Interreg
Baltic Sea Region

EUROPEAN UNION
EUROPEAN REGIONAL DEVELOPMENT FUND

EnviSuM

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Report from Learning Café on Sulfur Emission Control Areas (SECA)

Compliance monitoring, technical performance of abatement technologies, health, environment and socio economic effects of SECA

Table of content:

1. Introduction

This report presents the results from the learning café, which was held the 26th of October 2016 in Copenhagen during the Danish Maritime Days 2016.

The EnviSuM project is funded by the European Regional Development Fund and aims at:

1. Studying technical efficiency and social-economic impacts of clean shipping solutions.
2. Provide policy makers and authorities with tools and recommendations for development of future environmental regulations.
3. Guidance to support future investment decisions for the shipping sector.
4. Measurement and modeling strategies to assess present and future cost, the health and environmental effects of ship emissions.

You can find more information about the project here: http://mdc.center/envisum/

The learning café was a stakeholder forum for the maritime industry aimed at discussing what the new business opportunities in SECA are, how we monitor compliance, the pros and cons of different technical abatement technologies, as well as the health and environmental effects.

During the learning café the participants were asked to join one of four thematic discussion tables on the following topics:

Table 1: New business opportunities related to sulfur reductions

Requirements on sulfur reduction are perceived as the most expensive regulation ever passed by the IMO and comes with high costs for the shipping industry, especially when a global cap will enter into force in 2020-2025. On the other hand, it also provides the possibility for developing and testing new abatement technologies in the Baltic and North Seas, and exporting these to the rest of the world later on, when the global sulfur cap enters into force in 2020.

Table 2 Technical performance of different abatement technologies

Ship owners and producers of maritime equipment have developed various technologies to comply with SECA such as LNG, dry and wet scrubbers, methanol as well as low-sulfur bunker oils. But what is technical performance of different abatement technologies?

Table 3: SOx compliance monitoring

After the 0.1% sulfur limit in SECAs entered into force in 2015, developing an efficient c compliance monitoring system of air emissions has become a cornerstone in order to secure a leveled playing filed for the maritime industry. However, there are many technical, economic and regulative issues that need to be solved.

Table 4 Health and environment – socio economic effects of SECA

The main purpose of SECA regulation is to improve the human health by improving air quality.

Especially cardio-vascular diseases are supposed to decrease due to lower number of harmful particulates. The effects to natural environment are not expected to be so pronounced. Do you think it is worthwhile to study such effects after the regulation? And how?

Prior to the round table discussions, one presentation on each topic was given. The four presentations are available in the annexes of this report.

2. Participants:

The target group of the learning café are producers and vendors of maritime equipment and services, ship-owners, authorities, researchers as well as maritime organisations. The following persons attended the EnviSuM learning café:

Fornavn	**Efternavn**	**Company**
Adam	Kristensson	Lund University, Department of Physics
Aditya	Srivastava	WORLD MARITIME INSTITUTE, MALMO
Anders	Jensen	PureteQ A/S
Andrean	Rashkov	MAN Diesel & Turbo
Andreas G.	Jørgensen	TORM
Bo	Lund-Frank	FORCE Technology
Britta	Schulz	Student Jade-Hochschule Elsfelth
Charles	Hansard	Biofriendly Corporation
Christian	Wenske	Baltic Marine Consult Rostock
Christian	Blaesbjerg	GEA Westfalia Separator
Christian	Kämmerer	Lloyd's Register EMEA
Christian	Koch	Shipping
Christian	Hendriksen	Copenhagen Business School
Eunice	Olaniyi	Tallinn University of technology
George	Panagakos	DTU Management Engineering
Gunnar	Prause	Tallinn University of Technology, Estonia
Harilaos	Psaraftis	DTU
Hung	Nguyen	Environmental Admininistration in Gothenburg
Ian	Millen	Dryad Maritime
Jan	Boyesen	Maritime Development Center of Europe
Jan Eiof	Jonson	The Norwegian Meteorological Inst.
Jari	Walden	Finnish Meteorological Institute
Jaroslaw	Myskow	Maritime University of Szczecin
Jeevan	Bhatt	Maersk maritime Technology
Johan	Mellqvist	Chalmers University of technology
Johanna	Yliskylä-Peuralahti	Brahea Centre at the University of Turku/Centre for Maritime Studies
Jon	Knudsen	Explicit
Karol	Wieczorek	Cryogas M&T Poland S.A.
Line	Reinhardt	The Technical University of Denmark
Lone	Thomsen	Danish Transport Innovation Network (TINV)

Maurice	Meehan	BSR
Michael	Gauss	Norwegian Meteorological Institute
Mikkel	Lenskjold	Student, Copenhagen Business School
Minna	Alhosalo	University of Turku, Centre for Maritime Studies
Mårten	Spanne	Malmö stad
Niels	Prip	Alpha Ship Design
Peter	Krog-Meyer	Danish Maritime Authority
Sara Libera	Zanetti	Malmö Hogskola
Sari	Repka	University of Turku
Simon	Letout	Maersk Group
Solbjørg	Apeland	StormGeo
Stefanos	Karakelles	Intertanko
Søren	Skive	Lloyd's Register EMEA
Tadeusz	Borkowski	Maritime Univerity of Szczecin
Tuomas	Pohjola	University of Turku
Ulla Bjørndal	Møller	A2SEA A/S
Mads	Møller Jensen	AMS
Jeppe	Elgaard Jensen	AMS

3. Program:

The program of for the learning café was as follows:

A. **Welcome and introduction to the Learning Café** by Jan Boyesen, Maritime Development Center

B. **SECA: Business opportunities – Performance of exhaust gas cleaning – Compliance monitoring – Health & environment effects**

Presentation 1: New business opportunities related to Sulphur reduction by prof. Gunnar Klaus Prause, Tallinn University of Technology
Presentation 2: Technical performance of marine Exhaust Gas Cleaning Systems by prof. Tadeusz Borkowski, Maritime University of Szczecin
Presentation 3: Sox compliance monitoring by prof. Johan Mellqvist, Chalmers University of Technology & Adam Kristensson Lund Univerity
Presentation 4: Health and environment: the socio economic effects of SECA , Sari Repka, University of Turku

C. **Learning Café - Facilitated discussions in thematic tables:**

i. Table 1: New business opportunities related to Sulphur
ii. Table 2: Technical performance of different abatement technologies
iii. Table 3: Sox compliance monitoring
iv. Table 4: Health and environment - socio economic effects of SECA

D. **Wrap up, joint discussion and future steps** by Jan Boyesen, Maritime Development Center

4. Results from table discussions:

In the following the results from the three table discussions are presented. It was originally planned that there should have been four tables. During the learning café each participant could choose freely what table discussion to join. However, there were only few people who went to table one which focused on new business opportunities related to sulfur reductions. It was therefore decided to shut the table 1 down and take the subject up at another time.

Technical performance of abatement technologies - results from table 2

Participants: Tadeusz Borkowski, Maritime University of Szczecin **(chairman of the table)**
Charles Hansard, Biofriendly Corporation
Anders Jensen, PureteQ A/S
Andreas G. Jørgensen, TORM
Bo Lund-Frank, FORCE Technology
Maels Jensen, AAMS/ Marine and technical engineering
Jeppe Jensen, AAMS/Marine and technical engineering
Christian Koch, shipping professional
Jaroslaw Myskow, Maritime University of Szczecin
Niels Prip, Alpha Ship Design
Johanna Yliskylä-Peuralahti, University of Turku/Centre for Maritime Studies
(rapporteur of the group)

These four questions were discussed:

1. *Is there a perspective for combined exhaust gas treatment to handle NOx, SOx and PM emissions?*
2. *What are the main technical challenges of the IMO ship emissions and energy reduction programmes?*
3. *How are marine propulsions development driven by the environmental legislation?*
4. *What is the balance between fuel consumption and emissions?*
5. *What are the potentials and challenges of LNG for marine application?*

Conclusion:

1. Is there a perspective for combined exhaust gas treatment to handle NOx, SOx and PM emission?

The chairman introduced the topic and told that not all vessel emissions can be treated with one installation, because e.g. treatment of NOx emissions require a quite different approach regarding certificates and engine design (see Tadeusz Borkowski’s Learning Café presentation in the appendix).

NOx emission reduction regulations were postponed because not everybody was happy with available technical solutions. On top of this, from 2013 there is a new policy regarding energy efficiency

All above mentioned issues make it more difficult to combine everything in one installation on board of a vessel.

How do you see the possibilities to overcome all the different requirements to reduce the exhaust gas emissions? All emission cleaning systems need to be integrated into one installation and the propulsion system of a vessel, and ultimately there should be only one system for exhaust gas cleaning. The solutions are either focused on combustion or after-treatment. The latter is most common at the moment. However, there are problems with integrating the waste-heat recovery systems and emission abatement systems into one installation, because the waste-heat-recovery system is connected with engine performance which needs to work from low-load to medium load and up to maximum load. This is not the case with emission reduction, which needs to run all the time with the same rate of efficiency.

Each installation has its own requirements: for example the SCR system requires the so called thermal window. The producers of SCR systems have tried to install the SCR unit after the boiler in order to maintain (optimal) temperature.

There are not many combined systems yet. Usually SOx and NOx cleaning systems are combined.

Waste-heat recovery systems would be a good product. Maersk installed those 10 years ago in 2006-2007 when the oil price was high and it was expected to go further up. They paid 10 million USD for each ship and obtained a saving of 9%. Then came slow steaming, so the industry has burned their fingers a bit on these waste heat recovery systems, as energy consumption was reduced.

With present sulphur scrubbers, where ship owners are investing money on a high grade, alloy tower anyway. Depending on the type of scrubber, heat recovery system can be combined. The present water-injection (scrubber) systems have high energy efficiency.

Pay-back time can be good with combined NOx and SOx emission treatment systems that are connected to the boiler or heat exchanger of a vessel. Smaller installations of combined systems (on new-buildings) with 5-6 MW of main engine propulsion power are fairly straightforward. It is easy to package the system as combined control system with a system reducing the NOx emissions and a scrubber system reducing the SOx, and both work nicely together. The scrubber uses whatever temperature is left from the NOx system and the boiler. But even with a NOx system and a boiler one can receive some heat-recovery because you are heating the water. Due to the laws of evaporation the water temperature one never gets more than 15,7 degrees of Celsius water. As a rule of thumb, you get 2/3 of the energy of the main engine as a heat exchanger power. Normally investments are made to heat-exchanger anyway.

Combined solution is not causing too much costs but you need pumps afterwards. With a simple cargo vessel, it is possible to use the heat, but with Ro-Ro vessels and ferries it is technically tricky as there is no much space on board and requires a lot from the pumps.

With bigger vessels with 25 to 50 MW engines) the technical problems are larger. E.g Maersk and Alfa Laval are working on 2 or 3 different technologies.

Slow steaming – what is the optimal speed?

Maersk's latest ships (Triple-E) are designed to go with 19 knots but can go up to 23 knots. In the "good old days" everybody sailed at full speed. There can be many different strategies: you can go from Europe to Singapore in 30 days or in 60 days. If oil price goes up, speed goes down. Usually oil price determines the economically optimal speed.

With bulk carriers the criteria is different regarding the speed as ships can be on different trades.

2. What are the main technical challenges of the IMO ship emissions and energy reduction programmes?

EEDI and energy consumption was discussed. The hulls of the current vessels are already optimised. The optimisation has nothing to do with NOx or SOx emission. There are designs for big container ships that use no ballast water at all. Not many such ships have been built yet. Norske Veritas had such a project. One can save a lot of fuel if it is not need to transport ballast water.

Making a hull much better than the best hulls are made today is marginal in future. So much effort has been put to develop and test new hull models, but the gains (in terms of energy savings) are minimal. With paint and cleaning of the hull one can save up to 25% of energy costs – in theory at least. Realistic saving is between 5 and 8% of fuel costs when the main part of the vessel hull is maintained as it is. In the future greater savings with systems like these are expected.

Because the fuel prices are low, there are less economic motivations for fuel savings. Totally new energy forms (e.g. nuclear energy) may change the game totally. Achieving energy savings and complying with the EEDI certificate requires above all crew training and changes in behaviour: e.g. the main water pump does not have to run constantly. It's important that the marine engineers read the manuals of the engine manufacturers. One needs to take a critical look on everything that is going on in the engine room: frequency converters, ventilation, seawater systems etc. As an example, the charge air temperature should be 12 degrees and not 45 degrees (as with most ships). That would cause a huge saving.

Shipowners need to be careful when someone tried to sell them an energy saving equipment for a frequency converter, because it adds up engine room temperature and therefore costs. CO2 is abated but it is costly and there are always secondary effects: problems with space and energy consumption. If one is running reefers or passengers in Polar regions and everybody wants to be in a temperature of 19.5 degrees, there is a problem because there is not enough energy available on board of a vessel. The use of motion fuels can make a difference, but there is a lot of reservation with them.

3. How are marine propulsions development driven by the environmental legislation? What is the balance between fuel consumption and emissions?

MAN Diesel has many ideas. E.g. Temperature is an area where improvements can be made. NOX abatement is possible but it is costly (e.g. EDR system). There are no simple NOx abatement solutions available. Engine efficiency has consequences on fuel consumption and not much development is expected on the combustion process itself.

Backpressure is a critical factor, and it varies between different types of scrubbers. The higher the pressure, the better the cleaning result in a scrubber system. This is taken into account in Wärtsilä system regarding its different components. Cleaning has a cost and if one wants to make things a more compact, typically the back pressure goes up. These issues are not usually taken into account in OPEX calculations. The early generations of scrubbers were so called by-pass scrubbers. They were basically land-based technology fitted on a ship. In the early days the main concern was whether one would block the exhaust line of the main engine. The by-pass scrubbers are an excellent choice in terms of safety, because you will not get too much water down if something happens.

Today with 3rd or 4th generation of scrubbers the by-pass scrubbers are things of the past. Making an in-line system is possible. Even if one runs with low-sulphur fuels and would like to get a heat recovery, one can sprinkler water on the system on a low pressure. The system needs to be kept simple, otherwise the system is hard to operate in real life. With land-based power plants (running on HFO) it is possible to get 90% efficiency in total heat recovery but it is expensive. Especially the last stage is very expensive. One can clean the NOx and even remove the CO2.

4. What are the potentials and challenges of LNG for marine application?

LNG is a hot topic in the ECAs in the emission control area. In terms of the operating costs, LNG is much cheaper compared to low-sulphur fuel. However high investment cost hinders the use of LNG. In the container shipping Maersk have plans for LNG. If the bunkering infrastructure will be built all over the world, many shipowners would be interested to switch in LNG. However with long-haul ocean trade (e.g. Europe-Asia) the use of LNG is problematic, because a lot of space is needed for the LNG tanks.

LNG would be very relevant if one is trading in Europe or internally in Asia. With long-haul continental trade one needs dual-fuel engines, which are expensive. The price difference between diesel and LNG and safety concerns especially with passenger and cruise vessels are the main limiting factors of a more widespread LNG use. The main technical concern are the LNG tanks and maintaining the required very low temperature in them. In Norway the widespread use of LNG has only been possible with strict regulation and the NOx fund.

All the things discussed above are based on regulation. Without regulation the shipping industry is not doing any investments regarding reduction of the vessel emissions. A lot depends on the IMO and MEPCC 70's decision regarding a global emission cap either 2020 or 2025. If the MEPCC decision is postponed, environment, human health and safety pays the price because the IMO cannot make a decision.

Alternative to scrubbers is to use a low sulphur fuel. Many shipowners are waiting for a price signal that makes other alternatives economically viable. If one can use higher OPEX, you would never invest in CAPEX. Installing a new equipment on a ship and then finding out that regulations or engine requirements have changed e.g. due to slow steaming in 2-3 years time. Why would anyone wish to invest in anything as long as low sulphur fuels are available? When the new regulation on global SOx cap is decided, the price of low-sulphur price increases and those companies that have invested in scrubbers will have an advantage.

There are approximately 100 oil refineries and the top 5 can easily increase the supply of low sulphur fuel. The environmental upgrading is driven by economics. The shipping industry is currently not engaging with regulators. It is beginning to, but it still has a long road to go and it is lagging behind land-based industries. - The shipping industry will be soon hit by the "tsunami" where they have to accept being regulated, and when they have to comply with regulations just like the rest of us.

SOx compliance monitoring – results from table 3

Participants: Simon Letout, Maersk Group
Stefanos Karakalles, Intertanko
Peter Krog-Meyer, Danish Maritime Authority
Mårten Spanne, Malmö City
Soren Skive, Lloyd's Register
Hung Nguyen, Environmental Administration in Gothenburg
Sara Libera Zanetti, Malmö University
Jon Knudsen, Explicit
Michael Gauss, Norwegian Meteorological Institute
Jari Walden, Finnish Meteorological Institute
Johan Mellqvist, Chalmers University (**expert of the table**)
Minna Alhosalo, University of Turku, Centre for Maritime Studies (**rapporteur of the table**)

These four questions were discussed:

1. *Compliance checks, how is it done today?*
2. *Can remote measurements be used for compliance control of both sulfur and NOx?*
3. *What is the compliance level today in harbors and at sea?*
4. *Are the particle emissions reduced in the SECA?*

Conclusion:

Do you think it is necessary (compliance monitoring) to do more than it is done today? Yes or no?

- **Yes AND No**
- **No,** most are complying because the penalties are so high, if you don't comply. So you wouldn't falsify your records. For those few that don't comply, you can find them in other ways e.g. fuel samples. We do that for some companies some times.
- It has been written that there exist corruptions, especially in some companies and in some countries.

Another question

- **Compliance level today**, there is different independence evidence that points that it is at least 95% that comply of ships and it's about the same with us, with some exceptions in the SECA border where it's even higher. Is it fine/do you agree with that?
- Input from the port cities: ships have a good compliance when they are running, but when they are maneuvering in the harbours we have seen and heard that there is a lot of problems with scrubbers. And same from the air quality experts. We would like to see that the emissions in ports are reduced, because they are quite high due to the technical problems.

Have the particle emissions reduced?

- The whole idea with the Sulphur regulation was to reduce particles. Close to the sources there has been very little reduction. This is a positive effect for the background. But these close direct particle emissions, like in Göteborg or in Malmö, haven't been reduced very much, but maybe this are even worse because some of the SECA fuels, which are mixtures. There seems to be more like organic particles and might not always be positive.

- It should be possible to combining different technologies, e.g. a big infrastructure with a development. And therefore you look for other solutions. The combination of the staff causes that different problems are coming up.
- Skipping the particles, because in the IMO they thought that particles will come automatically, if we get the sulphur. Right now we are having black carbon. There are still big particle emissions in cities like Göteborg, and also NOx emissions. How well these SCR systems work, there are still issues with new emissions.
- Differences in black carbon measurements: concentrations whether using scrubbers or low sulfur content fuel? At Great Belt all components are measured, also in Göteborg for 3-4 months, and before in Los Angeles. Particle measurement is very difficult, because of different instruments and comparing different instruments.

Most people were of the opinion that we should do additional work.

Is remote measurements that you heard about a path to go or do you prefer online measurements?

We are looking for other solutions. The way it's done at great belt is too limited in Maersk's opinion. There are questions concerning the reliability. So we are looking one step further for solutions.

- Compliance level today is at least 95% or even better with an exception in the SECA border. We did a lot of flights and activities within another EU project (Compmon), flights in Belgium and different type of measurements. We have put them all together, and it looks like that the situation is consistent.
- We are wasting a lot of time to ships that are compiling (95%). We need to find out how to target those 5% that are probably non-compliant. All the ships we check are "bad ships". The resources need to be focused more.

Health and environment – socio economic effects of SECA – results from table 4

Table chair: Sari Repka, University of Turku

These four questions were discussed:

1. *Do you think it is relevant to study the socioeconomic effects of SECA also after the regulation has commenced? And why?*
2. *To which of your stakeholders do you think there are (and what type of) socioeconomic effects?*
3. *What are the short term and long term socioeconomic effects of SECA to your own activities?*
4. *Long-term effects (currently nothing is happening)*

Conclusion:

It's important to monitoring short and long term effects before and after for the future. SECA is coming and it is a long term project. To measure broader socioeconomic implications it takes time. And the complexity of impacts difficulties to focus on the SECA impacts requires time as well. The compatibility with previous EU studies is important. The shipping effects will affect the health effects there can result in years of lives lost. The measurements is necessary to validate the models, both permanent and semi-permanent measuring stations can be used to it. Low Sulphur fuel vs. scrubbers is something to consider. From a global perspective a simple solution is more attractive in the long term. LNG is not an option at a global scale.

To point out and promote the positive effects are important. Concretization is needed in communication about e.g. euros and extra years health. And the costs will be paid by the end of the users or customers. To many of the shipping companies the bottom line, as costs and lead time, is important and the green values come after that. To motivate members to comply more transparency is needed in the supply chain.

- Long-term effects on the industry needs to be added on the impacts list!

4. Long-term effects (currently nothing is happening)

Is there a technology push appearing?

- Will Mediterranean area benefit in the long term?

- In 2020 there will be a 0.5% level worldwide and this could help the European maritime equipment industry will have an advantage (if scrubbers are chosen or local waste water technology).

5. Appendix

Presentation 1

EnviSuM WP5: Economic Impacts

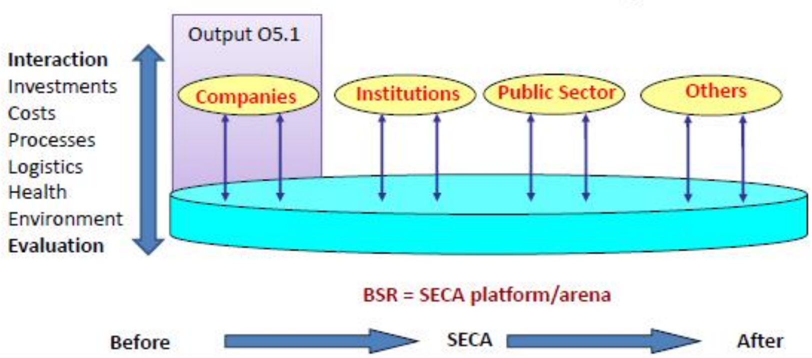
- WP5 aims for creation of **"Economic Guidelines for SECA"** & recommendations for political and maritime stakeholders by assessing costs & benefits of SECA/NECA regulations
  - *One important group of social benefits is the effect of regulations on innovativeness and economic growth. Stricter environmental regulations in the BSR will presumably force BSR businesses to innovate both in products and in processes. Complying with the regulations is not pure technology but also a social phenomenon, and social innovations will be needed. Knowhow and creativity is valuable for businesses and societies.*
- WP5 comprises 4 parts:
  - WP5.1: SECA Investment Analysis (SIA)
  - WP5.2: SECA Administration Cost/Benefit Analysis (SAA)
  - WP5.3: SECA Logistics Cost/Benefit Analysis (SLA)
  - WP5.4: SECA Socio Cost/Benefit Analysis (SSA)

Model for Empirical Activities

BSR regions & their actors interact with SECA regulations

Maritime Stakeholders = VIEWS, ACTIVITIES & VISIONS

The stakeholders benefit/suffer/interact with SECA regulations



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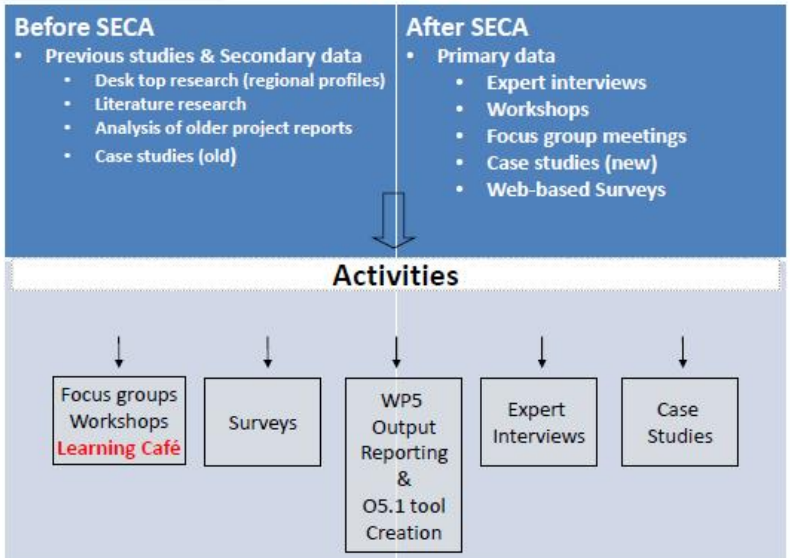

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SECA Survey

- Please help us and fill out our SECA survey on

Cost/Benefit Assessment of SECA Regulations for Maritime Stakeholders

http://sgiz.mobi/s3/EnviSuMSurvey

SECA survey is part of the EnviSuM project

Thank you very much in advance !

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Tentative Business Impact of SECA

Stricter environmental regulations in the BSR will presumably force BSR businesses to innovate both in products and in processes.

Business Threads

- High investment needs
- New operating costs
- Additional admin. burdens
- Decreasing attractiveness of BSR for investments
- Decreasing competitiveness of BSR compared to MEDPorts

New Business Opportunities

- SECA Innovation push
- Growing technology exports
- Spurred blue growth
- Blue branding of BSR
- Growing Blue tourism

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Discussion!

What are the new business opportunities related to Sulphur?

&

Delphi approach

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Specific SECA-related questions for Table 1

Do you think that SECA regulation compliance will…?

- Push blue growth and innovation in maritime sector in BSR?
- Increase the attractiveness of BSR as a target region for business investments?
- Have a significant impact on the company development/profitability/pricing in BSR?
- Change cargo flows within Europe especially between BSR and Mediterranean Sea?

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Thank you very much !

And don't forget the survey ! ☺

http://sgiz.mobi/s3/EnviSuMSurvey

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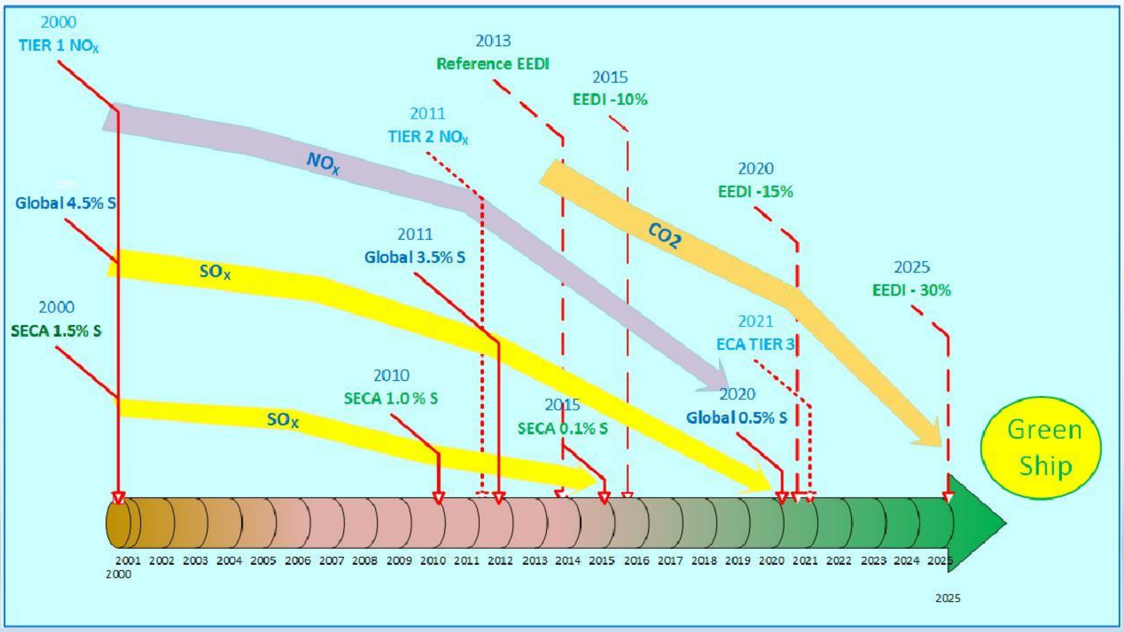
Presentation 2

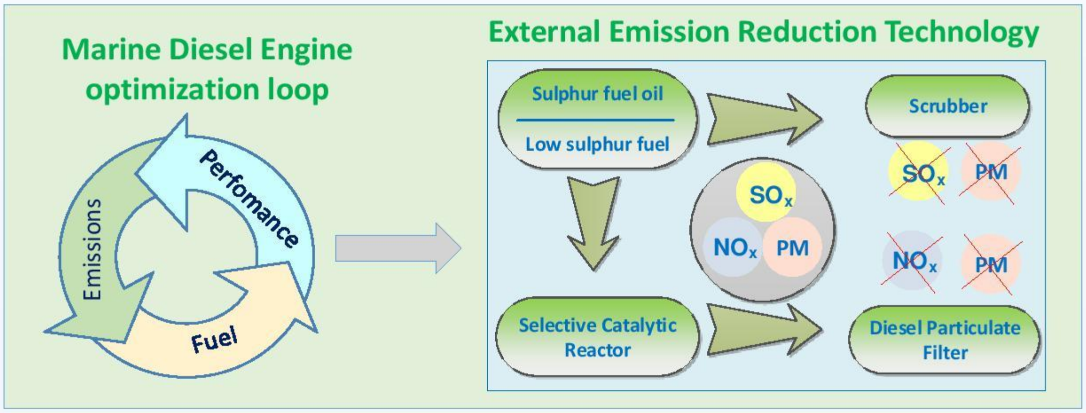
Contents:

Ship Emissions – Regulatory outline

1. International Maritime Organization adopted **MARPOL 73/78 Annex IV**:
   - Regulation 12 - **Ozone Depleting Substances**
   - Regulation 13 - **Nitrogen Oxides - NO_X**
   - Regulation 14 – **Sulphur Oxides - SO_X** and **Particulate Matter** - **PM**
   - Regulation 15 – **Volatile Organic Compounds**
   - RESOLUTION MEPC.203(62): **Energy efficiency for ships – CO_2**
2. EU Directive - **EU 2005/33/EC**, 2005 for ships moored in EU ports - **SO_X**



Marine diesel engine emission and reduction technology outlook



SOx emission control means may be divided into methods termed:

- **Primary** - formation of the pollutant is avoided (low sulphur fuels)
- **Secondary -** pollutant is formed but removed, prior to discharge to the atmosphere (wet scrubbers).

NOx reduction technologies can be divided into three basic categories:

- **pre-treatment** - lowering the combustion temperatures by external treatment or use of alternative fuels,
- **internal measures -** altering the engine configuration to modify the combustion process
- **after-treatment** - systems fitted externally to the engine and are applied directly to the exhaust gases.

Wet Scrubbing – functional basis

Wet scrubbing technologies are based either on fresh water added with alkaline (NaOH) ("**closed-loop**" concept), sea water ("**open-loop**" concept) or have a **hybrid** structure using either closed or open-loop for SO_X, depending on wash water inherent quality in area.

Preliminary stage – laboratory analysis

Wet scrubber **demonstrator model** to proof principle of operation:

- Fresh water
- Steady flow of synthetic gas – N_2,NO_2,O_2,SO_2,CO_2
- Stable process temperature

Outlet				
NO_2 [ppm]	SO_2 [ppm]	CO [ppm]	CO_2 [vol.%]	O_2 [vol.%]
255	**4**	284	1,23	18,02

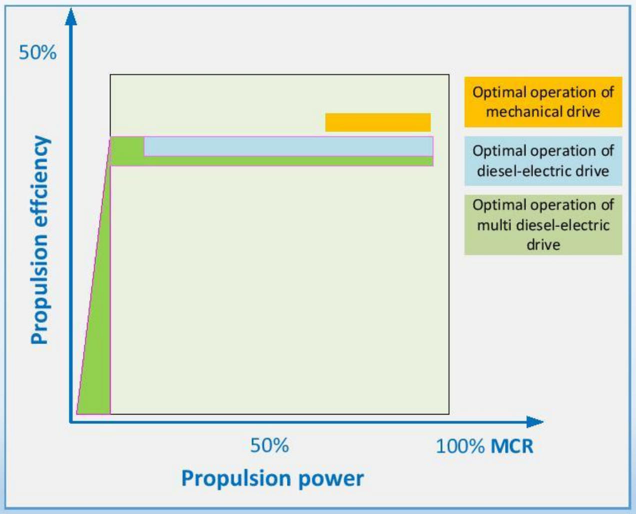
Inlet				
NO_x [ppm]	SO_2 [ppm]	CO [ppm]	CO_2 [vol.%]	O_2 [vol.%]
418	**353**	285	2,27	17,84

$$SO_2 \text{ removal efficiency} \approx 98.8\%$$

Exhaust Gas Cleaning System - on board survey

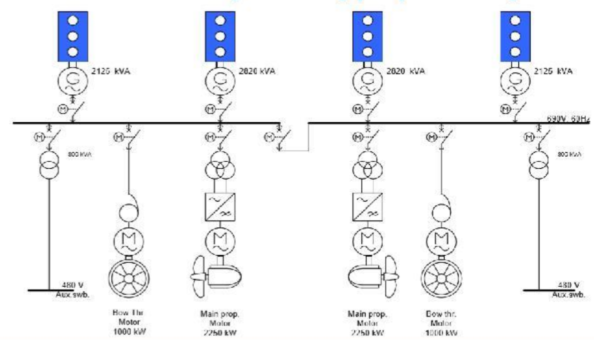
The design of marine wet scrubbers depends mostly on the size and characteristics of the propulsion installation, especially the main engine and electric generators installation.

Ship propulsion



m/f **NILS DACKE**
Passenger/Ro-Ro Cargo Ship

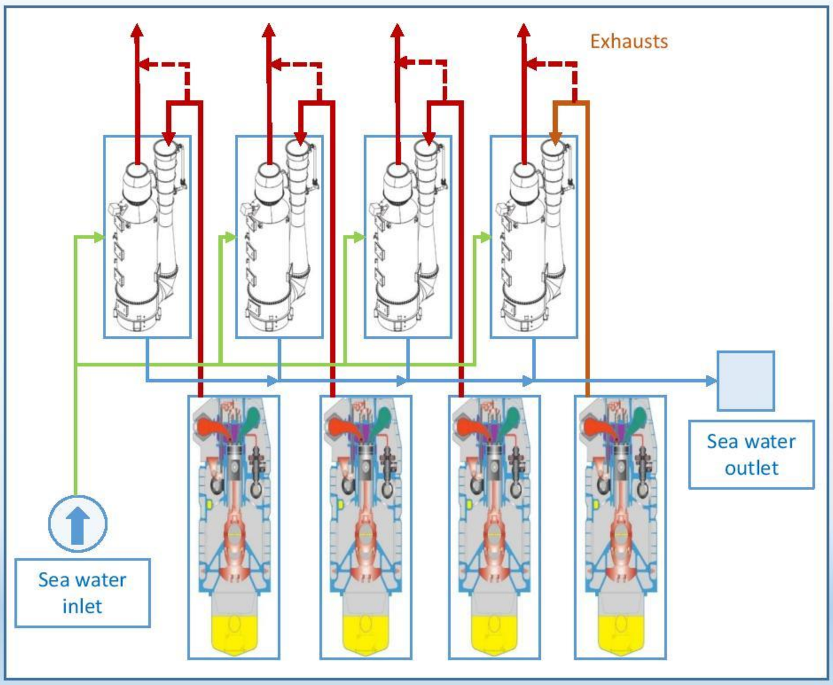
Diesel electric main/auxiliary propulsion system



Ship's EGCS general layout

Under MEPC.184(59) there are two possible EGCS compliance routes:

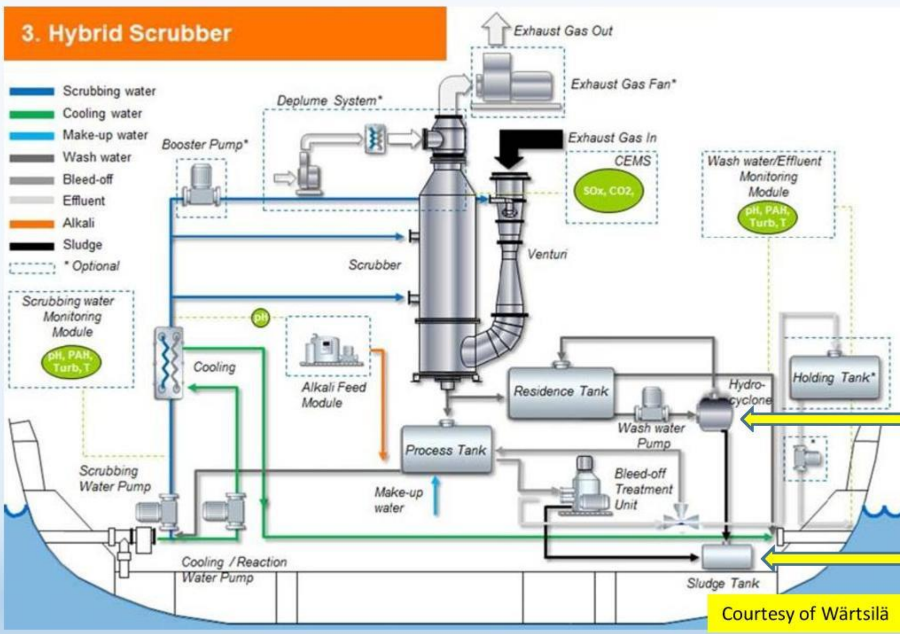
1. **Scheme A** – EGC System Approval, Survey and Certification using Parameter and Emission Checks,
2. **Scheme B** – EGC System Approval, Survey and Certification using Continuous Monitoring of Emissions.



- Main stream scrubbers are dimensioned for 100% engine load.
- Any fuel Sulphur content up to 3.50%.
- Exhaust gas cleaned to a level where exhaust gas SO_X emission is not exceeding an equivalent of fuel Sulphur content of 0.10%.
- Scrubber can be bypassed by closing the exhaust passage to scrubber. In such cases compliance with the regulations is to be achieved by using fuel with appropriate Sulphur content.

Single hybrid scrubber unit and relevant system installations

Hybrid wet scrubbers have the ability to operate in both modes, combining the simplicity of open loop operation with the advantages of a more complex closed-circuit wash water recirculation.

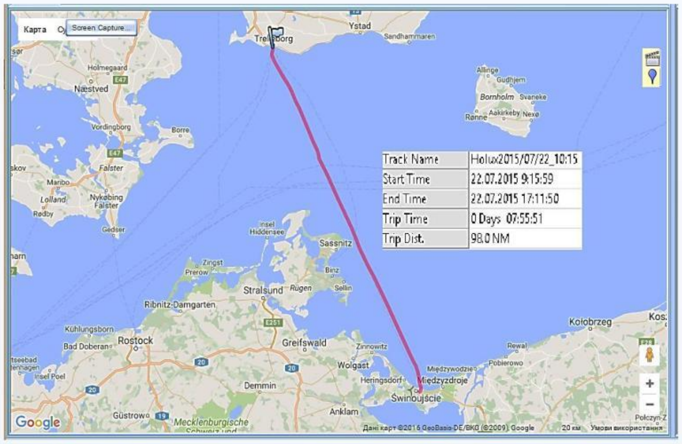


EGCS main component, enabling the exhaust stream from an engine be mixed with the water

A treatment plant to remove pollutants from the wash water after the scrubbing process.

Sludge handling facilities – sludge removed from the wash water.

Survey details – route, operation mode and propulsion power



Route: Trelleborg – Świnoujście

Distance – 98 NM

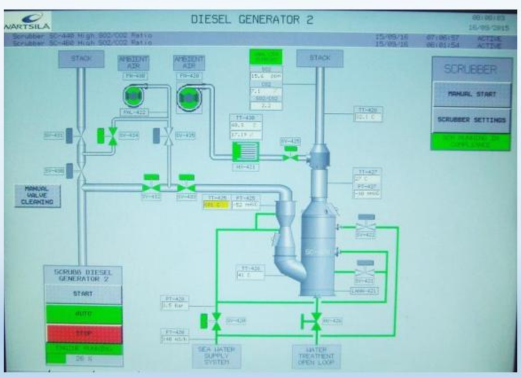
Average full steaming speed – 18 Knots

Number of trips attended – 76

Survey period – 2 months

EGCS operation – 2 months

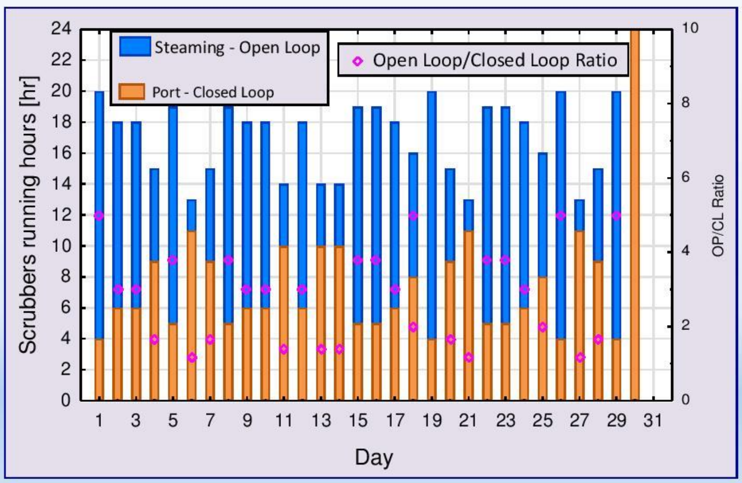
Fuel oil – HSFO 380 cSt, 1.75% S

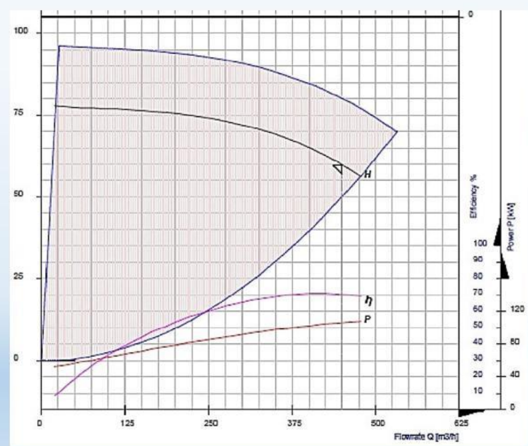


Survey details – operation mode and energy distribution

Date	Scrubber unit	Operation Mode	Engine Load		Water inlet flow
			kW	%	m3/h
1.09.2015	1	Open Loop	3945	91	190
	2		3840	89	192
	3		3800	86	191
	4				
2.09.2015	1	Open Loop	3680	85	191
	2		3840	89	188
	3				
	4				
3.09.2015	1	Open Loop	3900	89	190
	2		3824	86	189
	3		3720	85	191
	4				

Pump number	Scrubbing water pump operation parameters			Other
	A	kW	rpm	
P-101	172	63	2461	
P-102	153	67	2461	18 kn
P-103				P-106 Cooling 9kW 46.A
P-101	172	83	2555	
P-102				17 kn
P-103				P-106 Cooling 9 kW 45 A
P-101				15 kn
P-102	153	65	2432	P-106 Cooling 9kW 46.A
P-103	150	59	2433	





Data processing and EGCS parameters check

Single engine and scrubber unit parameters

DATE	CO2	ME LOAD	SCRUB. OUTLET TEMP	SO2	CO2/SO2 RATIO	SW INLET FLOW	VN-420 INLET TEMP	DG2 effective power	DG2 fuel cons.	SFOC	Ex. Gas Flowrate	Ex.Gas Flowrate	SO_2 inlet flowrate	SO_2 outlet flowrate	Scrubber efficiency	Specific SO2 emission
	[%]	[%]	[0C]	[PPM]		[m3/h]	[0C]	[kW]	[kg/hr]	[g/kWh]	[kg/h]	[m³/hr]	[kg/hr]	[kg/hr]	[%]	[g/kWhr]
21-07-15	0	10	25	0	0	147	66	450	139.7	310.3	4224.0	3283.9	4.88	0.0000	100.00	10.85
21-07-15	2.7	13	26	14.4	5.4	145	176	585	166.1	283.9	4893.5	3804.5	5.81	0.1556	97.32	9.93
21-07-15	2.7	34	27	14.4	5.4	145	242	1530	350.9	229.4	9580.6	7448.0	12.27	0.3046	97.52	8.02
21-07-15	2.7	55	29	14.4	5.4	185	279	2475	535.8	216.5	14267.7	11091.5	18.73	0.4536	97.58	7.57

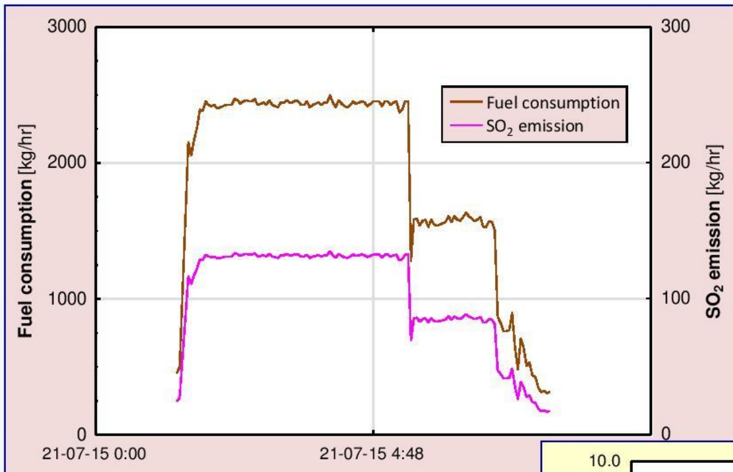
Sea processing and washwater water parameters

DATE	PAH SW	PAH WW	pH SW	pH WW	Process water density	SW flow alarm	SW Temp.	WW Temp.	Turbidity SW	Turbidity WW	WW flow alarm
	[ppb]	[ppb]	[pH]	[pH]	[kg/m3]		[0C]	[0C]	[NTU]	[NTU]	
21-07-15	0.1	0.1	6.9	6.3	1035	0	34.9	37.6	135	12	0
21-07-15	0.1	0.1	6.8	6.3	1035	0	35.1	37.6	136	12	0
21-07-15	16.6	0.1	7	6.4	1003	0	35.9	37.5	16	11	0
21-07-15	3.1	0.1	7.4	6.3	1005	0	30.5	36.5	8	80	0

Ship, propulsion and scrubbers system performance

DATE	TIME	SPEED	SPEED	Power	Fuel consump.	SFOC	Ex. Gas Flowrate	SO_2 inlet flowrate	SO_2 outlet flowrate	Scrubbers efficiency	Specific SO2 emission
		[km]	[kn]	[kW]	[kg/hr]	[g/kWh]	[kg/h]	[kg/hr]	[kg/hr]	[%]	[g/kWhr]
21.07.2015	01:26:55	7.88	4.26	1530.0	454.16	296.8	12587.2	15.9	0.064	99.60	10.38
21.07.2015	01:27:00	7.56	4.08	1755.0	498.18	283.9	13740.6	17.4	0.204	98.83	9.93
21.07.2015	01:27:05	8.14	4.39	4545.0	1043.94	229.7	28043.6	36.5	0.408	98.88	8.03
21.07.2015	01:27:10	8.64	4.66	7380.0	1598.51	216.6	42577.3	55.9	0.598	98.93	7.57

EGCS compliance



transitory non-compliance due to engine load fluctuations

Emission and wash water discharge limits:

- SO_2 /CO_2 ratio (In the exhaust gas after EGCS)
- Wash water pH (measured at the EGCS inlet and over board discharge)
- Wash water turbidity (measured at the EGCS inlet and over board discharge)
- Wash water PAH (measured at the EGCS inlet and over board discharge)

EGSC operational costs

No:	Open Loop	Nominal	Actual	In use	Hours in operation	Load Factor	Daily consumption
		[kW]	[kW]	[pcs]	[h]	[%]	[kWh]
1	Water Supply Pump	132.0	64.0	2	17	34.34	2176.0
2	Hydrocyklone Supply Pump	55.0	50.0	1	17	64.39	850.0
3	Scrubber 400V	7.5	7.0	3	17	66.11	357.0
4	Scrubber 230V	0.3	0.3	3	17	70.83	15.3
5	De-plume Fan	15.0	15.0	3	17	70.83	765.0
6	De-plume Heat Exchanger	150.0	150.0	3	17	70.83	7650.0
7	Equip. Room SB Cooling Fan IN	10.0	8.0	1	17	56.67	136.0
8	Equip. Room SB Cooling Fan OUT	7.5	6.0	1	17	56.67	102.0
9	Equip. Room PS Cooling Fan IN	35.0	32.0	1	17	64.76	544.0
10	Equip. Room PS Cooling Fan OUT	25.0	22.0	1	17	62.33	374.0
11	CEMS	4.5	4.5	1	17	70.83	76.5
12	SW Monitoring Module	0.5	0.5	1	17	70.83	8.5
13	Wash Water Monitoring Module	0.5	0.5	1	17	70.83	8.5
14	Alkali Tank Heating	6.0	6.0	1	17	70.83	102.0
16	Ventilation Fan	2.5	2.3	1	17	65.17	39.1
17	Ventilation Fan	2.5	2.3	1	17	65.17	39.1
18	Gas Monitor	1.0	1.0	1	17	70.83	17.0
				Total electric consumption			13260.0

EGSC operational costs

No:	Closed Loop	Nominal	Actual	In use	Hours in operation	Load Factor	Daily consumption
1	Water Supply Pump	132.0	42.0	1	7	9.28	294.0
2	BOTU Separator	18.0	18.0	1	7	29.17	126.0
3	Cooling Pump	55.0	48.0	1	7	25.45	336.0
4	NaOH Dosing Pump	0.4	0.4	1	3.5	14.58	1.3
5	Scrubber 400V	7.5	7.5	1	7	29.17	52.5
6	Scrubber 230V	0.3	0.3	1	7	29.17	2.1
7	De-plume Fan	15.0	15.0	1	7	29.17	105.0
8	De-plume Heat Exchanger	150.0	150.0	1	7	29.17	1050.0
9	Gas Monitor	1.0	1.0	1	7	29.17	7.0
10	CEMS	4.5	4.5	1	7	29.17	31.5
11	SW Monitoring Module	0.5	0.5	1	7	29.17	3.5
12	Wash Water Monitoring Module	0.5	0.5	1	7	29.17	3.5
13	Alkali Tank Heating	6.0	8.0	1	7	38.89	56.0
14	Equip. Room SB Cooling Fan IN	10.0	6.0	1	7	17.50	42.0
15	Equip. Room SB Cooling Fan OUT	7.5	32.0	1	7	124.44	224.0
16	Equip. Room PS Cooling Fan IN	35.0	22.0	1	7	18.33	154.0
17	Equip. Room PS Cooling Fan OUT	25.0	4.5	1	7	5.25	31.5
18	Make-up pump	5.5	5.1	1	1	3.86	5.1
19	Supply Monitor	1.0	1.0	1	7	29.17	7.0
20	Wash Water Monitoring Module	1.0	1.0	2	7	29.17	14.0
21	Ventilation Fan	2.5	2.3	1	7	26.83	16.1
22	Ventilation Fan	2.5	2.3	1	7	26.83	16.1
23	Effluent transfer Pump	8.6	7.0	1	1	3.39	7.0
24	Ressidence tank discharge Pump	45.0	38.0	1	0.25	0.88	9.5
				Total electric consumption			2594.7

EGCS types comparison

	SWS, open loop	FWS, closed loop	SWS, hybrid	Dry
Operation without discharge to sea	NO	YES (limited time)	YES (limited time)	YES
Weight *	30 ÷ 55 T	30 ÷ 55 T	30 ÷ 55 T	~200 T
Power consumption	1÷2 %	0.5÷1 %	0.5 ÷2 %	0.15 ÷ 0.20 %
Chemical consumable	NO	NaOH	NaOH	$Ca(OH)_2$
Compatibility with WHR system	YES	YES	YES	YES
Compatibility with EGR system	YES	YES	YES	YES
Compatibility with SCR system	NO	NO	NO	YES
PM removal	YES	YES	YES	YES

WHR – Waste Heat Recovery

EGR – Exhaust Gas Recirculation

SCR – Selective Catalytic Reactor

SWS – Sea Water System

FWS – Fresh Water system

* Typical values for a 20 MW engine SOx scrubber

Conclusions

1. The SO_X emission reduction can be achieved fairly simply, by switching to low-sulphur fuels or costly EGCS.
2. Numerous marine EGCS are available for ships and different types of main/auxiliary propulsion, however further reliability improvement is required.
3. Currently, a number of EGCS approvals communicated to the IMO reached more than 40.
4. Experiences gained with the use of EGCS show that there is a need for clarification of operational responses to different types of malfunctions and transitory non-compliance in the systems, and the related corrective actions as needed by the crew:
   - Non-compliance, caused by a breakdown of the EGCS itself, leading to unacceptable levels of SO2 in the exhaust gas and/or unacceptable levels of pH, turbidity and PAH in the wash-water discharge.
   - Malfunction of the monitoring system only, which does not interfere with the performance of the EGC System itself. This means that the EGC Systems may well be in compliance, but it cannot be proven to the full satisfaction of the guidelines - IMO Resolution MEPC 259 (68).
   - An EGCS suffers from transitory non-compliance (for example due to engine load fluctuation).
   - Possible non-compliance with the SOx emission limits during the running up and shut down of the EGCS.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Baltic Sea Region
EnviSuM
Thank you for your attention

Presentation 3

CHALMERS

Department of Earth and Space Sciences Chalmers University of Technology Gothenburg Sweden

IGPS

SOx compliance monitoring:

Professor Johan Mellqvist
Email: johan.mellqvist@chalmers.se

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EnviSuM

Questions table 3

SOx compliance monitoring:

1. Compliance checks, how is done today?

2. Can remote measurements be used for compliance control of both sulfur and NOx?

3. What is the compliance level today in harbors and sea?

4. Are the particle emissions reduced in the SECA?

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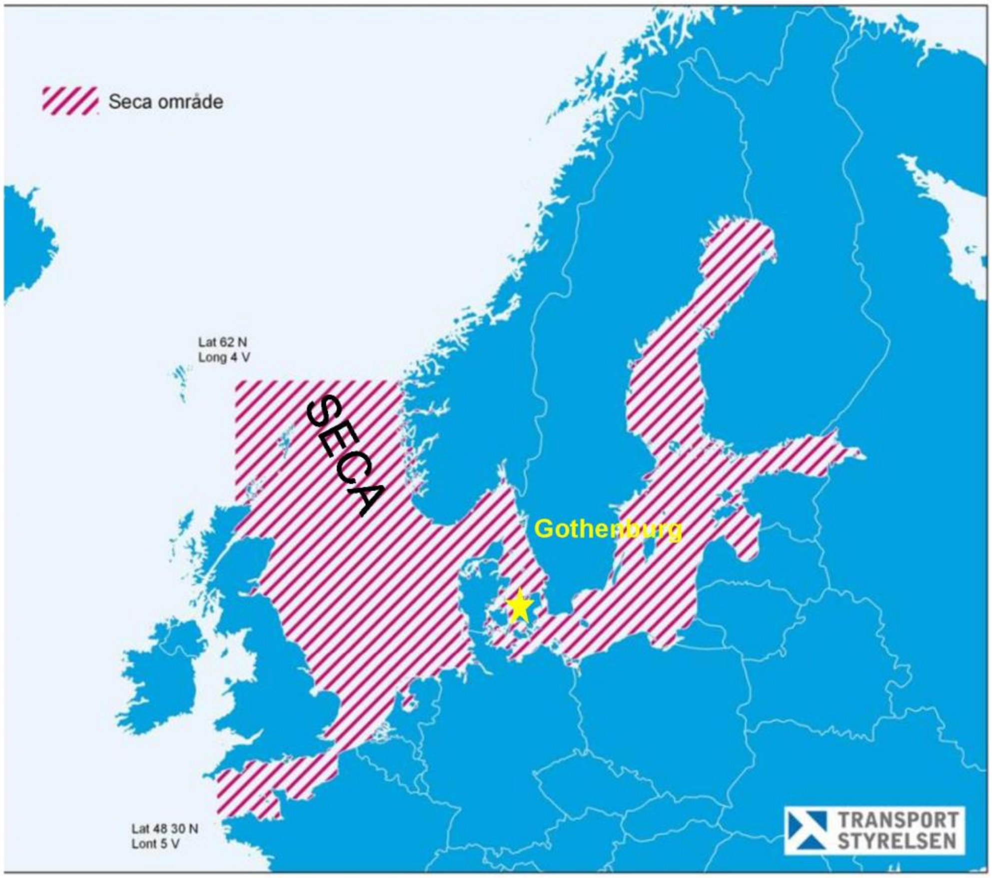

Seca område
Lat 62 N
Long 4 V
SECA
Gothenburg
Lat 48 30 N
Lont 5 V
TRANSPORT
STYRELSEN

Enforcement in EU

- The EC regulations are aligned with the revised MARPOL Annex VI, both inside and outside SECAs. i.e. 0.1% S from 2015 in SECAs.
- The penalty system varies and it is not yet implemented to full extent. In Sweden a fee will be charged rather than a fine.
- Additional inspections and fuel testing have been implemented all over EU
- In Sweden 200 annual fuel inspections are carried out (Only few percent % are high)
- Non compliant ships will be flagged in the European Maritime Safety Agency database THETIS-EU

Limitations of todays ship inspection and fuel testing

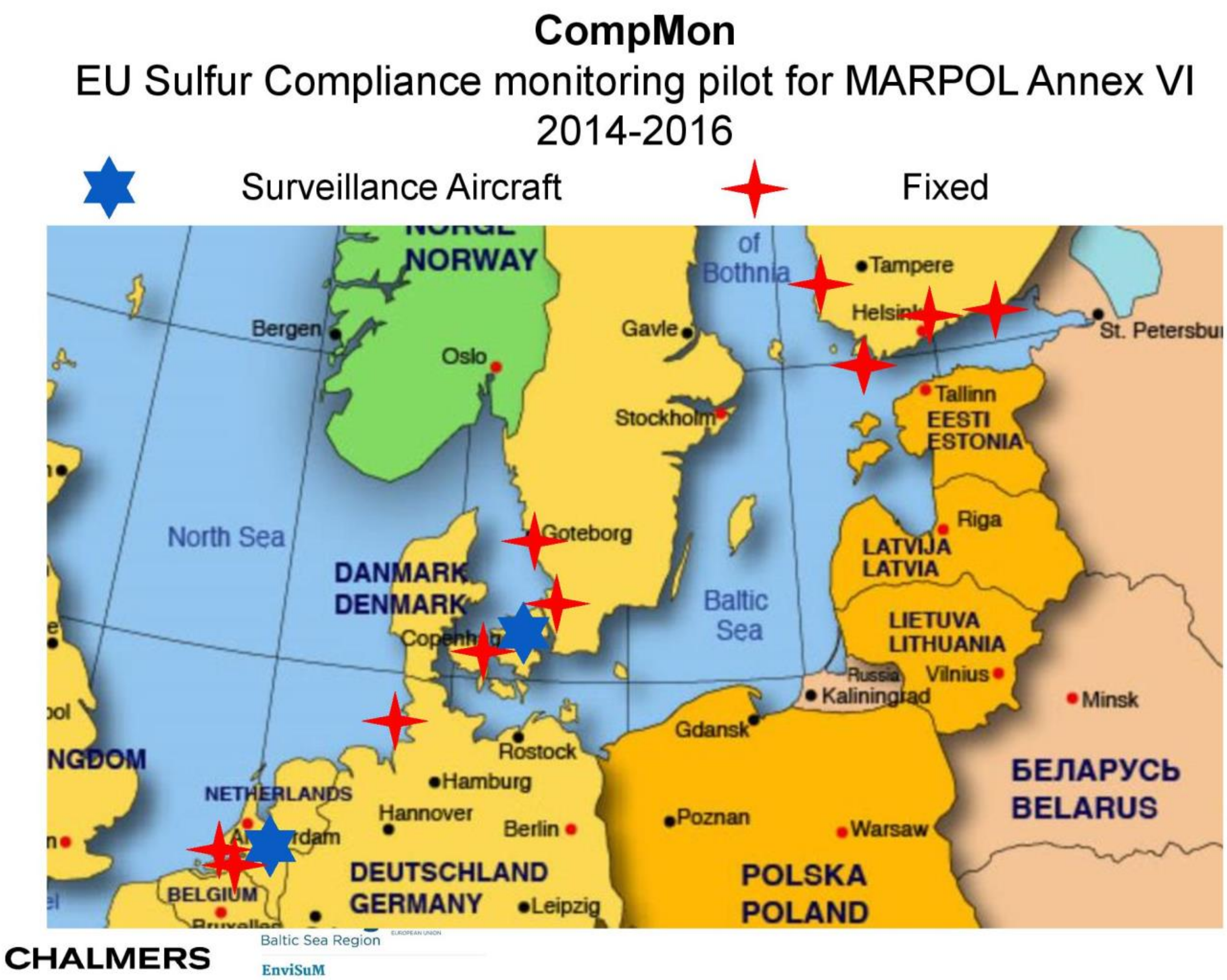
- Less than one percent of all ship calls are inspected
- Controls ONLY in port
- Ship can adapt to good behaviour in ports but use non compliant fuel outside
- The measurements are not representative for the open sea SECA waters
- The fuel test results is not obtained in real time. Lab analysis takes several days!. Therefore the ships often have left the port before further penalties can be implemented.

Improved ECA enforcement by using remote measurement technologies

- In Europe full scale pilot activities are carried out to improve the ECA enforcement by using remote measurement techniques
- EU interreg project, **Envisum**: New ship emission factors and compliance monitoring at Baltic sea and Gdansk/Göteborg/St Petersburg
- EU CEF project, **CompMon**, a pilot is carried out with port state control authoriries to test remote compliance measurements and fuel testing with hand held XRF
- Danish EPA, Full pilot with compliance monitoring at Great Belt bridge and airborne monitoring around Danish waters

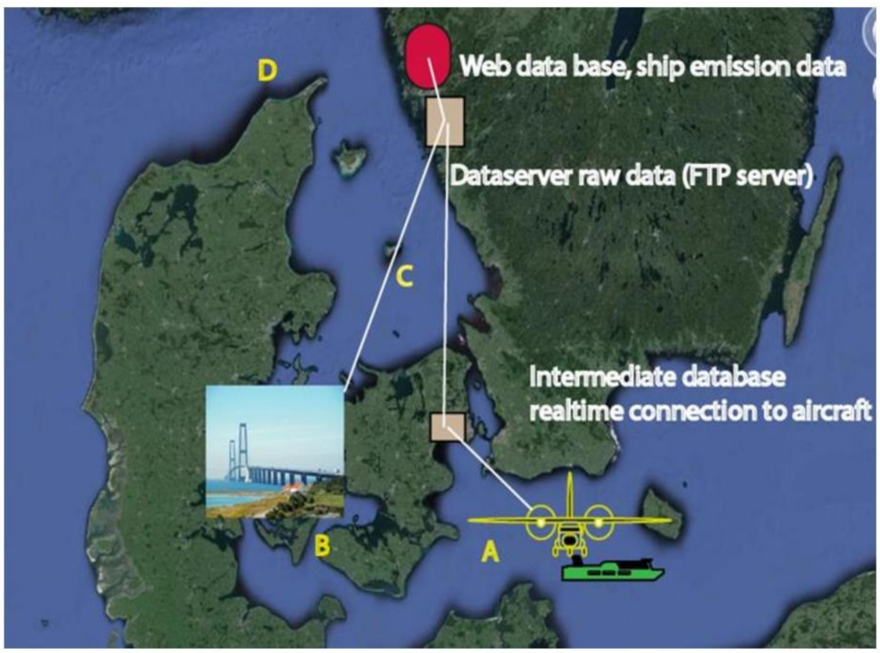
At this stage the data is not directly used as evidence, but instead to guide the control of the port state control authorities

The non compliant ships will be reported in the THETIS-S database used by PSCs


CompMon
EU Sulfur Compliance monitoring pilot for MARPOL Annex VI
2014-2016
Surveillance Aircraft
Fixed
NORGE
NORWAY
of
Bothnia
Tampere
Helsinki
St. Petersburg
Bergen
Oslo
Gavle
Stockholm
Tallinn
EESTI
ESTONIA
North Sea
Goteborg
Riga
LATVIJA
LATVIA
DANMARK
DENMARK
Copenhagen
Baltic
Sea
LIETUVA
LITHUANIA
Russia
Kaliningrad
Vilnius
Minsk
Gdansk
Rostock
Hamburg
БЕЛАРУСЬ
BELARUS
NETHERLANDS
Hannover
Berlin
Poznan
Warsaw
DEUTSCHLAND
GERMANY
POLSKA
POLAND
BELGIUM
Leipzig
CHALMERS
Baltic Sea Region
EnviSuM

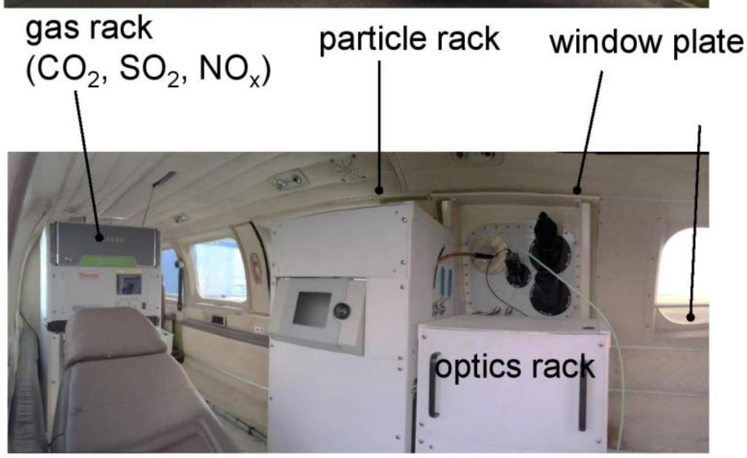
Full scale pilot Danish EPA project, 2015 to 2016

- Airborne measurements of 100 ships per month
- Fixed measurements at Great belt bridge 350 ships per month
- Monitoring on behalf of the Danish EPA (Dorte Kubel)



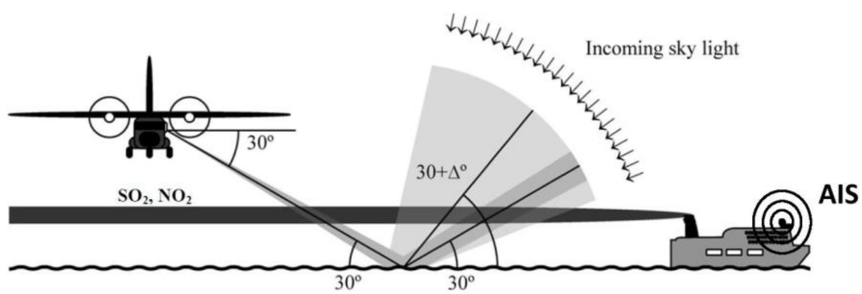
Ship surveillance aircraft in Roskilde, Denmark

Dedicated aircraft for ship emission monitoring of SO_2, NO_x and PM based on optical and sniffer measurements. Operated routinely in Danish waters.



Airborne optical measurement

- An optical ultraviolet spectroscopic sensor measures the path integrated concentration of **SO_2 and NO_2** in the ship plume by analyzing reflected solar light that passes through the smoke (also called DOAS, Differential Optical Absorption Spectroscopy).
- Ship emissions in the unit g/s can be obtained, if combined with wind.
- This sensor is used as a first alert system, distinguishing high sulfur (1%) from low sulfur ships (0.1%) remotely. When the ratio of SO_2/NO_2 is high this indicates a non compliant ship.

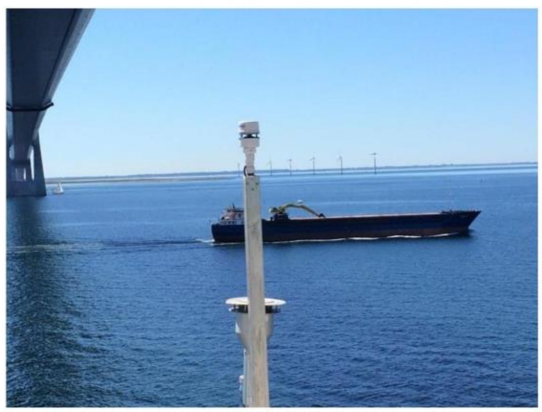


Airborne surveillance measurement on Danish waters

69 flight missions has been carried out as part of the Danish EPA project, 6-10 inspections per h

Fixed platforms – Great Belt Bridge

- Sniffer instruments in south-eastern pylon of Great Belt bridge
- Continous measurements since June 2015
- Fuel Sulfur Content is automatically analyzed and reported to a database.
- Good compliance, but a tenfold cases with non compliance



19

Interreg Baltic Sea Region

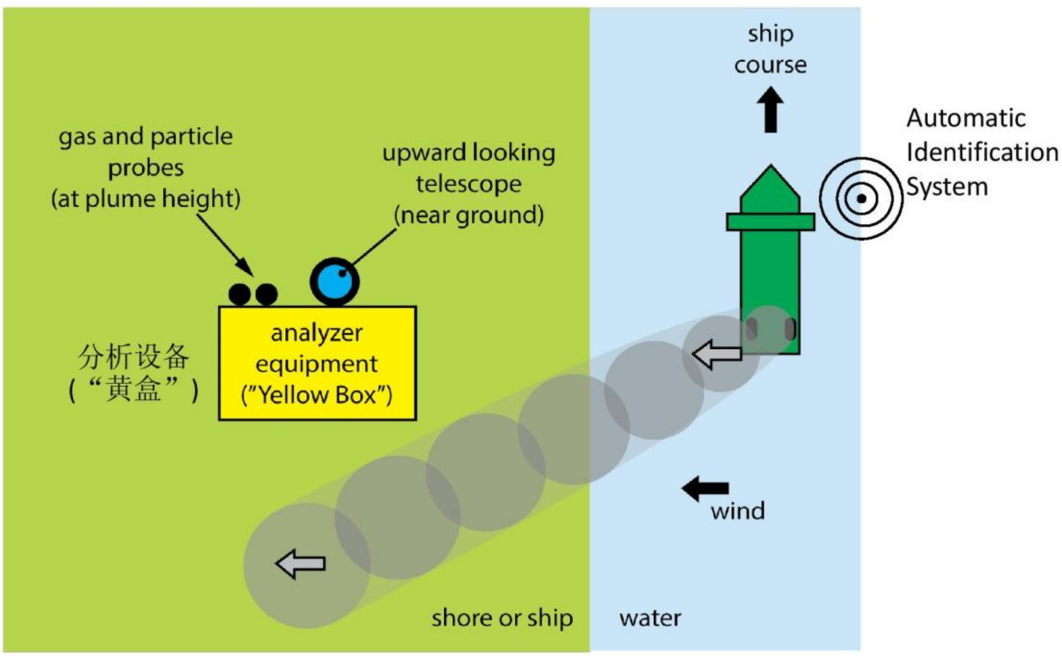
EUROPEAN REGIONAL DEVELOPMENT FUND

EUROPEAN UNION

EnviSuM

Fixed measurement.

The ship emission plume drifts over the site and the smoke is analyzed using a sniffer and sometimes optical sensor



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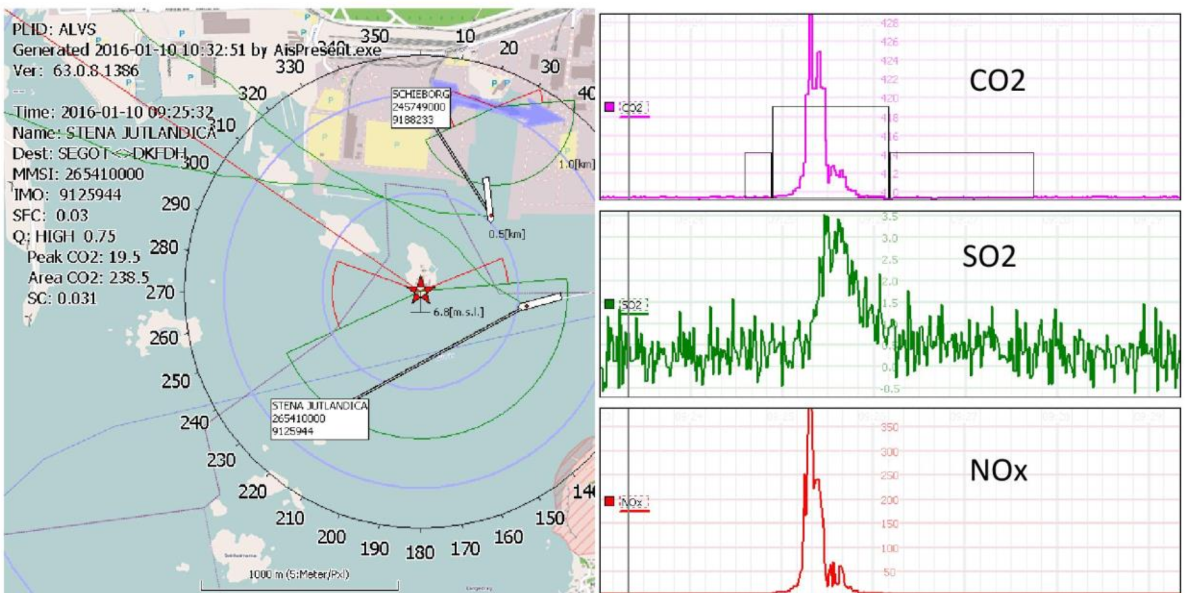
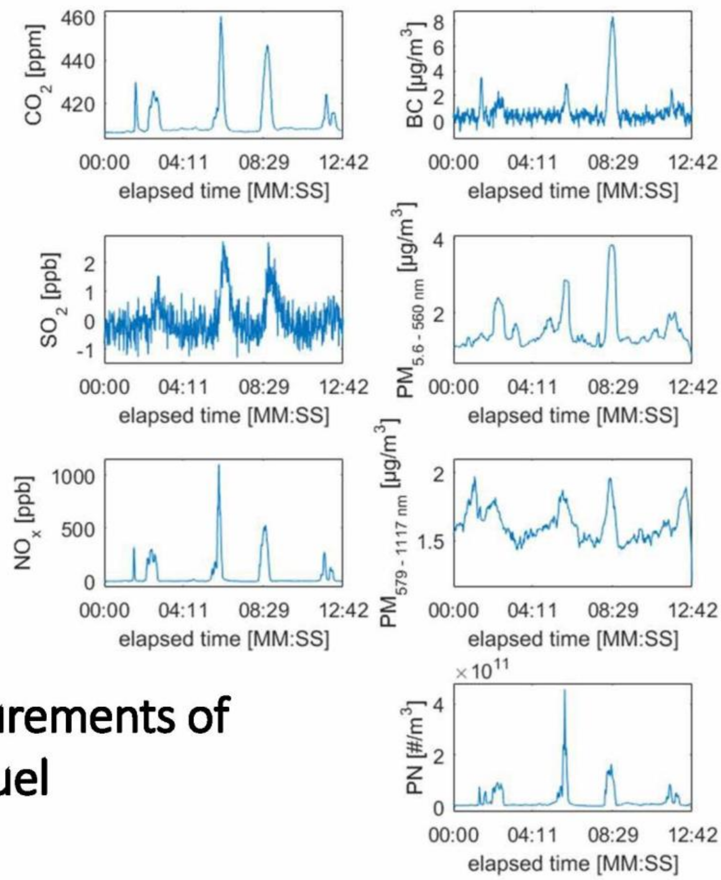
20

Automatic measurements (software) SHOW EXAMPLE

A special software communicates with instruments, identifies ships and calculates fuel sulfur content and NOx emissions per kWh and sends the data to a webdatabase

..\..\..\..\..\..\..\measurements\IGPS\DEmoCompMon\IGPS_Realtime.exe





Emission factor measurements of other species in g/kgfuel

The data is sent in realtime to a web database

Dashboard | Content | Structure | Appearance | People | Modules | Configuration | Reports | Help

Date	Record type	Value	Quality tag	Quality control	Platform	Platform type	Ship name	Ship type	IMO	MMSI	Shi
03/09/2016 - 10:56	SC	0.00	Poor	Automatic	Älvsborg	Stationary	HANS	Other Type	8996956	230034540	11.
03/09/2016 - 10:49	SC	0.06	High	Automatic	Älvsborg	Stationary	ICE STAR	Cargo	9142631	244264000	11.
03/09/2016 - 10:25	SC	0.02	Medium	Automatic	Älvsborg	Stationary	GEORGE	Other Type	8634077	230034510	11.
03/09/2016 - 09:44	SC	0.04	Medium	Automatic	Älvsborg	Stationary	STENA DANICA	Passenger	7907245	265177000	11.
03/09/2016 - 09:18	SC	0.02	Medium	Automatic	Älvsborg	Stationary	ASTINA	Tanker » Hazardous category A	9320063	266220000	11.
03/09/2016 - 08:56	SC	-0.15	Poor	Automatic	Älvsborg	Stationary	DELFIN	Tanker	0	265505100	11.
03/09/2016 - 08:44	SC	0.02	Poor	Automatic	Älvsborg	Stationary	STENA SCANDINAVICA	Passenger » No additional information	9235517	266343000	11.
03/09/2016 - 08:40	SC	-0.04	High	Automatic	Älvsborg	Stationary	STENA SCANDINAVICA	Passenger » No additional information	9235517	266343000	11.
03/09/2016 - 08:17	SC	0.07	High	Automatic	Älvsborg	Stationary	THUN GLOBE	Tanker	9229051	245573000	11.
03/09/2016 - 08:08	SC	-0.02	Medium	Automatic	Älvsborg	Stationary	HANS	Other Type	8996956	230034540	11.
03/09/2016 - 07:51	SC	0.01	Medium	Automatic	Älvsborg	Stationary	LEXUS	Tanker » No additional information	9310317	219157000	11.

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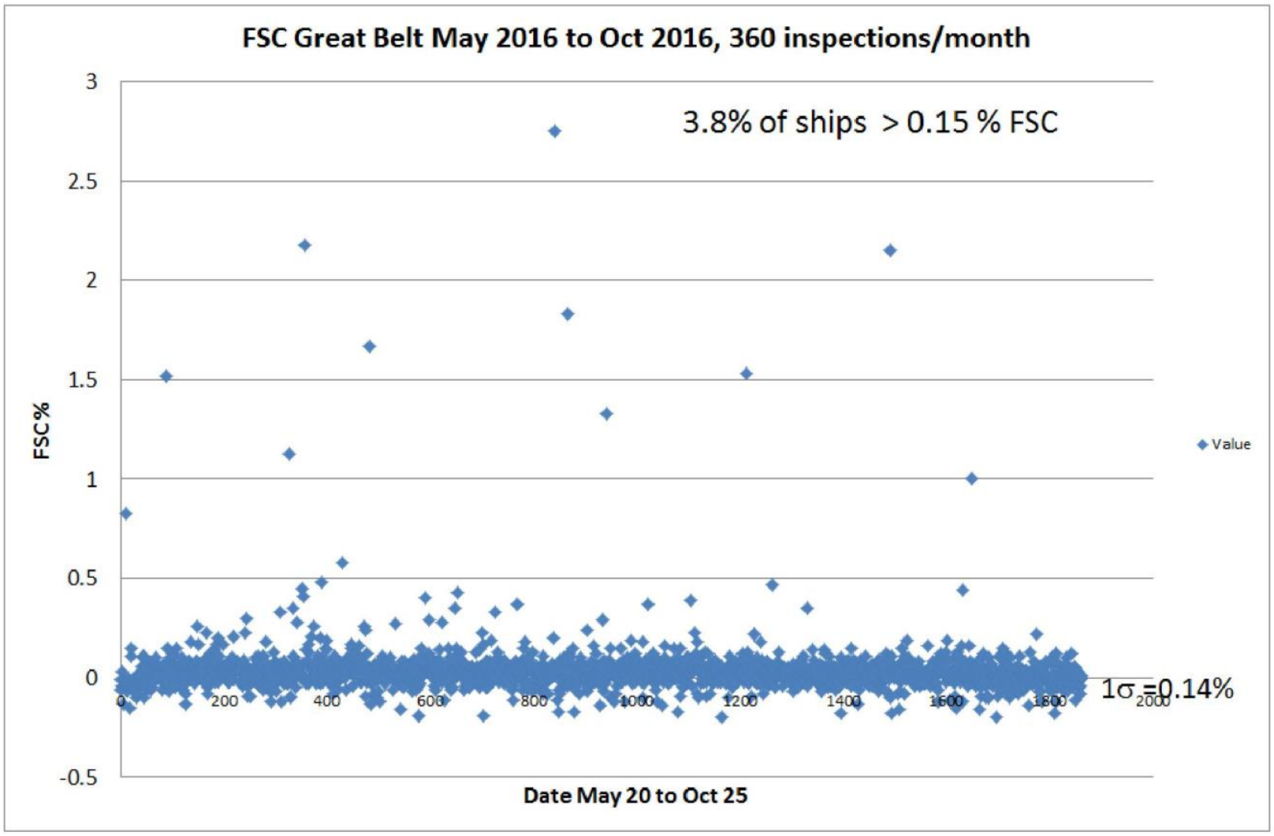
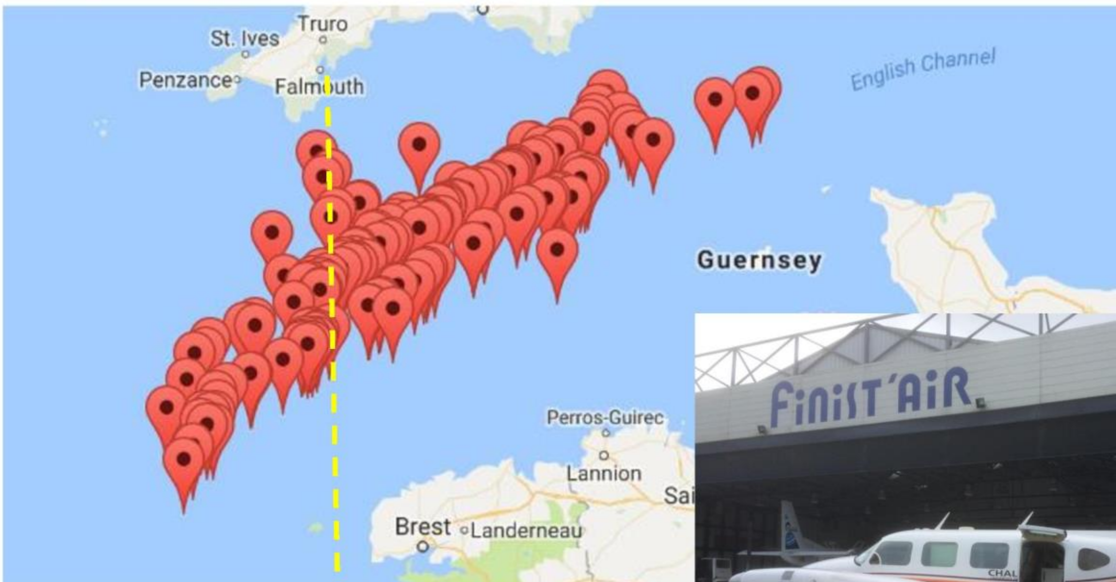
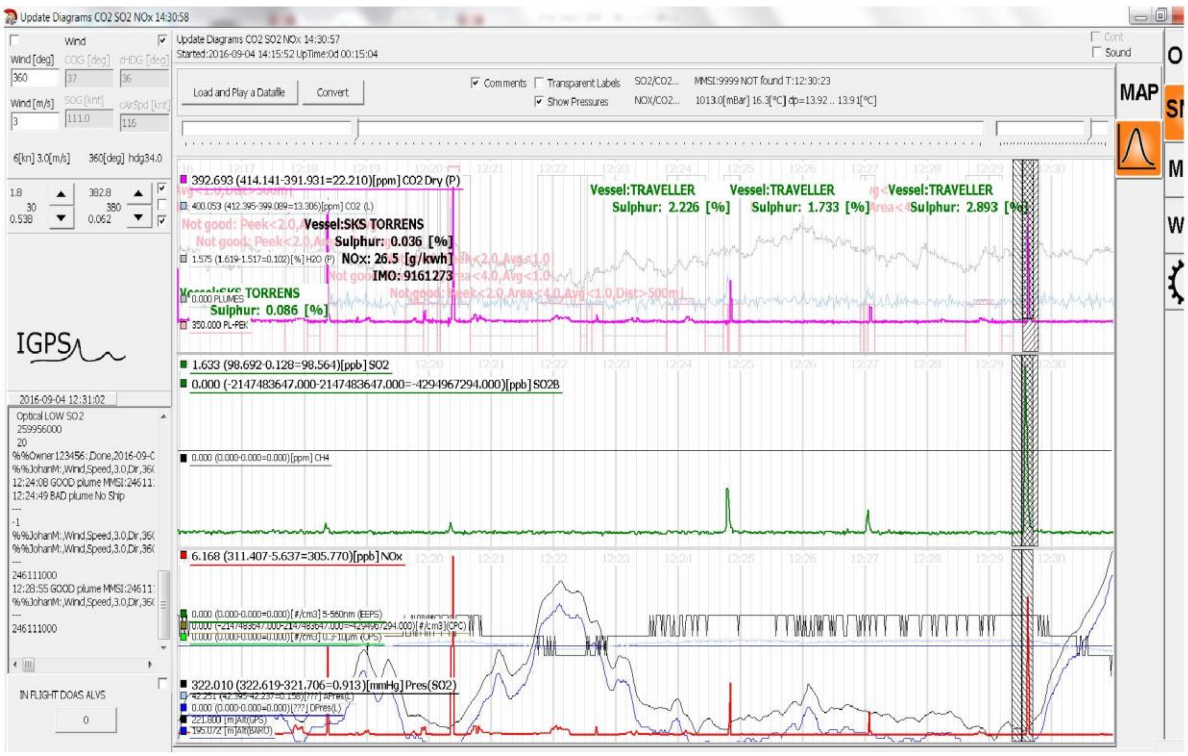

FSC Great Belt May 2016 to Oct 2016, 360 inspections/month
3.8% of ships > 0.15 % FSC
1σ =0.14%
FSC %
Date May 20 to Oct 25
Value
3
2.5
2
1.5
1
0.5
0
-0.5
0
200
400
600
800
1000
1200
1400
1600
1800
2000

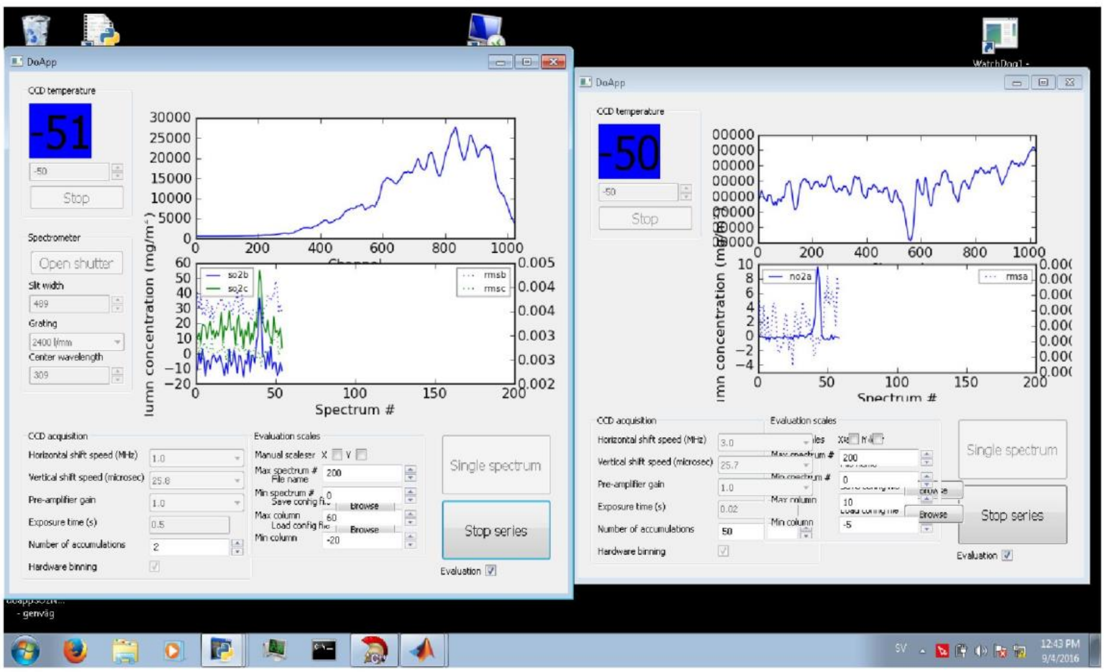
Airborne compliance measurements at SECA border (5 W)



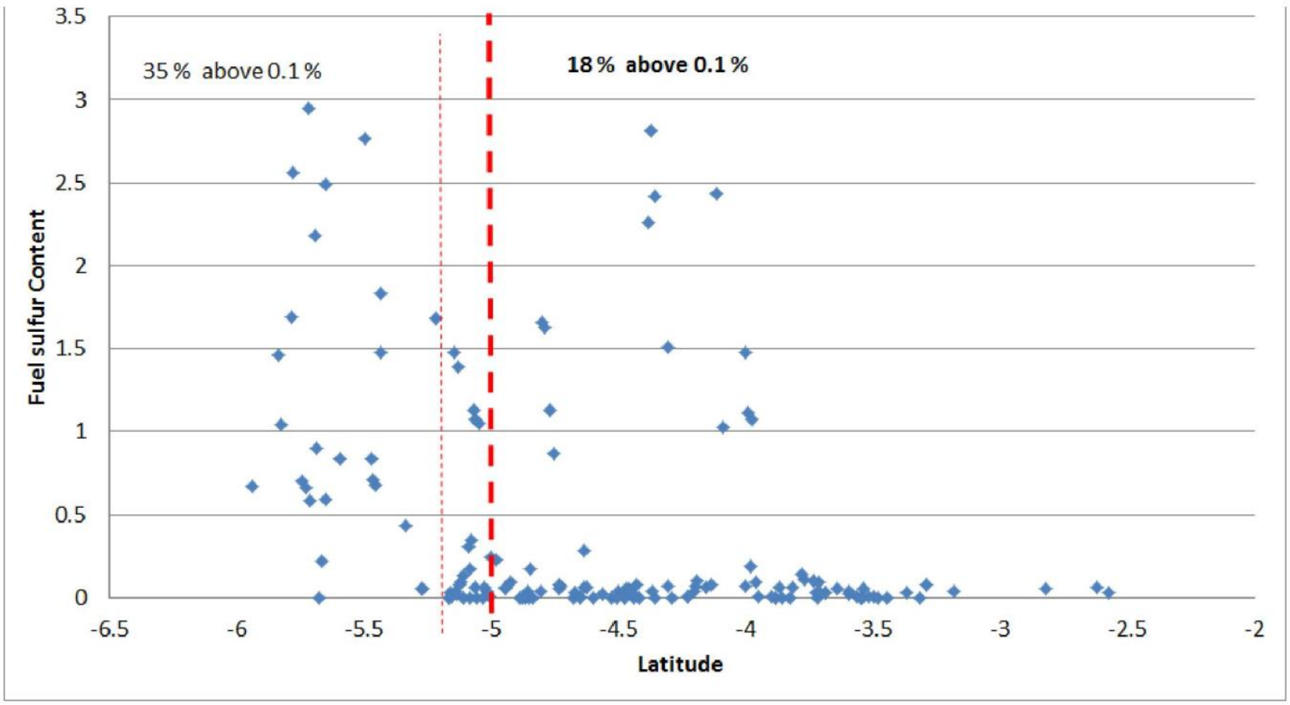
Sniffer measurement of the ship Traveller measured in the English Channel Sep 4 2016.



Optical measurement of SO2 and NO2 of the ship Traveller measured in the English Channel Sep 4 2016. Can be used in harbors for compliance control



Airborne compliance measurements at SECA border (5 W)



References

Berg, N., Mellqvist, J. et al., Ship emissions of SO2 and NO2: DOAS measurements from airborne platforms, Atmos. Meas. Tech., 5, 1–14, doi:10.5194/amt-5-1-2012, 2012

Alfoldy B., ..., Mellqvist J., et al., Measurements of air pollution emission factors for marine transportation, Atmos. Meas. Tech. Discuss., 5, 8925–8967, doi:10.5194/amtd-5-8925-2012 2012

Balzani Lööv J M…. J. Mellqvist, et al., Field test of available methods to measure remotely SOx and NOxemissions from ships, Atmos. Meas. Tech. Discuss., 6, 9735-9782, 2013,

Beecken, J., Mellqvist, J., Salo, K., Ekholm, J., and Jalkanen, J.-P: Airborne emission measurements of SO2, NOx and particles from individual ships using sniffer technique, Atmos. Meas. Tech. Discuss., 6, 10617-10651, doi:10.5194/amtd-6-10617-2013, 2013.

Beecken, Emission Factors of SO2, NOx and Particles from Ships in Neva Bay from Ground-Based and Helicopter-Borne Measurements and AIS-Based Model, ACPD, 2014

Presentation 4

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Socioeconomic effects of SECA

DMD
Copenhagen | 26th October 2016
Sari Repka

Effectiveness of regulation – case SECA


1982 Stockholm Conference on Acidification of the Environment

- Costs vs benefits
- Ex-ante analysis
  - Actually missing in case SECA
  - generally rather simple calculations comparing increased fuel costs to improved health benefits
- What about ex-post analysis?
- What actually happened after the regulation commenced, is it relevant to study in your mind?
- Why?
- For how long?


Photo: Pekka Sundberg

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Impact category	
Environmental impacts	Benefits of clean nature and biodiversity as valued by citizens and society Costs: potential inefficiency
Health impacts	Benefits of reduced mortality and illness for citizens and society Costs: potential inefficiency
Business impacts: ecological goods	Benefits of enhanced commercial ecological resources (e.g. fish, crops, forest) for businesses and society
Business impacts: compliance	Costs of compliance for the maritime industry, its customers, and society
Business impacts: innovation	Benefits for cleantech industries and on innovation inducement in cleaner shipping
Administrative impacts	Costs of administration, including direct and indirect administration costs
Macro-economic impacts	The macroeconomic perspective: e.g. national competitiveness


Photo: Anna Reunamo


Photo: Jörg Beecken


Source: Rolls Royce

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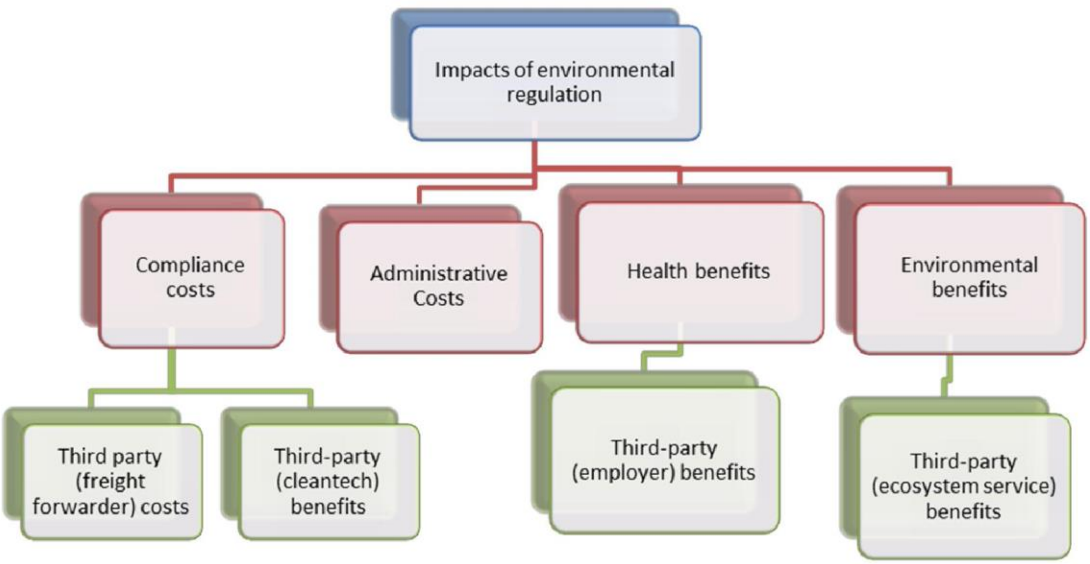

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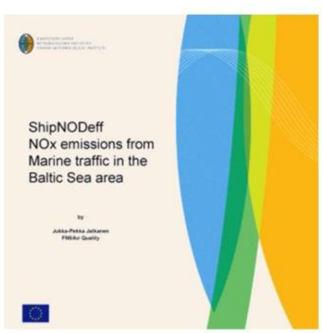
Measuring and studying, environment

- Modelling shipping effects before and after SECA on air quality and deposits on lakes and soil → Effects on plants and fishes



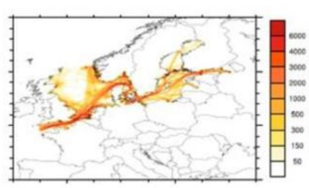


Figure 1. Ship emissions of SO_x (mgm^{-2}) in the Baltic Sea and the North Sea in 2009.

Jonson et al. 2015

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Measuring and studying, health

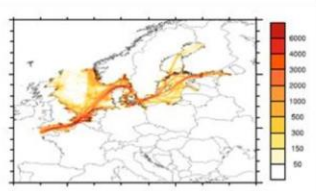
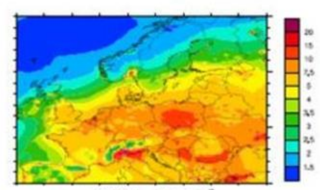
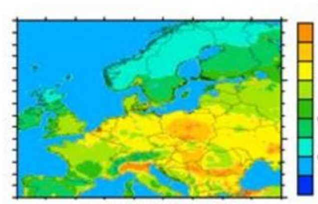


Figure 1. Ship emissions of SO_x (mgm^{-2}) in the Baltic Sea and the North Sea in 2009.



b) $PM_{2.5}$ in $\mu g\,m^{-3}$



a) 2010 (2009 Ships) YOLL

Jonson et al. 2015

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Valuation

- Human health has been valued
- Crops and forests have commercial value
- Building, statues have value

EXTERNALITIES IN MACROECONOMICS

	cases per person/year/microg/m3			Cost per case
	SO4	NO3	SO2	Million NIS
Acute death			7,13E-06	4,74E+01
Congestive heart failure	4,33E-06	2,59E-06		9,38E-02
Limited activity	3,36E-02	2,00E-02		2,45E+01
Bronchitis (adults)	7,62E-03	4,56E-03		2,02E+00
Coughing (adults)	7,84E-03	4,70E-03		2,34E+00
Lower respiratory tract problems (adults)	2,83E-03	1,71E-03		1,50E-01
Bronchitis (children)	9,03E-04	5,46E-04		2,39E-01
Coughing (children)	1,56E-03	9,31E-04		4,65E-01
Lower respiratory tract problems (children)	1,20E-03	7,21E-04		6,36E-02
Hospitalization for respiratory tract problems	3,46E-06	2,07E-06	2,04E-06	1,58E-01

Source: Israeli Minister of Environment Protection

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Valuation

- Valuation of clean air and clean water
- Clean water shows for instance in property prices near water
- Willingness to pay? How much would you be willing to pay for clean air and water?

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PROJECT PARTNERSHIP

Turun yliopisto University of Turku
ILMATIETEEN LAITOS METEOROLOGISKA INSTITUTET FINNISH METEOROLOGICAL INSTITUTE
HELCOM
AKADEMIA MORSKA SZCZECIN
CHALMERS
TALLINNA TEHNIKAÜLIKOOL TALLINN UNIVERSITY OF TECHNOLOGY
UNIVERSITY OF GOTHENBURG
Maritime Development Center of Europe
BALTICMARINECONSULT Planungs- und Ingenieurbüro Prof. Dr. Lüsch & Partner
Norwegian Meteorological Institute
Nordkalk
City of Gothenburg

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Questions - table 4

Health and environment – socio economic effects of SECA

1. Do you think it is relevant to study the socioeconomic effects of SECA also after the regulation has commenced? And why?

2. To which of your stakeholders do you think there are (and what type of) socioeconomic effects?

3. What are the short term and long term socioeconomic effects of SECA to your own activities?

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