather the gale resulting from the new emission regulations, in particular the sulphur limits entering into force on January 1, 2015 in the SECA areas. Although the forthcoming period of creative destruction is driven by regulations, innovation in technologies and business models is key to a successful transition to the new shipping regime.

Clean Shipping Currents takes the form of a serial publication. It is new and interactive platform for rapid public-private information sharing around the Baltic region. The platform acts as a compendium of knowledge receiving material from major scholarly institutions and the private sector in the Baltic region.

The content of Clean Shipping Currents is interactive. The partners who have subscribed have the possibility to individually share reports and information on the platform. Information is available to co-operators rapidly and is easy to access. The information on the platform is relevant and concise.

Most post categories are reviewed to ensure legitimate professionalism. The platform has emphasis on facts, results and data: Not much hypothesis is involved. Traditionally the review process is long and tedious; for Clean Shipping Currents, only the technical level of the post is reviewed, not its long-term relevance. The assessment of the long-term relevance is left to the market.



5.2 DEVELOPMENT OF THE "BALTIC SEA CLEAN MARITIME (BSCM) AWARD"

AUTHOR: HOLGER KRAMER (INSTITUTE OF SHIPPING ECONOMICS AND LOGISTICS)

BACKGROUND

The players in the maritime industry in the Baltic Sea – like all other actors in ports and shipping around the world - are facing the challenge to find sustainable solutions for avoiding or reducing emissions and negative impacts on the environment caused by shipping and port operations – while offering competitive and efficient transport services at the same time.

Against this background, the Baltic Sea Forum (BSF) has launched in cooperation with the EU project InnoShip and the Institute of Shipping Economics and Logistics (ISL) the "Baltic Sea Clean Maritime (BSCM) Award". The Baltic Sea Forum e.V. was founded in 1992 and has a wide network of members from business, politics and administration. The Baltic Sea Forum is a private non-governmental organization (NGO) and works closely together with intergovernmental and national, regional and local institutions to support the economical, political and cultural cooperation and integration among the Baltic Sea countries.

OBJECTIVE

The aims of the project BSR InnoShip project characterizes the contents of the award and is essentially based on the objectives of the Helsinki Commission. Accordingly, the award aims to promote approaches and ideas that meet the following criteria:

- reduce and prevent emissions caused by shipping and port operations in the Baltic Sea Region,
- reconcile the different interests and needs with-

in the Baltic maritime sector in order to foster a more environmental-friendly maritime sector,

- coordinate efforts to make the Baltic Sea a model area for clean and competitive shipping in Europe,
- contributing to a coherent maritime spatial planning covering the different activities in the maritime sector.

The award is presented now for the first time in 2013 and will be awarded in the future on an annual basis. All proposals meeting the criteria above in matters of innovation, qualification, coordination and implementation of technical skills are welcome.

PARTICIPATION AND SELECTION CRITERIA

Crucial criteria for participation is the project must correspond to the aims of reducing and preventing emissions caused by shipping and port operations in the Baltic Sea region. It is the clear aim of the award that mature projects as well as innovative ideas contributing to the objectives shall be promoted.

Selection of the best among the projects which meet the participation criteria will be based on:

- original and innovative character of the project,
- considering other relevant actors from the maritime sector,
- stage of development, feasibility and time schedule,
- description of impacts to the objective of the award,
- presentation and documentation.

JURY

The selection will be carried out by an independent jury of experts. The jury consists of seven independent members who are from different regions of the Baltic Sea, representing organizations as well as economic and public institutions.

DESCRIPTION OF THE AWARD

The award has a symbolic character, i.e. it is a non-financial award.

AWARD CEREMONY

The first BSCM Award will be officially handed out during at the final conference of the BSR InnoShip project on 10th of September 2013 in Brussels.

5.3 COMMUNICATION AMONG MARITIME STAKEHOLDERS – PROBLEMS AND SOLUTIONS IN THE FIELD OF SHIPS' AIR EMISSIONS

AUTHORS: BJÖRN HASSLER, ERIKA LOCKNE, MICHAEL GILEK AND ANNA MARIA JÖNSSON
(SÖDERTÖRN UNIVERSITY)

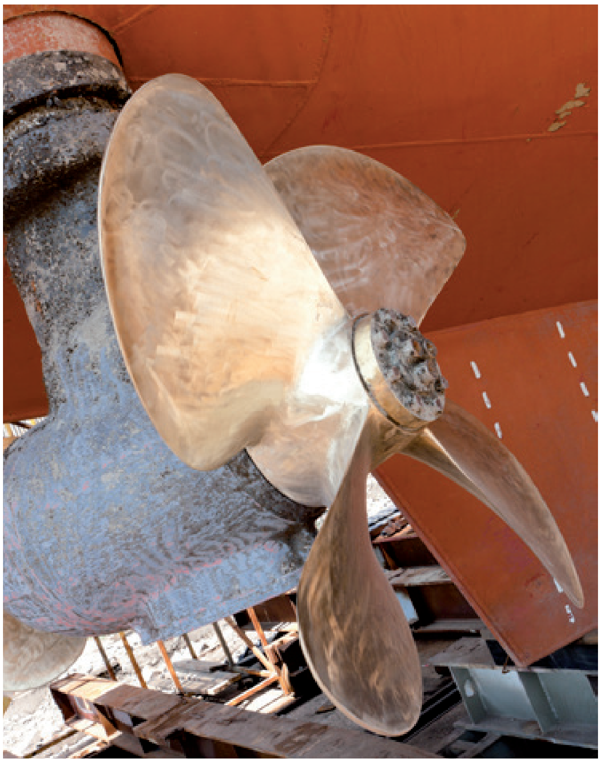
INTRODUCTION

Reduced air pollution from marine transportations is an area where international collaboration is pivotal, not only among governments and national authorities in established organizations such as the IMO (International Maritime Organization) and the EU, but as importantly among stakeholders in shipping companies, ports, sector organizations, research organizations and NGOs. If the work with the reduction of air pollution is to be successful, and without threatening sector competiveness, well functioning and effective communication among stakeholders is decisive. In this chapter we discuss communication efficiency among maritime stakeholders based on data from a web survey carried out in 2012. This survey was distributed to stakeholders that are, or have been, working with issues related to air pollution from marine transportation; researchers, public authorities, private and public ports, shipping associations, operators, construction companies, ferry lines, NGOs etc. The results show that various forms of hindrances exist in communicative processes. We label these hindrances communication barriers. In order to promote the technological state of the art in areas such as exhaust gas cleaning and alternative fuels it is important to better understand these barriers.

Possible obstacles to effective communication can be divided into several different categories that are more or less connected to each other. Some are related to processes of information exchange and are connected with ineffective networking and inadequate interactivity among relevant stakeholders. Others concern the character and content of available information.

NETWORKING AND COMMUNICATION AMONG MARITIME STAKEHOLDERS IN THE BALTIC SEA REGION

Communication efficiency is highly dependent on well functioning processes, platforms for information exchange and networks. The opposite, lack of networks or limited opportunities to come into contact with others, may constitute a barrier. Thus, communication efficiency is dependent on the qualities of interactive processes, how these are organized, how people involved communicate with each other and how they experience their legitimacy to do so (Johansson 2008: 246; Warg 2000: 50-51).



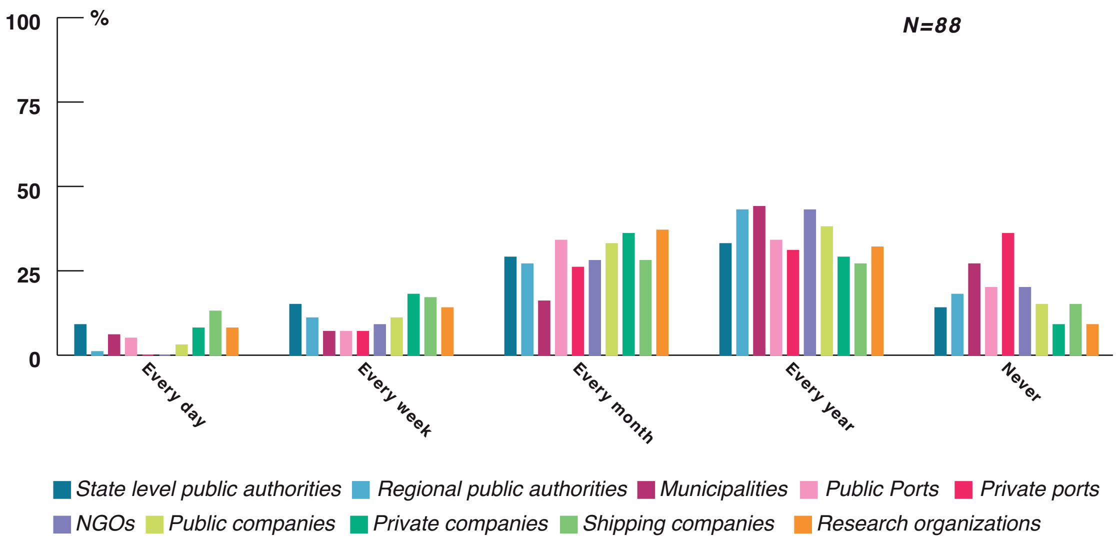


Figure 1. Expressed intensity in interactions with other stakeholders among different groups of actors.

We have investigated with whom various stakeholders communicate, within as well as outside of their organization, which networks they take part in, and how they experience their own communication space. The results show that the networking taking place among different stakeholders on how to decrease air emissions from shipping in at least some areas seems to be somewhat less developed than what could have been expected. Consequently, there is a demand among stakeholders for increased participation by, and contacts with, other actors. The respondents were asked how often they are in contact with other stakeholders and to what extent it is important to improve contacts with them. We also asked about how often the respondents were in contact with key intergovernmental organizations, such as HELCOM and IMO. The results indicate a rather limited interaction among the stakeholders. Among most stakeholders, these contacts with others take place only monthly or annually (Figure 1). Contacts with organizations (e.g. HELCOM and IMO) seem to be even less frequent. About 50 percent or more of the respondents are never in contact with them (Figure 2). At the same time a majority of the respondents expressed a need for extended and improved contacts with these organizations.

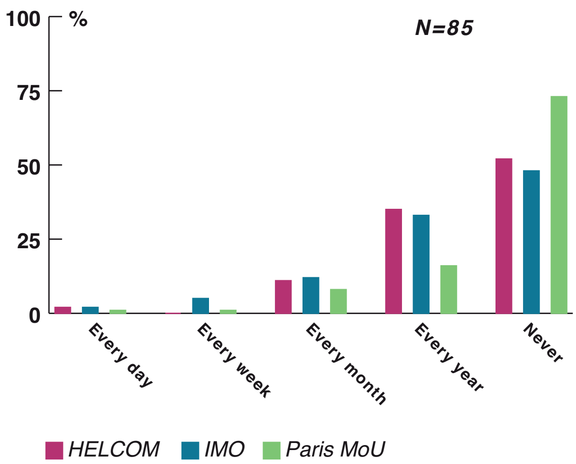


Figure 2. Expressed intensity in interactions with key maritime intergovernmental organizations among different stakeholder groups.

THE IMPORTANCE OF IMPROVED NETWORKS

Exchange of information on technical and procedural issues plays a central role in the management of environmental issues throughout the entire process; from the time a question is first raised, through decision-making and implementation processes and to evaluations of results (Renn 2008: 202). If large groups of stakeholders experience problems in networking with others, it is important to improve communication processes. Furthermore, for joint action, especially at the international level, to be perceived as legitimate it is important that key stakeholders and the views they represent are included in regulatory processes.

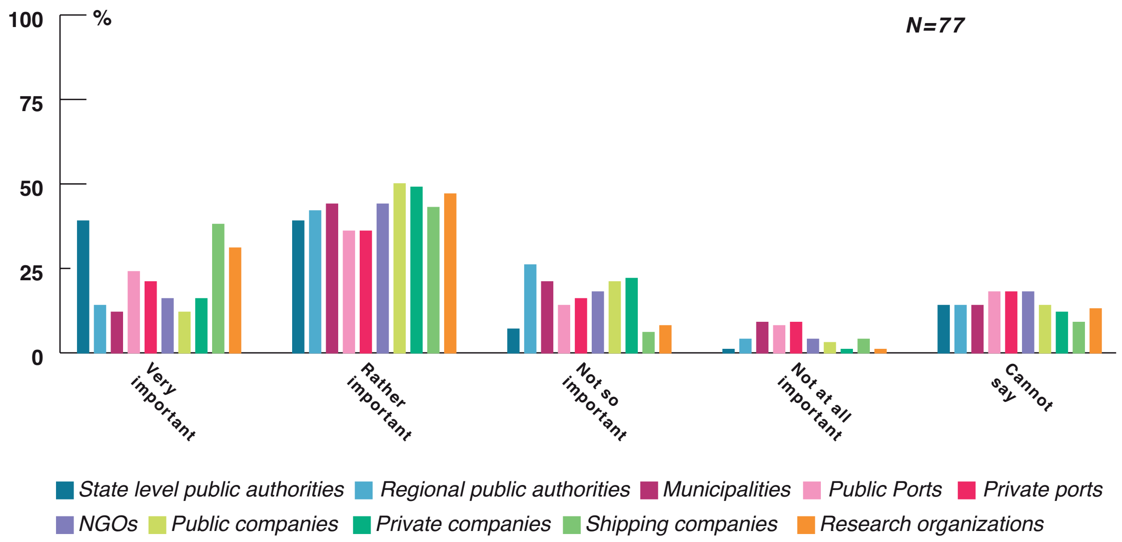


Figure 3. Expressed importance of extended collaboration with authorities, NGOs, research organizations, ports and companies

Our survey shows that stakeholders generally are positive to key international agreements and other measures to reduce air emissions (e.g. uniform economic incentives to stimulate sustainable praxis and collaboration on technological R&D) (Figure 3). But for those measures to be effective, well-functioning communicative processes are required. Therefore, it may be necessary that the intergovernmental actors, who have overall responsibility for international agreements and goals such as IMO, EU and HELCOM, increase their efforts in stimulating networking among key stakeholder groups.

KNOWLEDGE AND LANGUAGE BARRIERS

Common ground and starting points among individuals or groups are crucial for effective communication. The more dissimilar backgrounds stakeholders have and if they are starting off from different points of departure, obstacles and barriers can easily evolve that threaten communication efficiency (Johansson, 2008, pp. 245-247; Renn, 2008, pp. 244-247). This is the case when, for example, problems and questions are described in ways that are not easily accessible to relevant stakeholders.

The most obvious example of this is language barriers. In the questionnaire we asked whether information only available in English is problematic for the respondent. Approximately twelve percent of the respondents stated this to be a problem most of the time. This small group is comprised primarily of respondents that have categorized themselves as "others", that is, they are neither researchers, nor administrators or coordinators. In many cases, this group of stakeholders works with practical issues related to the maritime sector. On the other hand, a much larger group – 51 percent, comprising, for example, scientists – expressed that English as the working language never is a problem. In other words, there seems to be a need not to always and under all circumstances use English as the working language, although this in under most circumstances adequate. To improve communication efficiency, resources spent on translation of selected texts targeting groups of practitioners into national languages may be well-spent money from a communication effectiveness point of view.

We also asked the respondents whether they perceived the information they found to be too technical, too specific, too broad or not relevant for their purposes (Figure 4). Our main objective was here to find out if the information is perceived as satisfactory, accessible and usable by the stakeholders, considering their own perspectives, interests

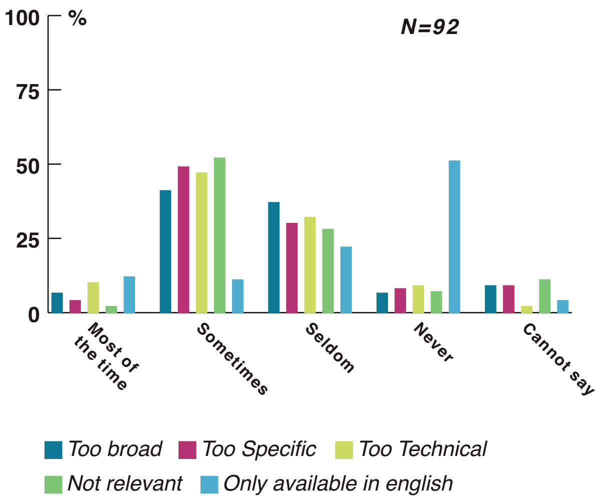


Figure 4. Stakeholders' views on how problematic it is that available information is too broad, too specific, too technical, not relevant or only available in English.

and views. Based on the stakeholders' responses, a possible barrier to effective communication was indicated. Almost 50 percent of the respondents thought that the information, at least sometimes, is too technical and ten percent were of the opinion that this was the case most of the time. In contrast, only nine percent of the stakeholders never experienced this to be a problem.

Based on these results a need for more accessible information concerning emissions, that does not require extraordinary technical competence to be understood, seems to be warranted. At the same time it is important to keep in mind that many stakeholders need precise scientific information, and that information that is too elementary could be just as problematic as if it is too technical. A clear diversification of information where different types of stakeholders more easily could find the type of information they are looking for could be an important way to address this issue.

THE INFORMATION FLOW – PROBLEMS WITH DELIMITATIONS

To ensure efficiency, communicated information preferably should be on a technical and conceptual level that corresponds to the recipients' needs, knowledge and competence. Especially when matters communicated are based on large amounts of complex information, the informant needs to sort and highlight what is essential for the receiver to understand (Falkheimer and Heide, 2007, p 81). So-called knowledge brokers could here play significant roles as conveyors of knowledge among stakeholders, not only between science and sector organizations, but also among stakeholders at large. The information communicated needs to relate recipient interests in order to induce them to "tune in" (Andrésen et al. 2000).

The survey results show that the stakeholders to a quite significant extent experience problems of finding the type of information they are looking for. Six percent states that the information is too broad most of the time and 41 percent that it is so sometimes. Problems related to information perceived to be too specific for the recipient needs seem to constitute an additional barrier: Four percent respond that this is the case most of the time, 49 percent sometimes and only eight percent of the respondents state that this never is a problem. This may indicate a barrier related to delimitation of available information. Additionally, more than half of the respondents, state that they, at least now and then, do not find the kind of information they need in a reasonable amount of time. About every second responder is of the opinion that he or she only sometimes finds information in a reasonable amount of time, while seven percent state that they only seldom do so. This seems to indicate problems with delimitation in the sense that it is sometimes problematic to structure the information flow in efficient ways, and possible barriers related to how different stakeholders find information at adequate levels of specificity and detail that fit their specific needs.

CONCLUSIONS

Due to the increased interest showed in marine pollution in recent years, intense intergovernmental cooperation as well as adoption of stricter rules on emission control, have emerged. However, for these regulations to become effective and efficient tools for Clean Shipping, while at the same time not threatening sector competiveness, they need to be perceived as legitimate among key groups of stakeholders. To achieve this high degree of legitimacy and to stimulate technological innovation, effective communication and as few barriers as possible are required. Effective stakeholder participation and communication is dependent on how they experience the problem of air emissions in relation to their own interests, needs and perceived role in the context of marine transportation.

We have found that, whereas information as such in most cases is available, its format is often not adequately adapted to the needs of the recipients. The information obtained by stakeholders is, for example, often perceived to be too technical, too specific or too general. This seems to point in the direction that the available information on air pollution from shipping needs to be more adequately structured. The information sought typically exists, but is often not effectively available. Therefore, hubs of knowledge with different entrances for different stakeholder categories, or other ways to sort the available information, seem to be called for. Related to this issue, many stakeholders ask for more proactive involvement by key intergovernmental bodies such as IMO and HELCOM, but also by various sector organizations. It might be possible for these important hubs of knowledge to, even more actively than today, act as knowledge brokers in this area, aiming at providing as many stakeholders with as adequate information as possible and in formats adapted to their specific needs. Various forms of projects funded by private or public sources targeting these needs could be important ways to improve efficiency in the maritime sector while at the same time promoting Clean Shipping.

Improvements of communication, both in terms of extended opportunities for networking and content of accessed information on Clean Shipping, are clearly requested by the stakeholders. Our results could be used to identify and tailor tools for improving communication linked to environmental problems in the Baltic Sea region. They could also be used to increase the general awareness of the key importance of communication and information in reducing air emissions from marine transportations.

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5.4 CONSIDERING COMPETITIVE LOGISTICS COSTS WHEN EVALUATING LOW EMISSION SOLUTIONS FOR BALTIC SHIPPING

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1. In the process of preparing decisions on environmental regulations for Baltic shipping it is not sufficient, to compare benefits in the field of human health and environment with costs in the field of shipping. Instead two more factors have to be taken into account:

- Competition between sea-based and land-based logistics costs,
- Importance of maritime transport for exporting and importing industries and their locations in the Baltic Sea Region.

That has not be done, for instance, in the study "Cost-Benefit Analysis to Support the Impact Assess-ment/accompanying the revision of Directive 1999/32/E4 on the Sulphur Content of certain Liquid Fuels" commissioned by the European Commission and prepared by AEA et.al. (2009). The study analyzed benefits and costs for Baltic Sea, North Sea, Mediterranean and Black Sea as Emission Control Areas with regard to SOx and NOx. The calculated benefits stem from improvements in the field of human health. On the cost side higher prices for 0,1%-fuel respectively for exhaust gas cleaning technologies were considered. Neither negative consequences for exporting and importing industries nor possible shifts towards road transport were taken into account. Both aspects were not even mentioned, so that the costs of the discussed regulations were not fully considered.

In the study report "Baltic NEA – economic impacts" conducted by University of Turku/Centre for Mari-time Studies on behalf of HELCOM in 2010 – to take another example – unintentional

traffic shift has been mentioned, but not consequences for exporting and importing industries. Only by including also these two aspects, a comprehensive assessment will be reached.

2. For geographical reasons Baltic maritime transport is competing with other transport modes. That is particularly true for routes between Western and Eastern Europe. In 2012, for instance, exports of high-value goods from Germany, France, Netherlands, Belgium, Luxemburg, Spain and Portugal to Russia and Kazakhstan were transported by road (62 per cent) and sea (33 per cent), only 4 per cent by rail (EUROSTAT data). Cost increases for sea transport, for instance because of stricter environmental regulations for ships, could result in even higher shares of road transport, meaning additional burdens for roads and possibly increasing the emission of CO_2.

Although for exports and imports of Sweden and Finland sea routes are used for 90 per cent of transport, also in these cases maritime transport can be switched to land (road) transport, in order to avoid higher shipping costs; the same is true for Denmark, Poland and the Baltic republics. For the SOx-Emission Control Area Baltic Sea it has been shown, that the expected price increase for 0,1 %-fuel in shipping will result in modal shift towards other transport modes (especially towards road traffic) and to changes of routes.[1] On the one hand expected modal shifts may replace combined sea-land alternatives by truck-only transports. On the other hand transport alternatives with longer sea-legs may be replaced by alternatives with shorter sea-legs and longer land-legs.

The conclusion reached in the BSR InnoShip project is therefore, that in cost-benefit-analysis assessing environmental regulations for Baltic shipping the consequences for possibly modal shifts in transport and their impact on emissions have to be taken into account.

3. Maritime transport is essential for all Baltic Sea countries, as substantial shares of their foreign trade are channeled through Baltic Sea ports, although – because of the specific geographic situation – this share is different in each of the countries. In terms of volume sea transport it is even the decisive transport mode for Sweden and Finland and the most important for Denmark and Russia. Poland has, due to its geographic situation, a maritime share of less than 30 per cent. An exception among the BSR countries is Germany with a considerably lower importance of Baltic Sea shipping. For Estonia, Latvia and Lithuania the relevance of maritime transport consist not only in its role as means of transport for foreign trade goods, but also in the considerable income generated by handling transit cargoes for Russia and other CIS countries.

Increasing costs of sea transport, therefore, will weaken the competitiveness of exporting and importing industries of Baltic Sea countries, as it was mentioned in Swedish and Finnish studies.[2] In certain cases that can result in a shift of location of those industries towards other parts of Europe or towards other continents.

The consequence reached in the BSR InnoShip project is therefore, that in future cost-benefit analysis assessing environmental regulations for Baltic Sea shipping the economic consequences for exporting and importing industries and for their locations have to be taken into account.

[1] See for instance: Analysis of the Consequences of Low Sulphur Fuel Requirements, European Community Shipowners' Association, Report drafted by Prof. Dr. Theo Nottebom, University of Antwerp and Dr. Eg Delhaye, Kris Vanherle, Transport & Mobility Leuven, 29 January 2010
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5.5 CHOOSING A GREEN SHIPPING CAREER FOR A CLEANER BALTIC SEA - BEST PRACTICES IN THE FIELD OF YOUTH WORK

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Recently the Baltic Sea shipping has faced a new challenge – labour shortage. Majority of the experienced professionals working on the field are on the edge of retirement and the shipping professions no longer seem to interest the youngsters. Shipping is already known as one of the most environmentally friendly ways of transportation and the shipping industry is working hard to further minimize the harmful effects of maritime transport. This could be an issue attracting the young generation and increasing their interest for choosing a shipping profession.

BSR InnoShip partners have actively been working among promoting of the international career opportunities around the area via local youth associations. The actions have included environmental education for younger children and introducing the environmental aspects concerning shipping careers for youngsters who are already thinking of their education possibilities for the future.

EXAMPLES OF THE ACTIONS OF THE LOCAL ORGANISATIONS

Youth organisations involved in the BSR InnoShip promotion work are:

- Sail Training Association Finland
- Polish Sea and River League, Poland
- The Association for Promotion of Danish Shipping, Denmark
- Juodkrante Liudvikas Reza Sea Cadet School, Lithuania
- Environmental Education centre for Children and Youth "Riga School of Natural Sciences", Latvia

In order to raise awareness and interest of the young generation youth associations dealing with Baltic marine environmental protection can be a successful instrument. In the BSR Innoship project such an association was established by the **Polish Register of Shipping** in cooperation with the Polish Sea and River League. The main output was an art contest in December 2011 entitled "Stop global warming of the Baltic Sea" for schools which are members of several Sea and River League school circles. In the beginning of the following year about a hundred children's art works were collected for an exhibition.

Teenagers building Lego ships at Tall Ships' Races 2013 in Arhus

That schools can also be very active in this field is proven by **Juodkrante Liudvikas Reza Sea Cadet School in Lithuania**, which works with the basic marine education for students whose age group is between 11 and 16. The meaning is to provide opportunities to develop life skills within the context of naval traditions, receive training in nautical and maritime subject and gain experience and knowledge related to shipping and navigation. As a start for a fruitful cooperation with the project an international youth seminar about ship emissions was arranged in July 2013.

It is of utmost importance to create interest among young people for a concrete career in shipping. In this field **the Association for Promotion of Danish Shipping** is spreading knowledge of the maritime sector amongst young people, their parents, teachers and advisers in different ways, for example:

School presentations and lectures at Danish Elementary Schools and High Schools about Danish shipping, the industry's naval officer educations as well as other maritime education possibilities.

Close contact with the nation's youth and guidance teachers.

Participation in education exhibitions and fairs, maritime events and by usage of the very beautiful wooden vessel, the Trainee Ship "Danmark" for practical work experience.

Publication of the magazine "Seapress", which is a source of information to the daily press, TV and radio as well as knowledge sharing in the maritime industry.

Logbook on the Association's homepage, which main purpose is to inform about the life in the Danish merchant navy. Thereby the information source is ensured for the young students at the nation's schools for projects and theme weeks about activities within the merchant navy and affiliated industries.

COMMON ACTIONS DURING THE TALL SHIPS' RACES 2013

A joint agreement and letter of cooperation on promoting measures to reduce pollution from shipping in the Baltic Sea by awareness rising in connection with the Tall Ships' Races 2013 was prepared and signed in April 2013, young students and educational institutions as the main target group. The aim of the Tall Ships' Races is to provide youngsters from across the whole of Europe an opportunity to compete in a friendly and informative race, where both skills and close cooperation amongst the crew are rewarded.

The Tall Ships Races started from Arhus on 4 July and end in Szczecin on 6 August, visiting the cities of Helsinki and Riga in between. All cities are homes of BSR InnoShip partners and different activities attracting the youth were organized by the project in the host cities. Taking advantage of this relevant maritime event promoting both maritime job opportunities and the vision of a cleaner Baltic Sea, proved to be a successful as well an efficient way to create awareness of the environmental challenges.

In Arhus the BSR InnoShip stand had a special high level guest, the Danish Minister of Science, Innovation and Higher Education, Mr. Morten Østergaard. He spoke about the possibilities, which a maritime career offers. "A maritime career is an international career," Morten Østergaard said. The Minister further expressed his support for increased co-operation in the internationalization of maritime career paths at all age levels.

This manual provides a collection of best practices in addressing the tightening exhaust emission regulations for ships. The manual is intended to serve as a high-level guidance for local and national authorities, ship-owners and logistics managers to prepare for the future shipping market, in particular in European emission control areas.

The manual is a main output of the Baltic Sea Region Programme project "BSR InnoShip – Baltic Sea cooperation for reducing ship and port emissions through knowledge and innovation based competitiveness", which was implemented in 2011-2013. This project was carried out by 20 partners from all Baltic Sea countries including Norway and Russia.

BSR InnoShip

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