
Demo Project

Summary

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Additional information of the DEMO Project (e.g. detailed test results) is available in the full DEMO project report and on the web page of the DEMO project (www.demoproject.org).

A. Introduction, Background & Scope

The Demo Project is an industry driven initiative launched in connection with the ongoing work of the European Union on a strategy to reduce atmospheric emissions from seagoing ships. The Demo Project promotes emission trading as a cost-effective way to reduce emissions of nitrogen oxides (NO_x) and sulphur dioxide (SO₂) by proposing and testing solutions to critical issues such as monitoring and verification.

The launch of the Demo Project was a direct response to the initiative by DG Environment as regards a request for a demonstration that monitoring and verification of nitrogen oxides (NO_x) and sulphur dioxide (SO₂) emission reductions at sea are feasible. The request to execute the demonstration was made to the Swedish Shipowners' Association and PricewaterhouseCoopers following their presentation of the proposal¹ for an EU-wide emission trading system of NO_x and SO₂, which includes shipping. DG Environment made a similar request to SEAA² following their proposals² for emissions credit trading schemes including shipping. According to the EU officials an emission trading system (which involves shipping) could be a successful way to reduce emissions from shipping in EU waters. However, to strengthen the possibilities for such a legislative development the EU officials recommended and requested that some critical issues should be demonstrated and clarified.

The main issues to be demonstrated and clarified were that:

- The reductions can be monitored and verified in practice
- The reductions are real
- Trading can be cost-efficient

By aiming at clarifying these issues in the Demo Project the participating ship owners and stakeholders will have an excellent opportunity to influence EU officials in their future policymaking regarding air emissions from ships.

A.1 Scope of the Demo Project

The scope of the Demo Project is to demonstrate (in practice) that the monitoring and verification of NO_x and SO₂ emission reductions from sea-going ships is feasible. The monitoring and verification will be tested on reduction techniques for NO_x emissions (*Selective Catalytic Reduction* and *Internal Engine Measures*) and reduction techniques for SO₂ (*Low Sulphur Fuel* and *Scrubbing technology*).

A.2 Project phases

The Demo Project was ordered and evaluated by the steering committee in the following project phases:

- Pre-evaluation of potential methodologies to monitor emission levels, calculate emission reductions and verify emissions reductions from different SO₂ and NO_x

¹"Emissions Trading Scheme SO₂ & NO_x", Swedish Shipowners' Association's response to: Discussion Paper "A COMMUNITY STRATEGY ON AIR POLLUTION FROM SEAGOING SHIPS", Gothenburg 26.02.2002, <http://www.sweship.org> and http://www.europa.eu.int/comm/environment/air/consultation_responses/swedishshipowners_response.pdf.

² <http://www.seaat.org>

reduction techniques. In this phase a pre-evaluation of potential methodologies to monitor emission levels, to calculate emission reductions and verify emissions reductions from different SO₂ and NO_x reduction techniques have been conducted. The phase has also included discussions regarding general requirements for trading of emission reductions in European waters.

- Onboard testing (on the ships of the project participants) of the selected monitoring methodologies (including calculation and reporting) – See section D
- Practical testing of verification methodologies – See section D below
- Communication of results and recommendations to policymakers and other stakeholders

A.3 Project organisation

The primary stakeholders of the project were the four ship owners *Broström, Rederiaktiebolaget Gotland (Gotlandsbolaget), the Peninsular and Oriental Steam Navigation Company (P&O) and Stena Line* and the international organisation *SEAA T (Shipping Emissions Abatement and Trading)*. Together with the *Swedish Shipowners' Association*, the primary stakeholders formed the Steering Committee of the DEMO project. The steering committee guided the project management, by several meetings during project. The sponsors of the project were *VINNOVA (Swedish Agency for Innovation Systems), Swedish Maritime Administration, Biofriendly Ltd and Wallenius Lines*. Throughout the project the members of the steering committee contributed to all parts of the project.

PricewaterhouseCoopers conducted the project management of the whole project. *PricewaterhouseCoopers and IVL (The Swedish Environmental Research Institute)* worked jointly in carrying out the tasks in the pre-evaluation and monitoring phases of the Demo Project. *CA Clase* was involved in one of the on-board tests.

B. General requirements for trading of emission reductions in European waters

In the DEMO Project an initial discussion regarding the basic requirements for trading emission reductions in European was performed in order to prepare the on board tests by creating a draft specification of requirements.

B.1 Organisational and operational boundaries

In the future trading system it will most certainly be the owner of the ships that will have the ownership of all the created marketable reductions (allowances or credits).

In the future system we suggest that the mobility aspect is handled by defining the ship and its engines as an emission source whenever within the geographical boundaries of the trading system, and as a non-source outside the boundaries. In this way all ships can participate in the emissions trading scheme whenever they travel within the boundaries of the scheme.

To deal with the different engines onboard a ship, it is proposed that in the future system the engines on board the ship shall be considered as separate emission sources, and thus separate emission entities. In this way the ship owner can choose to apply abatement techniques on one or several engines and also participate in the scheme with one or several engines.

B.2 The tradable emission reduction

For a ship owner it is the reduction of emissions below a certain reference scenario (or baseline) from one or more engines on board during a certain time frame (e.g. 1 hour up to perhaps 1 year) inside geographical the boundaries of the emission trading scheme that will represent an economic value. Consequently, in order to generate the tradable emissions reductions the ship owner needs to monitor and record:

- The position of the ship
- Time when the emissions occur and when the ship has a certain position
- The emission reductions, resulting from the difference between:
 - The actual generated emissions
 - The emissions of the reference scenario/baseline

B.2.1 Ship position

Since the trading system will involve mobile emission sources that may pass in and out of the geographical boundaries of the trading system it has to be demonstrated whether the emissions took place within or outside the system. As a consequence the bearings of the ship have to be taken and registered continuously. More specifically, this may not only have relevance for the cases of a ship being in and out of EU waters but also for possible boundaries defining different geographical areas with different markets, different port areas or more environmentally critical areas where future legislation may specifically apply.

Thus, a *future trading system* should have the position of the ship as part of the continuous logged parameters.

B.2.2 Time

A fundamental and critical requirement of a *future trading system* is that all logged parameters are related to time, which can be defined and referred to a standard e.g. UTC (Universal Time Constant), Greenwich meantime or Central European time.

B.2.3 The emission reduction (i.e. baseline emissions and actual emissions)

The emission reduction during a certain time frame (e.g. 1 hour up to perhaps 1 year) is thus the difference between the emissions that would be generated in a reference baseline scenario and the actual emissions generated during this time frame. A simple subtraction between the “baseline emission” and the “actual emission” (originating from the periods when the ship has been in the trading zone) results in the tradable emission reduction:

$$\text{Emission reductions} = \text{Baseline emissions} - \text{Actual emissions}$$

Consequently, when it comes to monitoring and verification of the emission reductions the determination of both the “baseline” and the “actual” emissions are of equal importance in minimising the overall uncertainty.

The aim of the project was also to demonstrate that the emission reductions can be monitored and verified whatever baseline methodology the policymakers may choose in future. Consequently, examples of the different baseline methodologies have been illustrated when performing the onboard tests.

C. Pre-evaluation of potential monitoring & verification methodologies

C.1 Quality Requirements and Principle for Selection

In the pre-evaluation phase the different approaches and methodologies for monitoring and verification of NO_x and SO₂ emissions reductions at sea were evaluated. In this pre-evaluation the methodologies judged as the most prosperous in a future trading system have been selected. PricewaterhouseCoopers and IVL carried out the evaluation process jointly with criteria from the following areas:

- Accounting and Reporting Principles
- Quality Requirements on Onboard Monitoring Equipment (e.g. technical feasibility)
- Potential cost-efficiency
- Harmonisation with existing and proposed IMO requirements and other international standards and standard proposals (e.g. ISO etc.)

C.2 Monitoring - Measurement parameters, equipment and other issues

The measurement parameters, systems and calculation routines proposed below are by no means the only solutions available.

C.2.1 Ship position

There are several ways of adding positions to the monitoring system. Today position is easily determined with good accuracy by using satellite based navigation (GPS) systems. There are several ways to hinder eventual manipulation of positions data. As an example taking the signal directly from the navigation system would make it dangerous (for navigation safety) to tamper with. Another example is to use more than one positioning source in the system (enabling one sealed system with a coded antenna and "black box receiver", which is not accessible for the crew). A rough estimate of the position of the ship at different times during the reporting period should also be possible through spot checks in logbook and receipts (when performing the verification of the emission reductions).

IMO is on course towards a mandated phase-in of so-called Automatic Identification Systems (AIS) or transponders. Position may be independently verified through the use of radar tracking with transponder identification. Radar position logs are usually not kept for fiscal purposes but the possibility exists to submit ships to random checks of position that may be compared to the logged positions by the ships systems. The Swedish Maritime Administration indicates that if requested the positions data can be stored for longer periods in the future.³

It is also possible to replace the continuous position registration with a default distance from a European port to the border of the emissions trading area. This would typically be the shortest distance to the border representing a minimum activity.

C.2.2 Time

Since the GPS system delivers an almost exact time, (satellite time) the time signal is already in the system. The time scale for recording data is suggested as taking a measurement value from all parameters every 15 seconds and storing a minute average value (based on four 15 second values). From this record, a summarised

³ Rolf Zetterberg, responsible for AIS at the Swedish Maritime Administration

“emission reduction report” can be registered giving total mass emission reductions (kg) for every hour.

C.2.3 NO_x reductions onboard ships using Selective Catalytic Reduction (SCR)

The central basis for the proposed monitoring system was the IMO Technical NO_x Code with references to the ISO standard ISO 8178, 1996. The Code allows for several different solutions to be applied.

A simple subtraction between the “baseline NO_x emission” and the “actual NO_x emission” (originating from the periods when the ship has been in the trading zone) gives the tradable “NO_x emission reduction”.

$$NO_x \text{ emission reduction (kg)} = \text{Baseline } NO_x \text{ emission (kg)} - \text{Actual } NO_x \text{ emission (kg)}$$

Actual NO_x emissions

The total actual mass of NO_x emitted is obtained by adding the actual hourly emissions while the ship has been in the geographical area designated for emission trading. Basically, the actual NO_x emission (NO_x mass flow) during a certain time period is calculated by multiplying the “NO_x concentration in the dry exhaust” and the calculated “Dry exhaust gas flow”.

$$\text{Actual } NO_x \text{ emission (kg)} = \text{Dry exhaust gas flow} \times NO_x \text{ concentration} \times \text{Time}$$

It is proposed that the parameter “NO_x concentration in the dry exhaust” is continuously recorded in the dry exhaust gas sample using a chemiluminescence analyser.

It is suggested that the parameter “Dry exhaust gas flow” is directly calculated preferably by using the carbon balance method (indirect measurement method from the IMO Technical NO_x code) assuming complete combustion. Direct measurement of exhaust flow is also permissible in the IMO Technical NO_x Code, but the current level of technology and documented long-term experience indicates high costs or measurement uncertainty. However, further development of this technology can make it the best solution for this application.

In order to calculate “Dry exhaust gas flow” and create a unit of measurement that is comparable with a baseline emissions factor (g NO_x /kWh) the engine effect needs to be monitored and registered. The engine effect is suggested to be defined as uncorrected brake power at the engine crankshaft (P). Ideally P can be measured via engine speed (optical principles) and torque (strain gauge), but the complexity and cost of obtaining these measurements to run continuously as a permanent installation are questionable (if not installed while constructing the ship). It is proposed therefore that for the start in a future trading system, other relevant engine parameters are used (e.g. fuel pump index) and if calibrated against more accurate measurements (cylinder pressure measurements for example) for several engine loads prior to the set-up of the system a suitable compromise can be reached between simplicity and accuracy. For auxiliary engines the power output at the generator (combined with a factor to account for losses) would be the most suitable easily logged engine parameter.

Baseline NO_x emissions

In the future trading system, the baseline NO_x emission will probably be in the form of a general baseline emission factor decided by the policymakers, e.g. following the IMO NO_x curve. In this case (and in the case of an engine specific emission factor previously measured) the emission baseline factor has to be corrected to the prevailing ambient conditions. Since NO_x formation from marine diesel engines is affected by air temperature, humidity, atmospheric pressure and the performance of the air intercooler on the charge air measurements not performed at the same time needs to be corrected with a NO_x correction factor for humidity and temperature (KHDIES). If

the policymakers decide on ship specific baseline emissions, these emissions can be measured continuously (e.g. sample exhaust gas before the SCR) at the same time as the actual NO_x emissions and consequently no correction for different ambient conditions is needed.

Consequently, the total baseline NO_x emission (in mass) for the prevailing ambient conditions is obtained by a multiplication of the baseline NO_x emission factor (in g/kWh) with the NO_x correction factor for humidity and temperature (if needed) and with the total power (in kWh) i.e. engine effect (in kW) multiplied with time (h), while the ship has been in the geographical area designated for emission trading and

$$\text{Baseline NO}_x \text{ emission (kg)} = \text{Baseline emission factor} \times \text{KHDIES} \times \text{Engine effect} \times \text{Time}$$

C.2.4 NO_x reductions onboard ships using Internal Engine Abatement

In comparison to the methodology presented previously for a ship using Selective Catalytic Reduction (SCR), there are very few differences as far as monitoring is concerned for the internal engine abatement (IEA) case. Thus the results and suggestions of the SCR ship apply directly for the IEA ship.

One option however that will not be available for the IEA ship is a parallel baseline measurement. On the other hand there is a high probability that some form of project/ship specific baseline measurement will have been performed in order for the IEA system to be designed.

C.2.5 SO₂ reductions onboard ships using Scrubbers

As with the NO_x emissions a simple subtraction between the “baseline SO₂ emission” and the “actual SO₂ emission” (originating from the periods when the ship has been in the trading zone) gives the tradable “SO₂ emission reduction”.

$$\text{SO}_2 \text{ emission reduction (kg)} = \text{Baseline SO}_2 \text{ emission (kg)} - \text{Actual SO}_2 \text{ emission (kg)}$$

Actual SO₂ emission

At present, the most suitable and advanced option in the future trading system for monitoring SO₂ onboard a ship using a scrubber will be through a continuous exhaust emission monitoring system similar to that outlined for NO_x. Thus gas concentrations of SO₂ need to be measured in the exhaust downstream of the scrubber together with engine power (and thereby fuel consumption). The dry exhaust flow is suggested to be calculated using the carbon balance method (or a direct measurement method if suitable) and combined with SO₂ exhaust concentration data to obtain the sulphur mass flow.

$$\text{Actual SO}_2 \text{ emission (kg)} = \text{Dry exhaust gas flow} \times \text{SO}_2 \text{ concentration} \times \text{Time}$$

The concentration measurement of SO₂ suggested to be continuously recorded in the dry exhaust gas sample using a NDUV analyser, a NDIR analyser, or pulse UV fluorescence. The analyser forms part of an extractive measurement system utilising a stainless steel gas probe, heated gas transport line, gas conditioning system, and calibration system.

In contrast to monitoring NO_x emissions, ambient data are not required for correction purposes for SO₂ emissions.

Baseline SO₂ emission

The “baseline emissions” will most likely be calculated from a politically fixed limit or cap on sulphur content in fuel or a SO₂ emission rate (g per kWh) corresponding to a certain sulphur content in fuel. If the fuel sulphur content is used the baseline will be calculated by multiplying the fuel consumption (from engine power or measured directly if possible), during the time the ship has travelled in the geographical area

designated for emission trading, with the limit or cap value of the fuel sulphur content (the trading zone). If a SO₂ emission rate (g per kWh) is used the baseline is calculated by multiplying this rate with the engine effect (monitored and registered in the same way as in the case with NO_x above) and time.

C.2.6 SO₂ reductions onboard ships using low sulphur fuel

A simple subtraction between the “baseline SO₂ emission” and the “actual SO₂ emission” (originating from the periods when the ship has been in the trading zone) gives the tradable “SO₂ emission reduction”.

$$SO_2 \text{ emission reduction (kg)} = \text{Baseline } SO_2 \text{ emission (kg)} - \text{Actual } SO_2 \text{ emission (kg)}$$

Actual SO₂ emissions

For cost efficiency and simplicity, we suggest that exhaust sampling and SO₂ monitoring is not required in this application. Instead continuous monitoring of activity data i.e. engine effect (and thereby fuel consumption) will be conducted. SO₂ emissions are calculated from the sulphur contents measured in the fuel analyses coupled with data on fuel tank usage and the fuel consumption rate, following the assumption that all fuel sulphur is oxidised to SO₂ in the combustion process.

In the *future trading scheme* the required measurement parameters would be, in addition to time and ship position, engine power (to calculate fuel consumption), heating value of fuel, fuel sulphur content and data on fuel tank assignment and usage (i.e. indication of which fuel is being used from which fuel tank if the ship has several fuel tanks with fuels of different sulphur content) or a direct measurement of the sulphur content in the fuel pumped into the engine. Since some ships will operate on dual fuels and switch to the low sulphur fuel in the geographical area of the trading scheme; it is important that this switch to a different fuel (linked to a certain fuel sulphur analysis) is recorded. As for the previous systems, all measurement parameters should be logged continuously. It is also proposed that the bunker delivery notes (and fuel sulphur analyses) should be stored on board and produced during verification procedures.

Baseline SO₂ emissions

For calculating the baseline emissions for a ship using low sulphur fuel, one could use a politically assigned S fuel value or the fuel S content of high sulphur fuel on board (which is used outside the trading zone). Either way the sulphur percentage is easily multiplied by fuel consumption rate to give the baseline emissions as described in the previous section.

C.2.7 Uncertainty in monitoring

The overall uncertainty of the tradable emission reduction will be very dependent on the uncertainty associated with the baseline methodology adopted, i.e. a politically agreed/general baseline (sulphur limit of fuel and the IMO NO_x-curve) or the emissions that would be generated without any abatement installed.

Overall uncertainty for NO_x monitoring onboard a ship using SCR and IEA

A politically agreed/general baseline emission factor (as defined carries “no measurement error”) and the determined emission reduction will have an “uncertainty” at 11 – 16 % (95% confidence level). In the case when the baseline emission is measured in parallel with the actual emissions (and thus many of the uncertainties on both measurements will work with each other) the uncertainty in the emission reduction can be expected to be around 11 – 16%. In the case when a baseline emission has been measured previously at a specific engine load setting, the

uncertainty in the real emission reduction can be expected to be around the 16 – 23% interval.

It should be noted that the NO_x emissions monitoring of the land-based units covered by the Swedish charge on nitrogen oxides (continuous emissions monitoring is mandatory) has a corresponding average uncertainty of 10 – 20 % as a rough estimate.

Overall uncertainty for SO₂ monitoring onboard a ship using Scrubbers

The uncertainty in the tradable emission reduction can be expected to be around 5 – 10 % when using a politically agreed/general baseline fuel sulphur limit and 5 – 15% using the actual sulphur content in the fuel as baseline.

Overall uncertainty for SO₂ monitoring onboard a ship using Low Sulphur Fuel

The uncertainty in the tradable emission reduction will depend on the uncertainty in determining S in the fuel analysis and also calculation of fuel consumption. In view of this one can expect an uncertainty at ca. 4 – 7% level.

C.2.8 Multi-engine measurement systems

The ship owner will decide if monitoring of emissions (reductions) is required for one or more engines on board a ship. Thus two basic alternatives exist, either a separate emission monitoring system for each engine, or a single emission monitoring system serving all engines. The latter is clearly more cost-effective but means that emissions from all engines cannot be measured entirely simultaneously and continuously. In the future trading scheme, we suggest that switching between engines is permissible and at a frequency which may be subsequently specified with IMO. For demonstration purposes measurements of emissions from two engines using a valve switching system were carried out in one of the onboard tests (The Stena Jutlandica SCR monitoring test).

C.2.9 Continuous emissions monitoring and other alternatives

In view of the continuous emissions monitoring routines practised at land-based emission sources and the fact that measured marine emission reductions is proposed to trade against data thereof, the assurance level of the measurement data should ideally be equivalent, i.e. resulting in demands for continuous emission monitoring also for the ships participating in the scheme. Continuous emissions monitoring onboard ships require accurate, reliable and durable monitoring equipment (i.e. exhaust gas analysers and accessory equipment must tolerate the marine environment), routine maintenance and calibration intervals (calibration routines can be set-up automatically) and shipboard personnel well acquainted with the system and with available time. Since this could be hard to achieve for some ships other alternatives should be considered.

One solution (i.e. a level between continuous emissions monitoring and intermittent monitoring) is combining continuous monitoring of parameters correlating to emissions (e.g. fuel consumption and/or engine power (in kW)) with short-term, periodic or intermittent monitoring of actual emissions to create fixed or variable emission factor (e.g. kg NO_x/kWh).

The monitoring requirements could also be adjusted to the amount of emissions each ship creates, e.g. a larger emitter is required to report with higher accuracy (e.g. continuous emissions monitoring) but smaller emitters could use simplified and less expensive methods with larger reporting uncertainty (e.g. intermittent monitoring or general emission factors). Such an approach generates lower monitoring costs without losing accuracy in the same range. This approach has been used in the Monitoring

and Reporting Guidelines for the installations included in the EU Emissions Trading Scheme for greenhouse gases.

Another possible approach (or an approach to combine with the approach suggested above) is that the ship owner is responsible for the uncertainties exceeding a certain limit value, e.g. if the ship owner is reporting reductions with an uncertainty exceeding the limit value a deduction, corresponding to the excess uncertainty of the reductions created, is made.

It should also be noted that new monitoring equipment (e.g. new sensors types) are under development and may in the future enable monitoring at a reduced cost and improved measurement uncertainty. This development of emission monitoring technology would most certainly be stimulated by the implementation of emission trading schemes including shipping.

C.2.10 Management system (quality assurance routines)

In our opinion the policies and routines (management, maintenance, etc) needed for the monitoring and reporting of NO_x and SO₂ emissions/emission reductions could be fitted into the overall management or security systems of the ships. Prior to this the ship owner needs to conduct a risk assessment and an uncertainty analysis to qualify data. The quality assurance (QA) of the measurement and performance checks to be made are significant (daily assurance routines and automatic calibration). Both the IMO Technical NO_x Code and more or less all standards applying to permanent land-based measurement systems include these. The QA requirements for a future trading scheme including shipping, will probably represent a compromise of both land-based QA and those from the IMO.

C.3 Reporting

When reporting the proposed emission reductions, the ship owner will not only need to present the figure of the proposed reduction but also a short description of the reporting organisation, management system, data sources, calculation routines, quality assessment, quality controls etc. This permits the assurance provider to be able to conduct a review as proposed for the future trading system.

With today's technology data storage is not a major challenge. Basically what is needed is a modern, off the shelf, data logger and PC system with the appropriate software including security and backup systems. For land-based systems, a purchase of an emission monitoring system (including gas analysers, conditioning system, etc.) normally includes an integrated central logger. The supplier can specifically tailor the design of the logger to the needs of the ship owner (e.g. multi-engine switching, frequency of automatic calibration etc.). Furthermore a central logger can be equipped for report writing presenting hourly emission reductions on a 24-hr basis for example. In order to send information to a central logger, cables may need to be wired from the engine room (engine power signal), the bridge (GPS signal) and the emission monitoring equipment. This can be done according to established principals for wiring of electrical equipment on ships (and is no major according to electricians in this line of business).

C.4 Verification

Most forms of corporate disclosure gain credibility through an external, independent verification process. Emissions reductions traded as emission credits, surplus emission allowances, or environmental differentiated reimbursements on harbour and fairway dues in a future system are no exception and consequently need to be reliable and credible. Thus these reductions cannot be proven to be real unless they are monitored, calculated, reported and verified. The latter will be a vital requirement for

the marketability of the emission reduction. The higher the level of accuracy the ship owner can produce, the higher the trustworthiness and, therefore, the higher the market value of the emission reductions. We strongly recommend that the emissions or emission reductions be verified by an independent assurance provider in the proposed future trading scheme (The ship owner should not be able to sell the emission reductions before they are verified). We also propose that the verification process will be based on the generally accepted financial accounting and reporting principles adjusted with the specific technical and environmental demands for air emissions at sea. Both these approaches have been utilised in the verification standards of the EU Emission Trading Scheme for Greenhouse gases.

When it comes to the subject matter requirements for verification in the proposed future trading scheme, the assurance engagement will consider both the verification of data and management systems as well as the behaviour of key personnel as equally important. Appropriate evidence needs to be available to support the presented reduction being subjected to external verification. Assertions by management for which there is no available supporting evidence cannot be verified. The ship owner and their ships will have to guarantee the existence, quality and retention of data and documentation in order to create an audit trail of the presented reduction. Accounting and reporting principles in the proposed future trading scheme is suggested as relevance, reliability/accuracy, completeness, consistency, transparency, and timeliness.

In the beginning when the trading system is immature the verification would most likely need to provide a higher level of assurance. Considering that the reductions are likely to be monetised once markets are set up, meaning that they may be the object of transactions with corresponding financial flows, the issue of their accounting treatment arises which also stresses the need for a high level of assurance (this results in site visits, and control of data, management systems, behaviour, etc).

When the future trading system has matured and a more detailed monitoring and reporting standard has evolved the verification engagement can be performed as agreed upon procedures (lower assurance provided).

C.4.1 The Verification Process & Methodology for Emissions Reductions

Our suggested Verification Process and Methodology for providing Assurance on Air Emission at Sea is based on fixed, core financial auditing standards and principles, and is overlaid with technical and environmental principles specific to the nature of the Shipping Industry and Air Emission at Sea. This result in a process of three steps including: Planning, Execution and Completion.

The planning) is suggested to include a general risk assessment, a materiality, scope and sample selection and assessment of the control environment. The execution is suggested to include audit assertions (based on quality requirements e.g. an unbroken audit trail), detailed procedures (e.g. document review, interviews with key personnel, observation of practices/operations, examination of equipment, examination of records, spot checks/random sampling of measured data, recalculation of data, etc). The completion is suggested to include management representations, verification reporting (e.g. procedure and verification statement) and management reporting.

D. Conducted on-board tests - Emissions monitoring & verification

Within the scope of the project five on-board tests have been performed by and/or engaged by the project participants, One test each for the reduction techniques listed in the scope of the DEMO project (NO_x emissions: Selective Catalytic Reduction (SCR) and Internal Engine Measures and SO₂ emissions: Low Sulphur Fuel and

Scrubbing technology). Additionally one test was focusing on the positions monitoring, logging of parameters and reporting of emission reductions (on a web page). Table 1 summarises the on-tests board conducted within the scope of this project.

| Abatement method / Ship/ Ship owner | (Emission) monitoring parameters against time | Activity monitoring parameter against time | Engaged by/ Conducted by/Time |
|--|--|---|---|
| NO_x | | | |
| SCR MS Stena Jutlandica Stena Line | NO _x and CO ₂ (exhaust) Ta, Ra, Pb (ambient parameters) | Engine output giving also fuel consumption rate | PwC IVL August 2003 |
| Internal engine measures Manon Wallenius | NO _x and CO ₂ (exhaust) Ta, Ra, Pb (ambient parameters) | Engine output giving also fuel consumption rate | PwC IVL July 2003 |
| SO_x | | | |
| Low S fuel Bro Atland Broströms | Fuel analyses | Fuel flow meter and Engine output (e.g. fuel pump index) giving also fuel consumption rate | PwC IVL December 2003 |
| Scrubber Pride of Kent P & O Lines | SO ₂ and CO ₂ (exhaust) | Engine output (e.g. fuel pump index) giving also fuel consumption rate | P&O/SEAaT MES ⁴ Aug 2003- Dec 2004 |
| Logging and reporting | | | |
| SCR MS Stena Jutlandica Stena Line | Position | Engine output | PwC CA Clase April-June 2004 |

Table 1 Summary of the conducted on-board tests

D.1 NO_x reductions - Ship (Stena Jutlandica) using Selective Catalytic Reduction

D.1.1 Monitoring

The onboard monitoring test was conducted on the passenger ferry Stena Jutlandica of Stena Line during 13th-14th August 2003, i.e. six 3 hr 15-min crossings each between Gothenburg (Sweden) and Fredrikshavn (Denmark). The on-board test was conducted by IVL with assistance from the crew of Stena Jutlandica.

The Stena Jutlandica runs on a regular basis between Gothenburg (Sweden) and Fredrikshavn (Denmark). As an average Stena Jutlandica makes about 6 voyages every 24 hour 6 days a week. The ship is equipped with Selective Catalytic Reduction (SCR) on all diesel engines for reducing NO_x emissions.

Scope and activities

The objective of these measurements was to demonstrate the functionality of the measurement equipment and methodology suggested in the DEMO project report, i.e. to provide a practical demonstration of the feasibility of using continuous emission

⁴ Marine Exhaust Solutions Inc.

monitoring for determining NO_x emission reductions of a ship (during typical voyages) using SCR as NO_x abatement technology.

The measurements were carried out on main engines 2 and 4 following the proposals for continuous NO_x emissions monitoring. Exhaust gas analysing was conducted using gas probes in sampling holes of the two the stacks (ME 2 and ME 4). A multi-engine measurement system (valve switching system at the gas conditioning system) was used to follow the NO_x emissions from main engines 2 and 4. For Stena Jutandica engine specific emissions (i.e. measured without SCR in operation for ME 2 and ME 4 respectively) were used as baseline emissions were used in contrast to a general emission baseline (e.g. IMO NO_x curve).

Results

As a general result the measurement equipment and calculation routines outlined in the DEMO project report were shown to be suitable and functioned as planned.

For the two engines studied, a marketable reduction of 1737 ± 347 kg NO_x for the six voyages was determined (based on a ship specific baseline methodology i.e. separate measurements on the engines without SCR in operation).

D.1.2 Verification

A verification of the emission reductions monitored and reported from Stena Jutlandica was conducted. The scope of this test was to simulate a full-scale review (with the suggested Verification Process) as far as possible considering the scope of the Demo Project. However, since the Subject Matter (Ship Owner and the tested Ships) will not have management or emission monitoring system implemented, the verification will concentrate on the temporary monitoring equipment and the data received.

The auditor visited Stena Jutlandica during the monitoring test 14 August 2003 and joined for one of Stena Jutlandica's daily runs back and forth to Fredrikshavn from Gothenburg. Interviews with the ships staff responsible for NO_x-reduction and monitoring personnel as well as physical inspections were conducted.

Recalculations of three sets of spot-checked data were done when performing the test of the unbroken audit trail.

The results of the review were that emission reductions could be verified (i.e. the emission report have been prepared in accordance with the instructions outlined in Demo Project and give a true and fair view of the emission reductions created by "Stena Jutlandica").

D.2 NO_x reductions - Ship (Manon) equipped with Internal Engine Abatement

D.2.1 Monitoring

In this on-board test measurements were undertaken on the Pure Car/Truck Carrier, Manon of Wallenius Lines on a 17-hr voyage from Malmö (Sweden) to Drammen (Norway) during 18th-19th July, 2003. The on-board test was conducted by IVL with assistance from the crew of Manon. Manon has one main engine. Low-NO_x slide fuel valves have been installed on the main engine.

Scope and activities

The objective of these measurements was to demonstrate the functionality of the measurement equipment and methodology suggested in the DEMO project report, i.e. to provide a practical demonstration of the feasibility of using continuous emission monitoring for determining NO_x emission reductions of a ship (during a typical voyage) using internal engine abatement to reduce NO_x emissions.

The measurements were carried out on the main engine following the proposals for continuous NO_x emissions monitoring in the DEMO project report. Exhaust gas analysing was conducted using a gas probe in a sampling hole of the stack. For Manon a general emission baseline set at the IMO NO_x emission limit curve (i.e. 17 g/kWh_{corr}) was applied⁵.

Results

As a general result the measurement equipment and calculation routines outlined in the DEMO project report were shown to be suitable and functioned as planned.

The low-NO_x slide fuel valves installed on the main engine of Manon were shown to achieve a marketable NO_x reduction of 660 ±106 kg NO_x for the test voyage within EU waters.

D.2.2 Verification

A verification of the emission reductions monitored and reported from Manon was conducted in the DEMO project. The scope of this test was to simulate a full-scale review (with the suggested Verification Process) as far as possible considering the scope of the Demo Project. However, since the Subject Matter (Ship Owner and the tested Ships) will not have management or emission monitoring system implemented, the verification will concentrate on the temporary monitoring equipment and the data received.

No ship visit was performed for Manon. A thoroughly follow-up interview the person responsible of the monitoring was conducted. All raw data, calculation models and background documents (electronic & paper) were reviewed. Monitoring equipment set up was also checked during the interview. The person responsible for environmental issues at Wallenius Lines was also interviewed regarding the installation of low NO_x slide valves.

The results of the review were that emission reductions could be verified (i.e. the emission report have been prepared in accordance with the instructions outlined in Demo Project and give a true and fair view of the emission reductions created by "Manon").

D.3 SO₂ reductions - Ship (Pride of Kent) using Scrubber technology

D.3.1 Monitoring

Within the scope of the DEMO project the primary stakeholders P&O and SEAaT engaged Marine Exhaust Solutions Inc. to conduct SO₂ emissions monitoring as part of the ECOSilencer® "System Trial", conducted on the passenger ferry Pride of Kent (P&O Lines) during August 2003 to December 2004.

Scope and activities

The possibilities to monitor SO₂ emissions at sea were tested as a result of the evaluation of the effectiveness of the SO₂-scrubbing techniques (the tests involved measuring of SO₂ levels both before and after scrubbing the exhaust gas).

The sample gas was extracted from the scrubber inlet and outlet ducts and then transferred to the analyser system and data logger. The measuring equipment is a non-dispersive infrared (NDIR) detection unit placed in the exhaust pipe. The reduction was calculated as the difference between the emissions and the expected emissions based on the sulphur content of the fuel.

⁵ Note that Manon was delivered before year 2000 (i.e.1996) and hence it does not need to comply with the IMO NO_x-curve.

Results

With minor corrections this method for measuring sulphur dioxide is considered suitable when using scrubbing techniques, i.e. monitoring of SO₂ reductions from scrubbers is feasible.

D.4 SO₂ reductions - Ships using Low Sulphur Fuel

D.4.1 Monitoring

The test was conducted on Bro Atland of Broströms (a tanker for oil products and chemicals) between December 18th and 19th during a 23-hour voyage from Antwerp to Le Havre. Bro Atland has one main engine and four auxiliary engines.

The scope of this onboard test was to demonstrate that it is feasible to measure sulphur dioxide emissions by:

- Measuring engine power to get fuel consumption.
- Measuring fuel sulphur content to get the emissions of SO₂.
- Jointly log the following parameters:
 - “engine load”
 - “fuel tank in use”

During this test the fuel consumption of the main engine was monitored in two separate ways;

- by calculating the fuel consumption from a signal that varies with engine load.
- by periodical readings of the permanently installed fuel flow meter (used as reference) and,

Actual sulphur content of the fuel was obtained from the latest bunker delivery note and also measured at a certified laboratory, as there are well-documented methods for measuring sulphur content this should not create any problems for the future.

To be sure of which tank that is in use, the tank level measurements were used. The tank level measurements are not accurate for registration of true volume but give an indication signal for which tank that is decreasing in volume. This method was coordinated with the manual fuel entry logbook.

The method (e.g. measurement equipment and calculation routines) outlined in the DEMO project was shown to be suitable for sampling fuel oil, monitoring which fuel that has been used and monitoring fuel consumption, e.g. monitoring is possible and functioned as planned.

D.4.2 Verification

A verification of the emissions monitored and reported from Bro Atland was conducted. The scope of this test was to simulate a full-scale review (with the suggested Verification Process) as far as possible considering the scope of the Demo Project. However, since the Subject Matter (Ship Owner and the tested Ships) will not have management or emission monitoring system implemented, the verification will concentrate on the temporary monitoring equipment and the data received.

The auditor visited Bro Atland during the monitoring test (18 December 2003) and joined Bro Atland when the vessel arrived at the port in Le Havre. Interviews with the ships staff responsible for engine functions, electricity system and monitoring personnel as well as physical inspections were conducted.

A more thoroughly follow-up interview with the person responsible of the monitoring was conducted a couple of weeks later. All raw data, calculation models and background documents (electronic & paper) were reviewed.

The results of the review were that the emissions could be verified (i.e. the emission report have been prepared in accordance with the instructions outlined in Demo Project and give a true and fair view of the emissions created by "Bro Atland").

D.5 On-board test - On-line position and emissions monitoring and reporting test (central logger)

The test was conducted on Stena Jutlandica, Stena Line. The test started March 26, 2004 and was terminated at June 24, 2004. The test and the application were made available by PriceWaterhouseCoopers, Stena Line, CA Clase and HiQ.

The Stena Jutlandica ferry runs on a regular basis between Gothenburg (Sweden) and Fredrikshavn (Denmark). Stena Jutlandica has four main engines (ME 1-4), all equipped with Selective Catalytic Reduction devices (SCR:s) in order to reduce (mainly) NO_x.

Scope and activities

The overall objective of this DEMO Project on-board test was to analyse and confirm some of the reporting methods proposed in the Demo Project.

Installation of hardware, monitoring devises, etc and creation of software

In the preparations a laptop computer was upgraded with the necessary hardware, e.g. data communication system. The software needed for the automatic monitoring of parameters from the Voyage Management System ("Time" & "Position" as electric signals), and General Control System ("Engine load" as electric signals), the automatic creation and calculation of emissions report and the automatic sending of emissions report to shore was created and tested several times before installed on the ship.

The prepared laptop and the cabling adherent to it were installed and connected to the Voyage Management System and General Control System of the ship. In order to convert engine load from % to kW and then to engine energy kWh, a simplified method using engine data together with the time for the monitoring period (1 h) was applied. The emission factor (in g NO_x/kWh) derived from the previous on-board monitoring test conducted on Stena Jutlandica was used to calculate the NO_x emissions from the engine energy (in kWh). The specific emission factors were based on the assumption that the SCR:s are running as normal⁶. As baseline emission factor the corresponding IMO NO_x-curve values for Stena Jutlandica (15 g NO_x/kWh) were used⁷.

In order to receive emissions report data and present them on a webpage available on the internet, construction and programming of software on different land-based servers were conducted. As pilot device plotting the position on a map was also constructed.

Logging of data and creation of an emissions report

The following data signals were collected from the Voyage Management System (VMS) and General Control System (GCS) of Stena Jutlandica (via signal cables from VMS and GCS to the monitoring lap computer):

- Date & Time from VMS – logged 1 time/hour
- Position (Latitude & Longitude) from VMS – logged 1 time/hour

⁶ This was not controlled on a regular basis in this test, since the scope was on the automatic reporting procedures.

⁷ Note that Stena Jutlandica was delivered before year 2000 and hence it does not need to comply with the IMO NO_x-curve

- Engine load in % (for the four main engines, ME 1-4) from GCS – logged 1 time/second & calculated average 1 time/hour

The installed laptop logged the data and created an emission report every hour containing the actual emissions, the baseline emissions and the resulting emission reductions during the period (1 hour). Total accumulated reductions since the start of the test were also included in the report.

Transmission of emission report and publication on the DEMO web page

By utilising a mobile data communication system the emission report was automatically transferred every hour to a server computer ashore. The software of the server computer received, stored and automatically published the new data received on the DEMO project web page (<http://www.DEMOproject.org>).

Results

This test demonstrates that it is feasible to:

- jointly log the key parameters of the emission report: ("time", "position" and "engine load")
- automatically create an emission report using existing ship data and ship specific emission factors
- automatically transmit the /emission reports to a "register" ashore and
- to follow the emission reductions created on-line on a web page on the internet

The total NO_x reductions monitored during the test were 144 366 kg (based on the assumption that all the SCR:s were running all the journeys during the test) : During this test. These test results indicate a potential of (with the emission factors used) about 600 tons of avoided NO_x emissions annually.

If the results from this Stena Jutlandica on-board test (focusing on the logging and reporting aspects) is combined with the results of the other monitoring tests (on Stena Jutlandica; Pride of Kent, Manon and Bro Atland)), a full scale monitoring and reporting system, most likely to meet all requirements of a future emission trading system including shipping, is completed.

E. Main results and conclusions

The conclusions of the Demo Project are based on the pre-evaluation and the following practical tests. The main results and conclusions from the DEMO project are the following:

- The pre-evaluation and the onboard tests have demonstrated that monitoring of nitrogen oxides (NO_x) emission reductions created by ships equipped with SCR or Internal Engine Abatement is feasible (with the technology and knowledge existing today)
- The pre-evaluation and the onboard tests have demonstrated that monitoring of sulphur dioxide (SO₂) emission reductions created by ships equipped with Scrubbing Technology or by ships using Low Sulphur Fuel is feasible (with the technology and knowledge existing today)
- The pre-evaluation and a onboard tests have demonstrated that the construction of an onboard full scale monitoring and reporting system (sending emissions data to a server ashore) is feasible
- The pre-evaluation and the practical tests have demonstrated that verification of reported nitrogen oxides (NO_x) and sulphur dioxide (SO₂) emission reductions

created by moving ships at sea is feasible. Additionally a verification process has the ability to offset any uncertainties in the measuring process, and hence make the reductions credible.

- The pre-evaluation indicates that the policies and routines (management, maintenance, etc) important for the monitoring and reporting of NO_x and SO₂ emissions/emission reductions could be fitted into the overall management or security systems of the ships
- The monitoring and verification of emission reductions at sea is a vital part in any future emission trading scheme that will include shipping. The success of such an Emission Trading Scheme will be the balance between the costs of implementing emission abatement and monitoring technology together with their operating and maintenance costs, opposed to the financial gains from trading emission reductions. Consequently the regulators must take the cost effectiveness into account when deciding on the demands for measurement uncertainty
- The DEMO project have in general focused on continuous emissions monitoring methods with advanced equipment and uncertainty levels in the same range as the larger land-based emitters. If a emissions trading system is to be cost effective the monitoring (and verification) requirements should be adjusted to the amount of emissions each ship creates within the geographical boundaries of the trading scheme, e.g. a larger emitter could be required to report with higher accuracy (continuous emissions monitoring) but smaller emitters could use simplified and less expensive methods with larger reporting uncertainty. This has been the approach in the EU Emissions Trading Scheme for greenhouse gases.
- A launch of an emissions trading scheme for NO_x and SO₂ will most certainly drive the development and marketing of new monitoring techniques and technology which may enable monitoring at a reduced cost and improved measurement uncertainty.
- Examples of issues to investigate more thoroughly in the future, if monitoring and verification are to developed even further, are:
 - the impact of extreme shipboard conditions over the long-term
 - the possibilities to developed AIS so it can be used to store data for longer periods (improved verification of position) and potentially contain emissions data
 - the optimal modes for transmittance of data ashore, e.g. via satellite
 - the possibilities for the ship's crew to entirely operate and calibrate the emissions monitoring system (continuous emissions monitoring systems are operated by the crew on certain ships already today, e.g. Stena Jutlandica)
 - the possibilities to improve the logging of HFO entries and the following fuel tank transfers